Make an ER-16 Collet Holder for your Unimat

Doug Collinge Jan 16, 2019

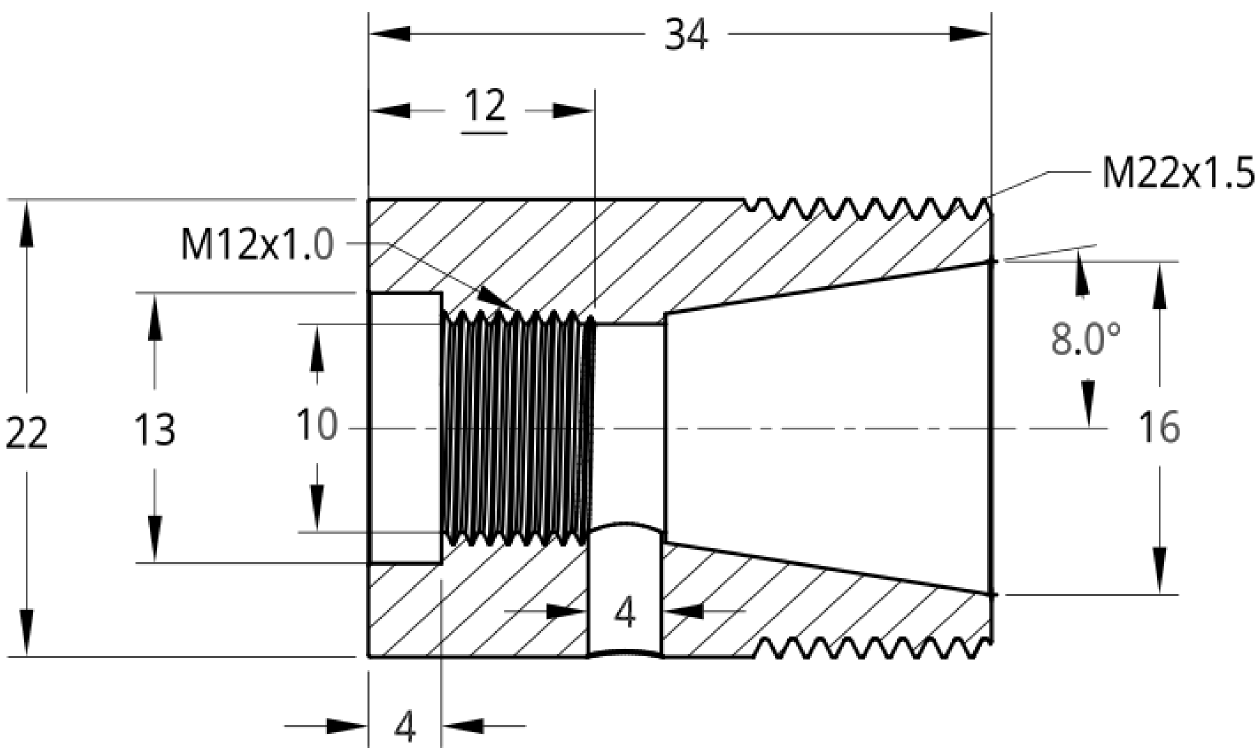
ER-16 Collets are a great addition to the Unimat DB/SL lathe but commercially made collet holders with the necessary 12mm spindle interface are only sporadically available and quite expensive. Fortunately, you can make a perfectly good one right on the Unimat! After all, why do we have Unimats if not to make tooling for Unimats?

ER-16 collets are easy to use and have a wide 1mm clamping range, so they cover 1 to 10 mm in 10 collets. Imperial sizes are also available. They can be very accurate and repeatable as long as you are using accurately round stock. They grip the stock or tool extremely tightly and are accurate enough to allow you to reverse or reposition a workpiece without worrying about losing concentricity most of the time. The extraction groove feature is the real master stroke: it makes extracting the collet easy, no matter how tight it was, using only the wrench you tightened it with.

This project is not particularly difficult and the results can be quite good. Mine came out well enough that I cannot measure the run-out with my dial indicator. It is at least as good as the collets I have. Some special tools are required but are mostly things that you probably already have - or should have. For example, you will need a dial indicator and a M12x1.0 tap but both these tools are pretty much essential anyway. At the end of this article is a list of all the tools required and what they are for. Here is what the finished part looks like:

The Drawing

The image above is a rendering of the part I designed in OnShape. Here is a link to the [project in OnShape], which you can duplicate and modify as you see fit. OnShape provides free accounts, which are fully functional as long as the project is viewable by the public. You can also export files in formats you can open in desktop CAD software.

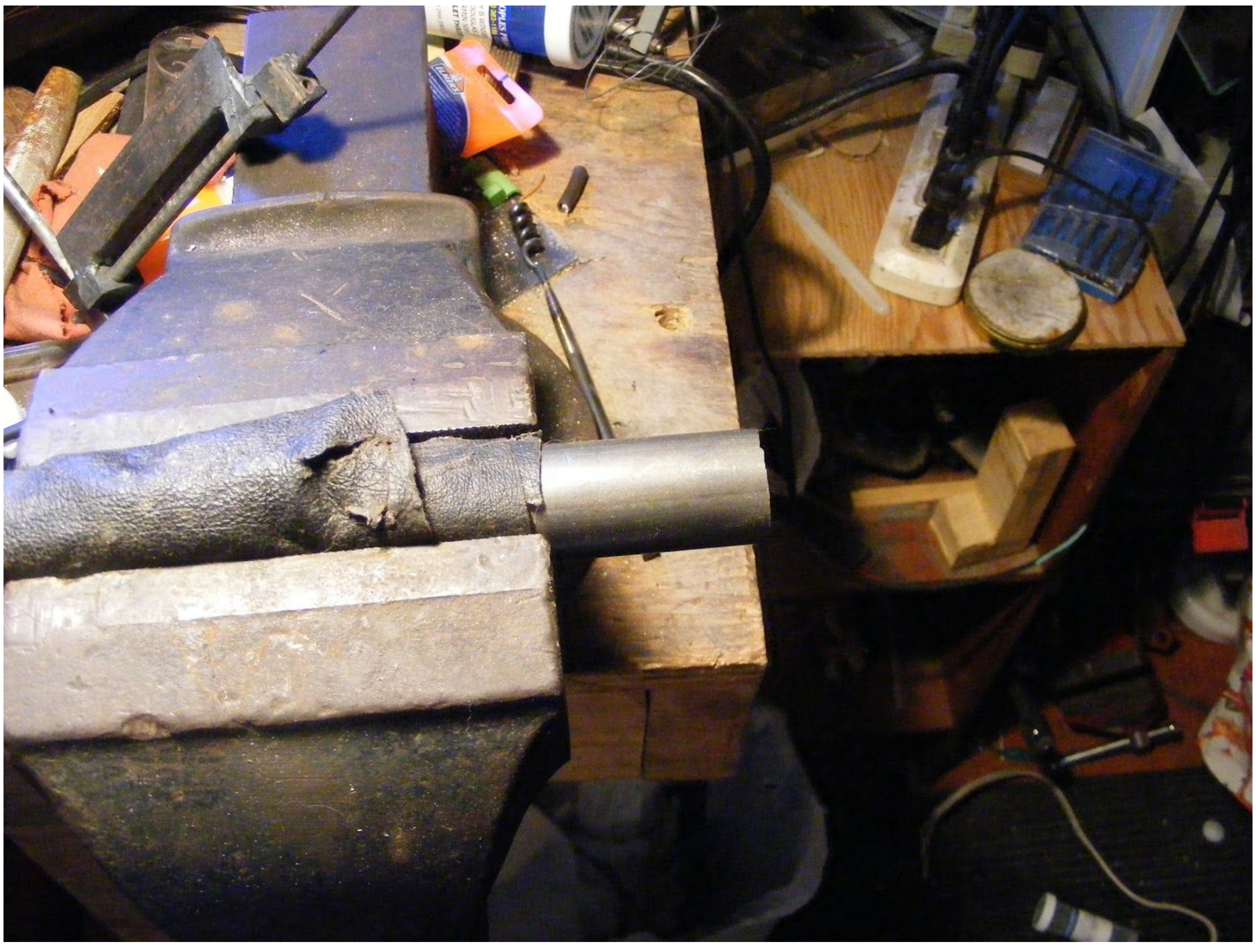


This is a drawing of what we are making. You can get the full drawing from the OnShape document. The drawing conforms to the ER-16 specifications, which are available on the website of Rego-Fix. They invented ER collets so they ought to know. The 4mm section in the middle is for a cross-hole for a tommy bar. Having already made one, I think that this 4mm could be eliminated, making the total length 30mm. Workpiece envelope length is a critically limited resource on the Unimat so it should be conserved wherever possible. So, you could replace the tommy bar hole with flats for a wrench (or start with hex stock) or else leave more metal on where the spindle threads are and drill a hole there.

The alert Unimat user may have noticed that the 12mm spindle register is accommodated with a 13mm bore in the collet holder. That is not a mistake. More on that later.

Choice of Stock

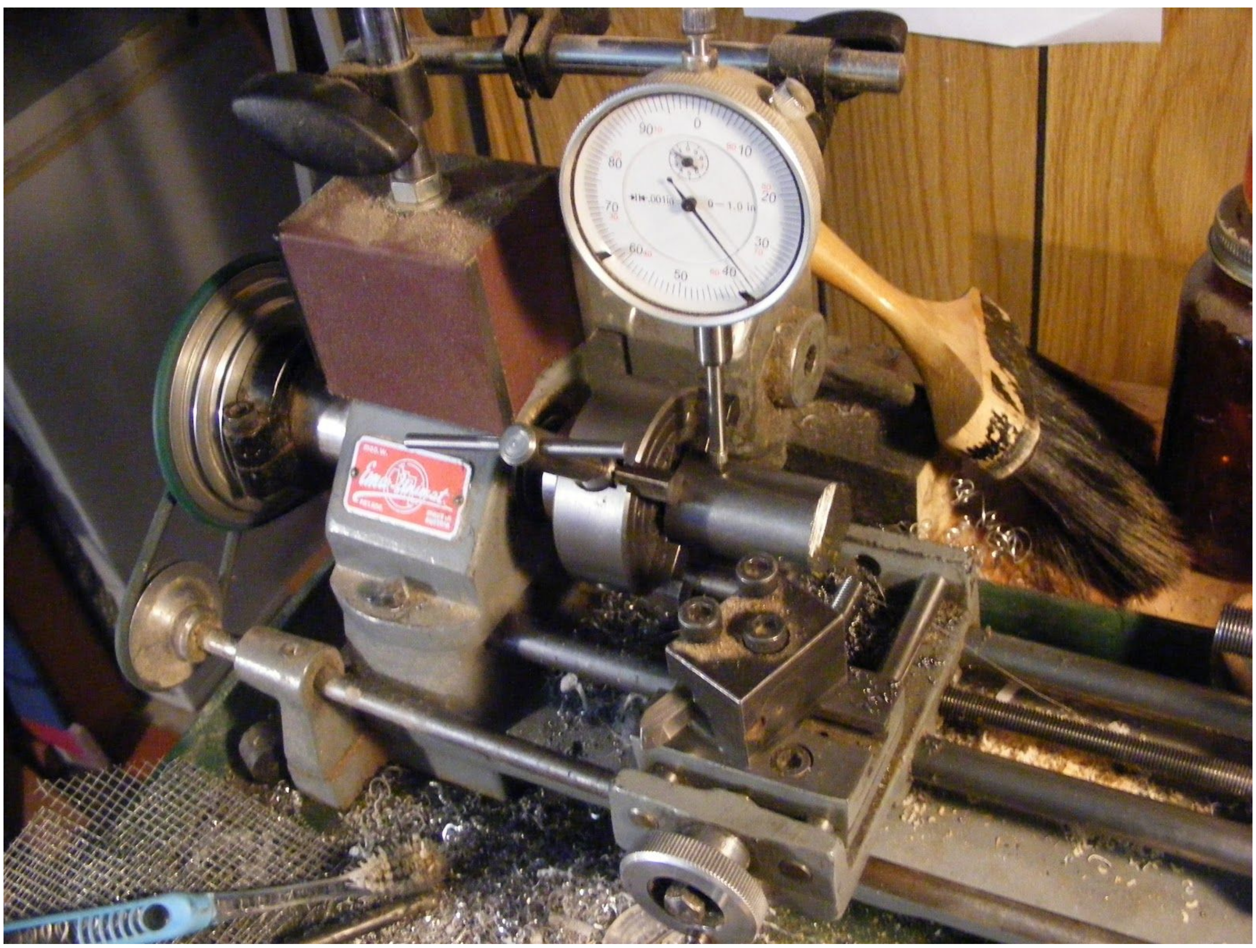
The stock I used was a hunk of one-inch cold-rolled steel I happened to have around. It needs to be turned down to 22mm so, at 25.4mm it is the perfect size. If I did it again I think I would use brass or aluminum but the steel worked out ok. One inch of steel is close to the practical limits of the Unimat but we can still manage it. Take light cuts with a very sharp tool. Or else rough in the part on a larger lathe.



Work Holding

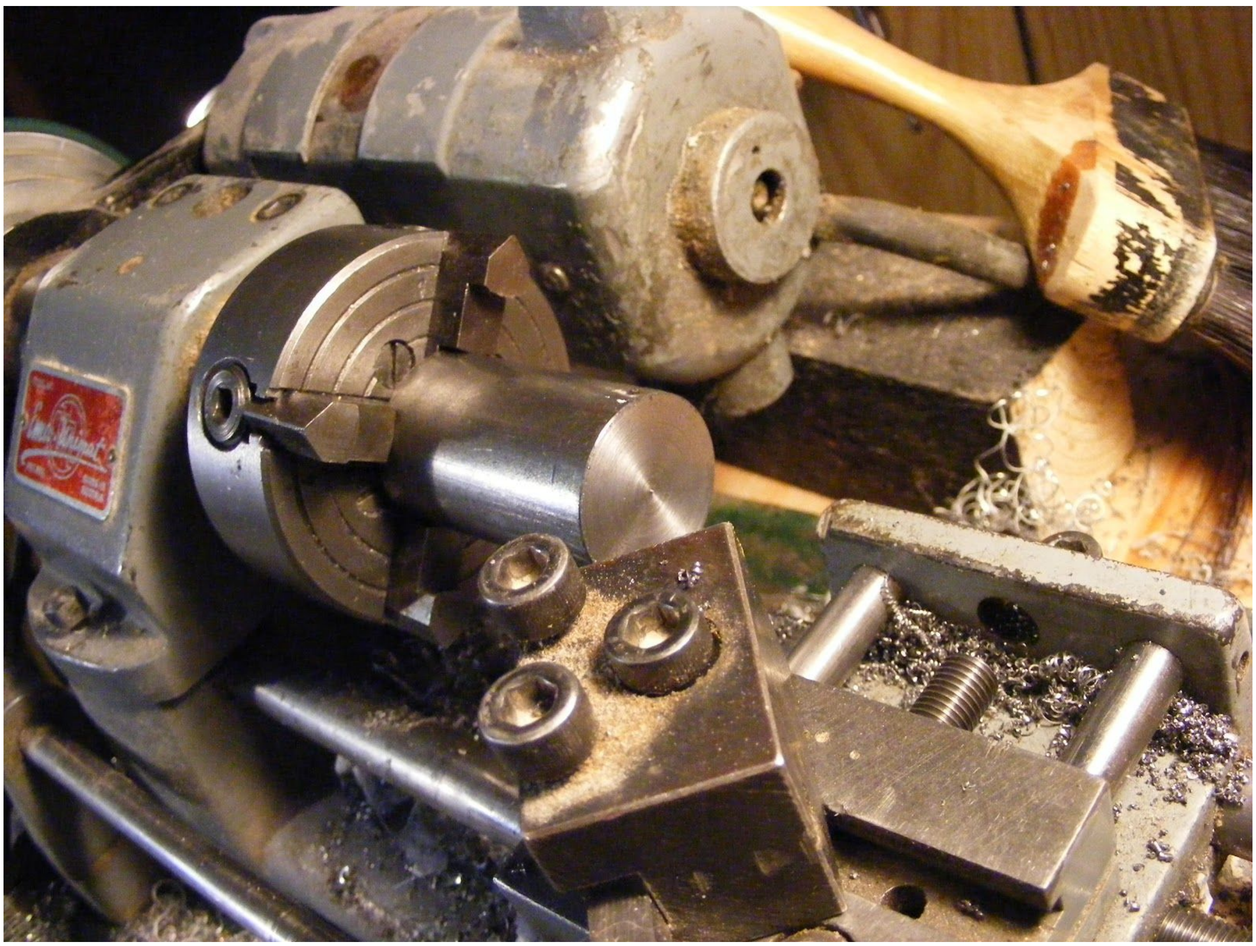
I used the 4-jaw chuck because it's more accurate and holds the work better but if you don't have one, you could also use a three-jaw. If your chuck isn't holding as well as mine did, you might want to put in a center and use the tailstock to press the workpiece into the chuck. We'll need that center hole later anyway.

The magnetic base of my indicator is stuck on the headstock of my lathe. If your Unimat is not cast iron like mine you will need some other way of holding your indicator. Mounting the entire lathe on a steel plate seems like a good idea to me. I guess you could put the indicator on the cross-slide, too.



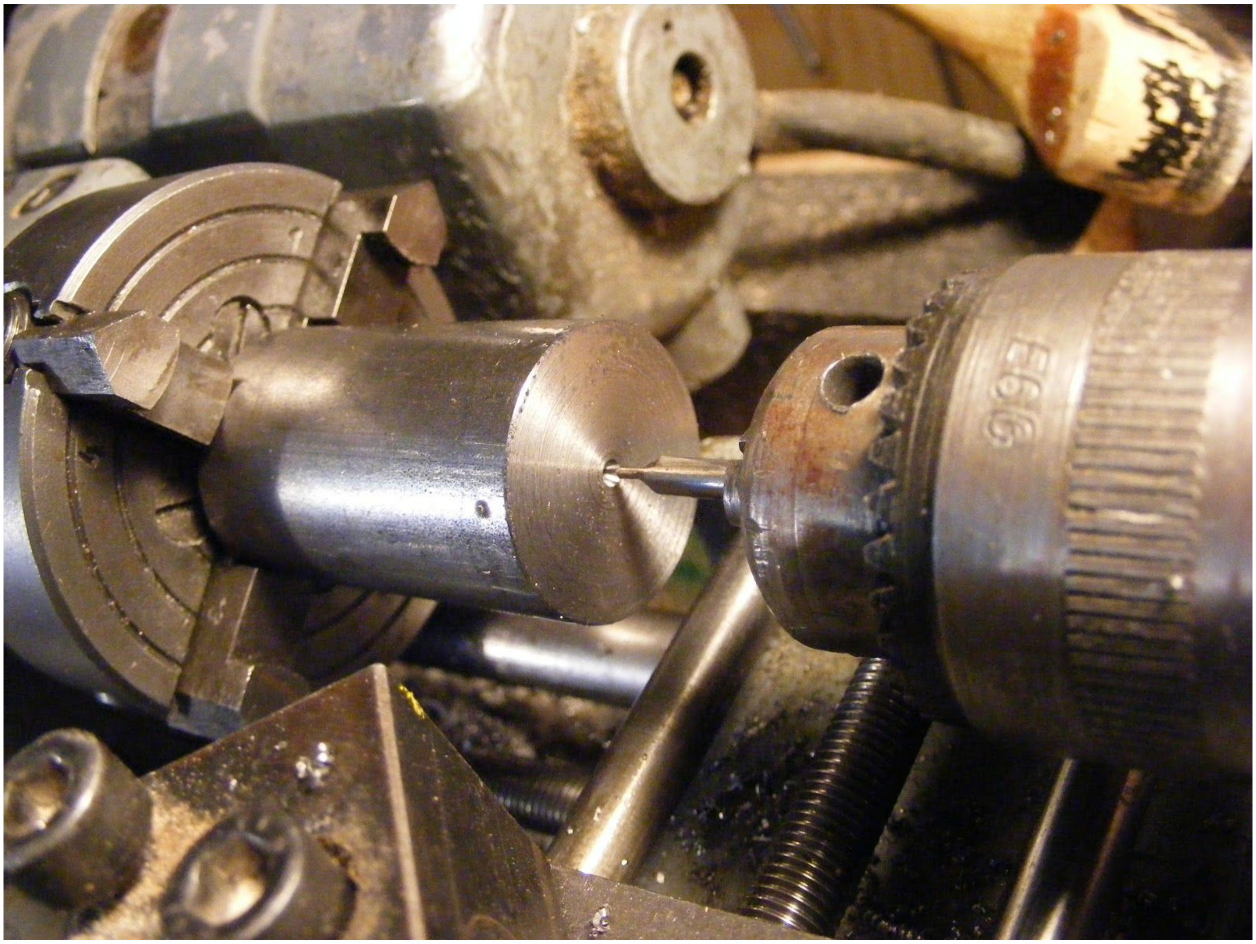
One End Faced

Note the reversed jaws - if I had chucked it with the jaws the usual way around the jaws would not have cleared the ways. Note how little jaw is actually holding the work. You have to be careful when working with this much overhang to avoid having the piece jam and fling itself out of the chuck - possibly right at your face. That didn't actually happen - all went fine during this operation and I still have all my front teeth.



Center Drill

It is good to have the stock accurately chucked for this step but it doesn't actually matter in the end as long as it's decently close. We will be turning the outside surface down a couple of millimeters later so any small error will be removed then.



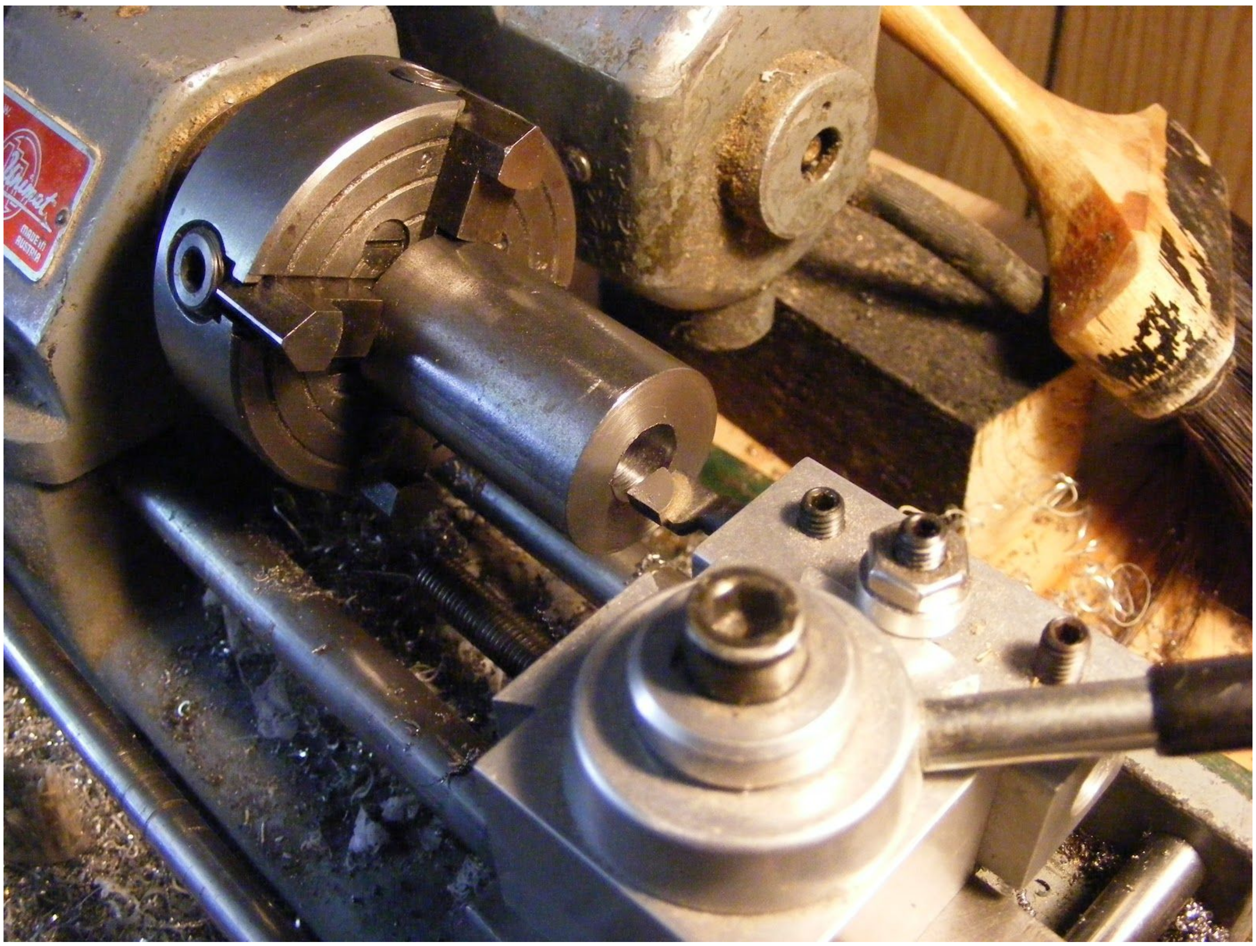
Drilling for the Spindle Interface

We are going to first make the spindle interface, then mount the workpiece directly onto the spindle to finish it. This procedure ensures that the important surfaces are all accurately concentric with the spindle axis. That's more-or-less the whole point of using collets.

Here I'm using a drill press to make a hole big enough to get a boring bar into. This hole will be eventually threaded M12x1.0 to fit on the spindle. The tap drill for this thread is 11mm but I didn't have anything that big, so I bored it to that size on the lathe. If you had an 11mm drill you could drill this hole and not bore it. 27/64" is 10.716mm, pretty close. I could have drilled it on the lathe but then I would have had to drill a smaller hole and do much more boring, which is - ah-hem - boring. Don't drill the hole all the way through because we are going to need the stock on the other end temporarily to do the threading. We also need the bottom of the hole for a later operation to get the bottom surface lined up.

Bore to Tapping Diameter

Here I am boring out the hole to 11mm. When this is finished it is necessary to bore a relief for the spindle register, which is 12 mm. You do NOT need an accurate fit on this 12mm section. You actually need clearance to avoid putting sideways pressure on the threads, so bore it out with clearance, like 13mm. That's a lot of clearance but it doesn't matter. The precision is required elsewhere.

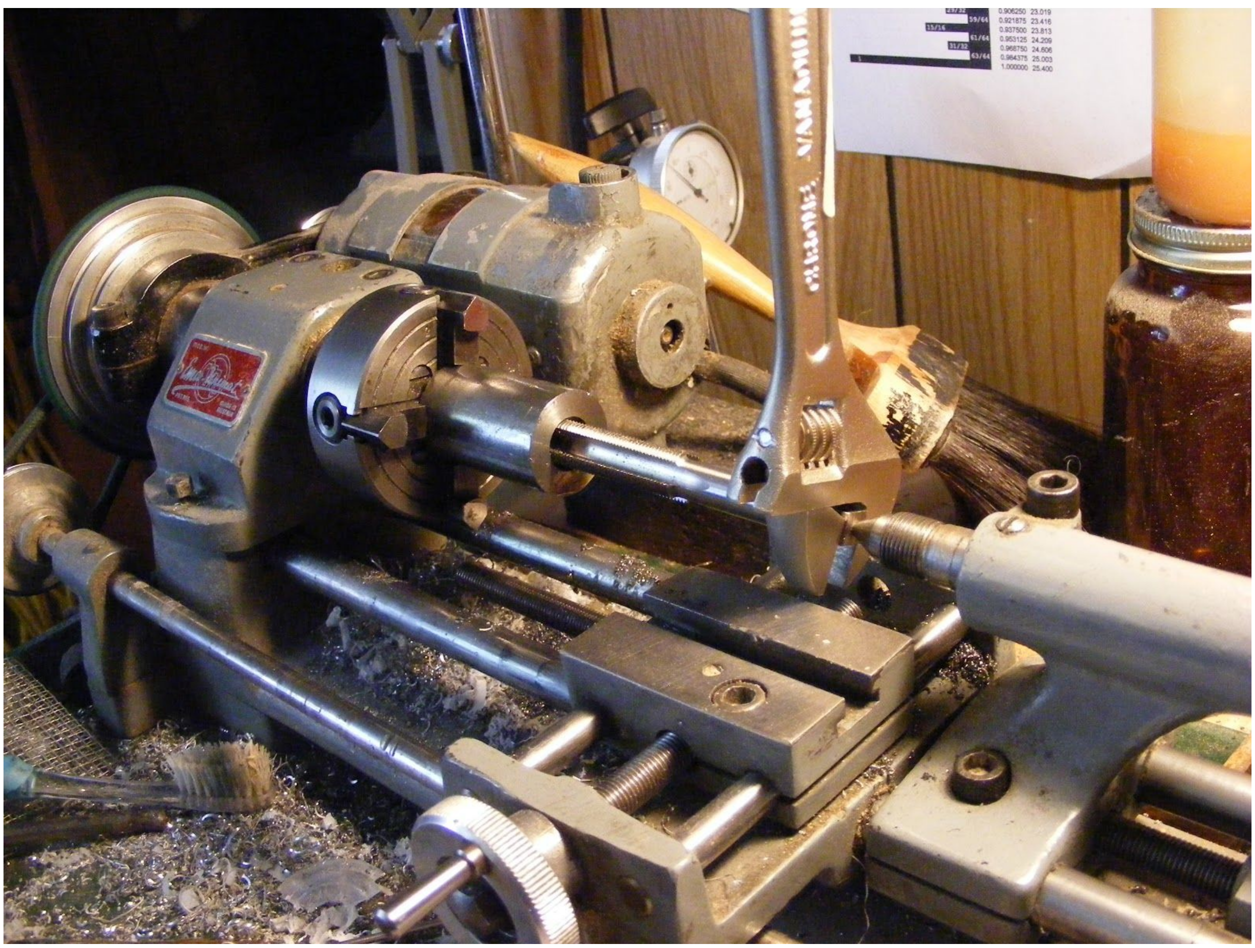


It is actually the conical shape of the threads that aligns things concentrically on the Unimat spindle. If the cylindrical “register” section actually makes contact then it will force the axis of the collet holder to a slight angle with respect to the axis of the spindle, which will create repeatability problems. So there should be no contact. If there is no contact then there must be clearance, and if there is clearance then it does not matter how much clearance there is. The shoulder of the collet holder must come down accurately against the shoulder of the spindle and both must be accurately perpendicular to the spindle axis. We’ll make this happen in a later step.

Tapping the Spindle Bore

Here I am tapping the 11mm hole M12x1.0 to fit the spindle. The dead centre holds the tap straight. You have to feed the tailstock in as you turn the tap in order to keep it straight. You could tap the entire hole this way but it is awkward and you really need a way to apply serious torque to the workpiece - putting that much force on your chuck seems unwise to me. I forgot to drill the tommy bar hole, which I should have done before I started this step. It would have made turning the tap a lot easier. I am just going to start the tap here to get the threads going straight.

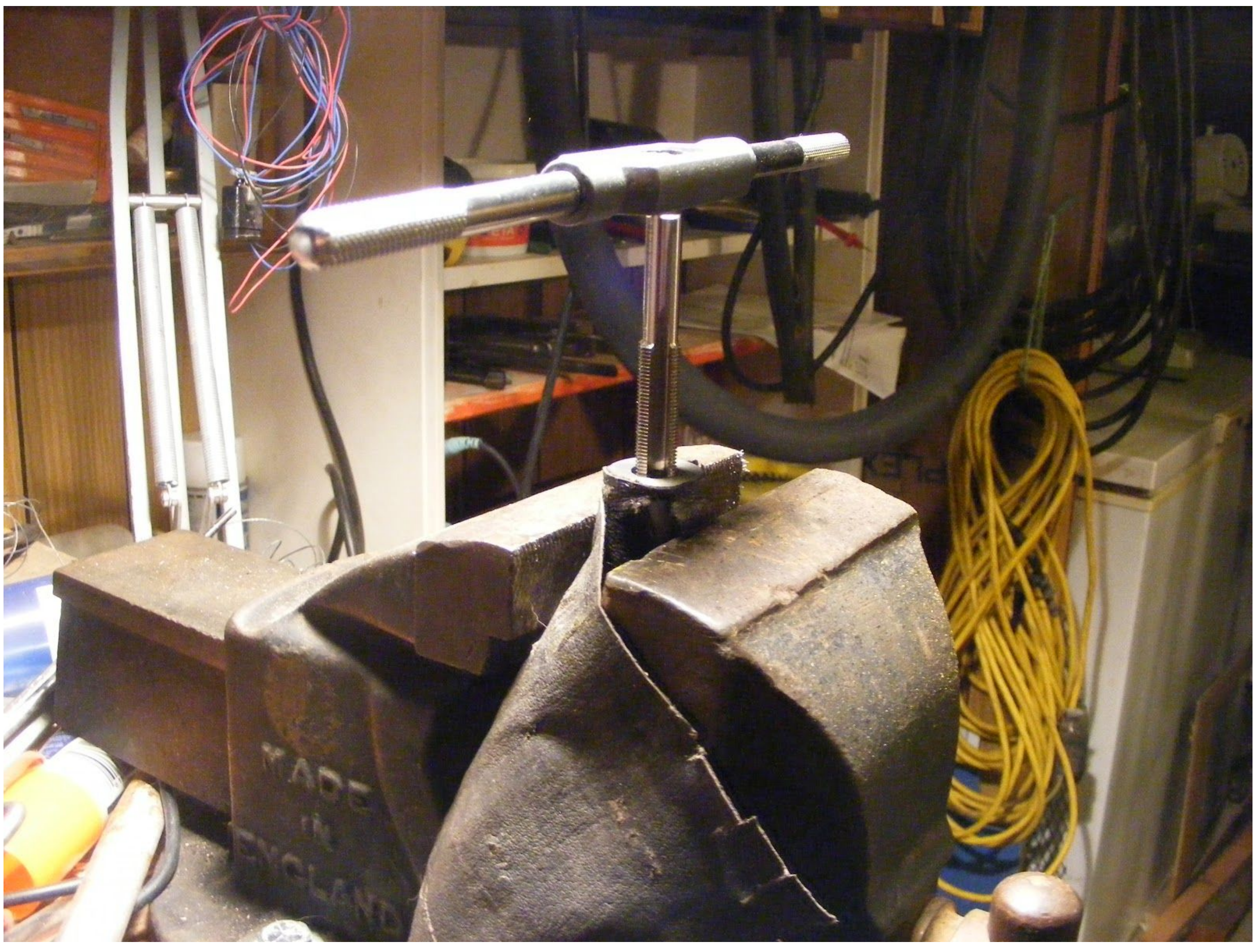
You could also mill, grind, or file flats on the adaptor in order to use a wrench on it and they would be very handy at this stage. I prefer the tommy bar scheme because I already have tommy bars lying around for the 3-jaw and drill chuck so I won't need another special wrench for this purpose.



Finishing the Threads

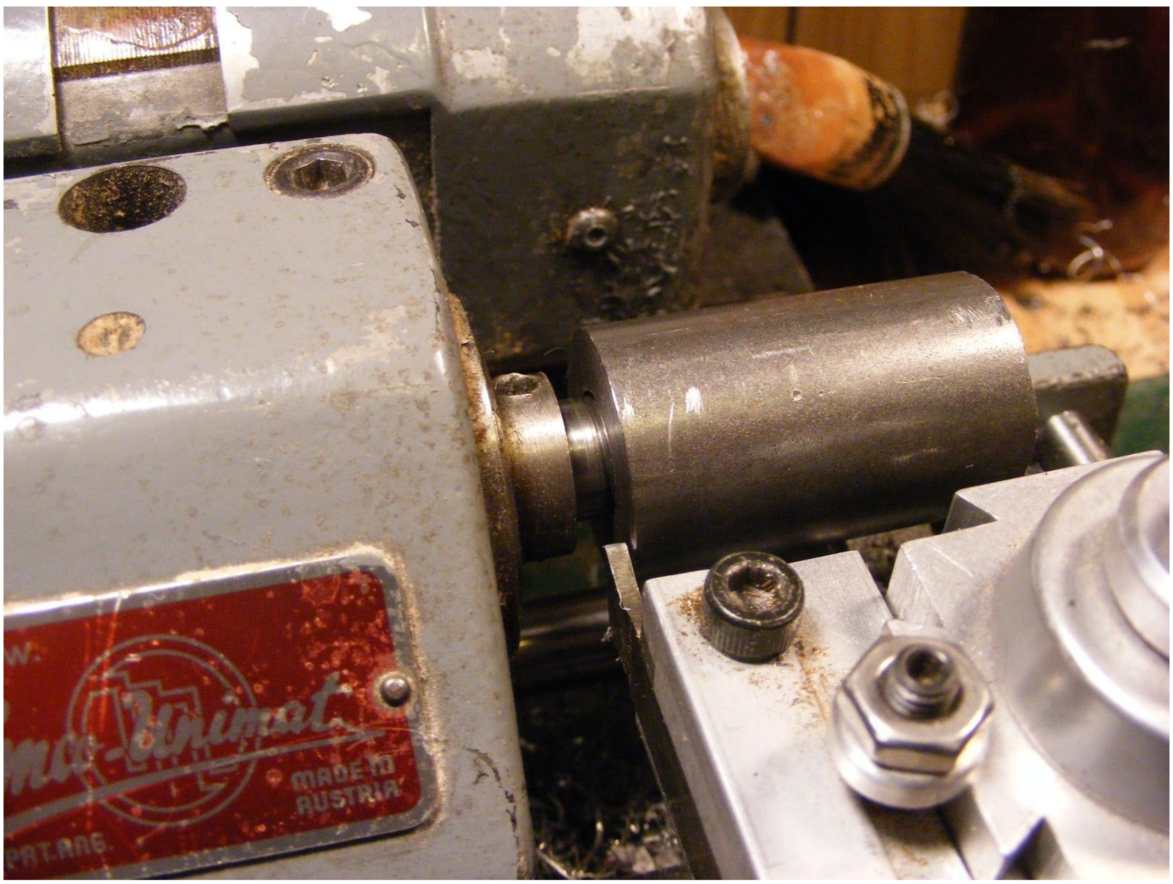
It's much easier to develop the required torque with a firm grip on the piece and a tap handle. This is a plug tap. I also have a bottoming tap but it was not necessary to bottom the threads in this project because there is plenty of clearance at the bottom of the hole.

I wrapped the piece with leather to avoid marring the surface but this is not strictly necessary because we are going to take off a couple of millimeters later anyway.



Truing Up the Shoulder

It is essential that the shoulder of the collet holder is accurately perpendicular to the axis of the threads. Although we THINK we have the threads straight there are a couple of ways we could have gone slightly wrong and got them a little wonky. To make sure that surface is perpendicular, we'll mount the holder on the spindle and true it up. To get some clearance for the cutting tool, the threads are tightened up against a dead center in the spindle, which produces that gap between the workpiece and the spindle shoulder and allows the threads to seat firmly and concentrically. The next step is to use a narrow tool like this cut-off tool to very lightly true up the back face of the work so that it will seat cleanly on the shoulder. Assuming the threads were cut nicely, this is the only place where precision is required in the spindle interface. This face should come down perfectly flat on the spindle shoulder so that it puts zero side force on the threads. All force should come parallel to the spindle axis. Then the conical surface of the threads will force them to align concentrically with the spindle. Don't run the tool into the spindle threads, of course - leave a little burr right next to the threads and cut it off later.



Spindle Interface Finished

Remove the workpiece and cut, file, or grind off the burr next to the threads.

The spindle interface is now finished. Remove the dead center from the spindle, blow out any chips, and put the workpiece back on. It should go onto the spindle smoothly and lock up really tightly as the end surface hits the spindle shoulder simultaneously all around. If it jams on tightly that is a sign that you have done it right. If it doesn't you may have some chips in there or in the threads, or maybe you didn’t leave enough clearance around the register. I actually found that I had to take a very light cut on the spindle to remove a small nick where someone had dropped something on the shoulder surface.

Now turn the entire outside surface down until you have a fresh cylindrical surface. It should be accurately cylindrical at that point so check with a micrometer or whatever you have and adjust the headstock angle slightly if necessary. The headstock alignment pin cannot be relied on to get it accurate enough. We actually need this to be a cylinder in order to get the angle of the interior cone later, which must be accurate or the collet will not grip a cylindrical tool or workpiece properly. Now turn it down to 22mm for the collet nut threads we will be putting on later.

Drill for the Guide Threads

We are going to put some temporary threads in the other end to guide the cutting of the threads that hold the collet nut. Precision is not required here.

I might have done this on the lathe but I don't have a short enough drill bit of the right size. Again, I could have drilled smaller on the lathe and bored it out but why would I, since I have this drill press?

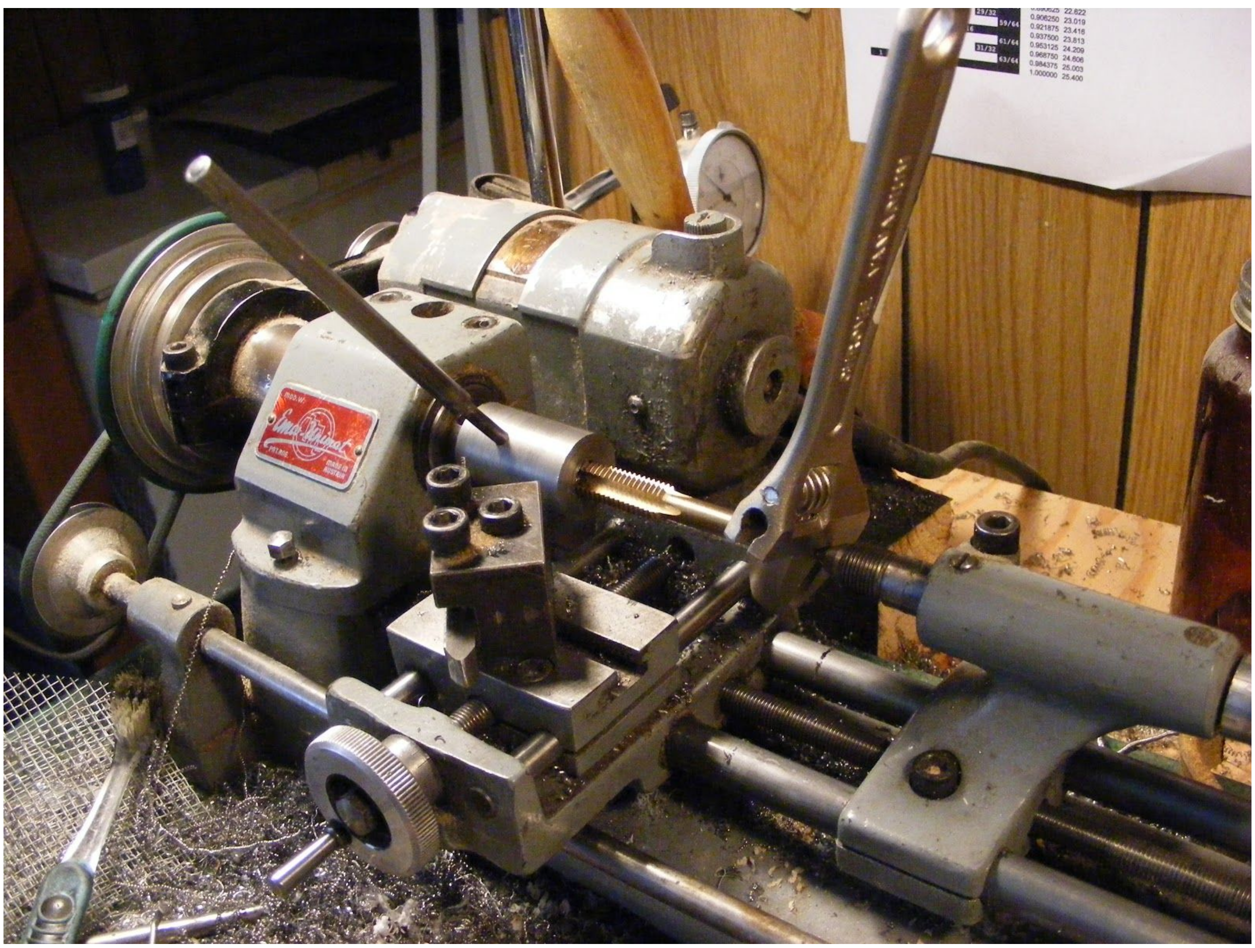
What’s going into this hole are M10x1.5 threads, so this is a “Q” drill, the tap size drill for that thread. 8.5mm is the official tap drill, if you have one.

Tapping the Pilot Threads

Tapping that hole with a M10x1.5 tap. Why this particular thread? Because we are going to copy that 1.5mm thread pitch onto the 22mm outside surface, which will give us M22x1.5 threads as required by the ER-16 closing nut.

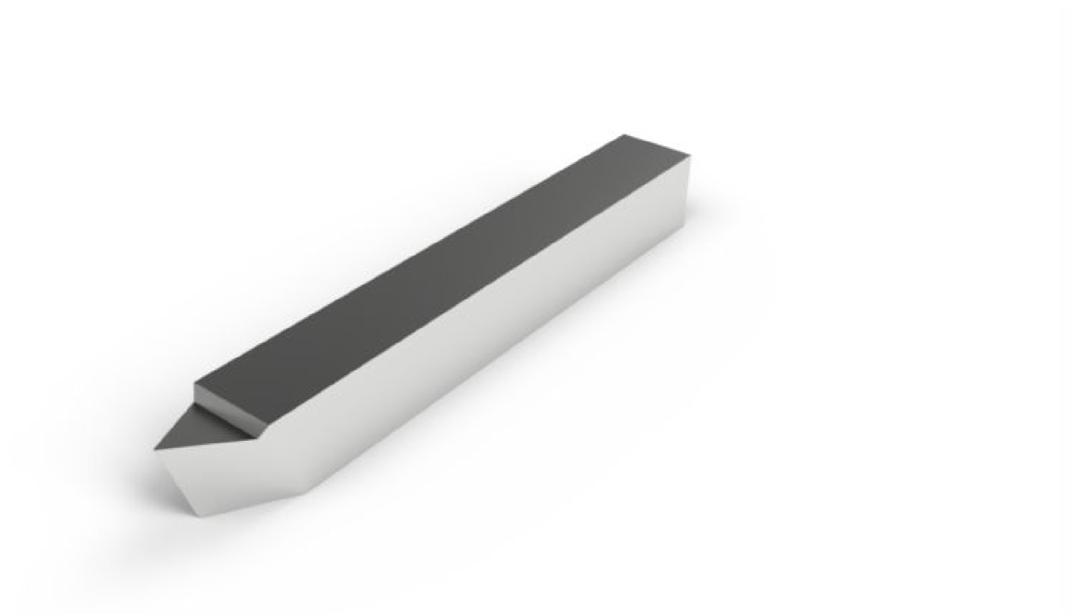
Note that by this point I have remembered to put in the tommy bar hole, which is helping me get torque on the workpiece. As before, once the tap has been started straight, take the workpiece out of the lathe and put it into a vice where everything will be much easier.

I’m sure it would be just fine if you just jammed the tap in the hole and lined it up straight by eye. These threads don’t need to be concentric or exactly straight and they are just going to be cut out later anyway.



Threading Tool

You are going to need a threading tool next. If you don't have one already, you need to grind one. Not a difficult task. Here's a picture:



The point must be accurately 60 degrees, so use a 30-60-90 triangle or whatever to line it up when you grind it.

I have drawn it here with 10 degrees of side rake on both sides and with 10 degrees of back (or top) rake. This number is not particularly important so long as you have some. Different materials prefer different rake angles so look it up, if you like, but it's not going to make much difference for cutting this one thread.

You can put a radius on the nose to make the threads stronger but it must be quite small for this thread, and this is a low-stress application so it's probably easier just to leave it sharp. There is no way you are going to break these threads with a closing nut!

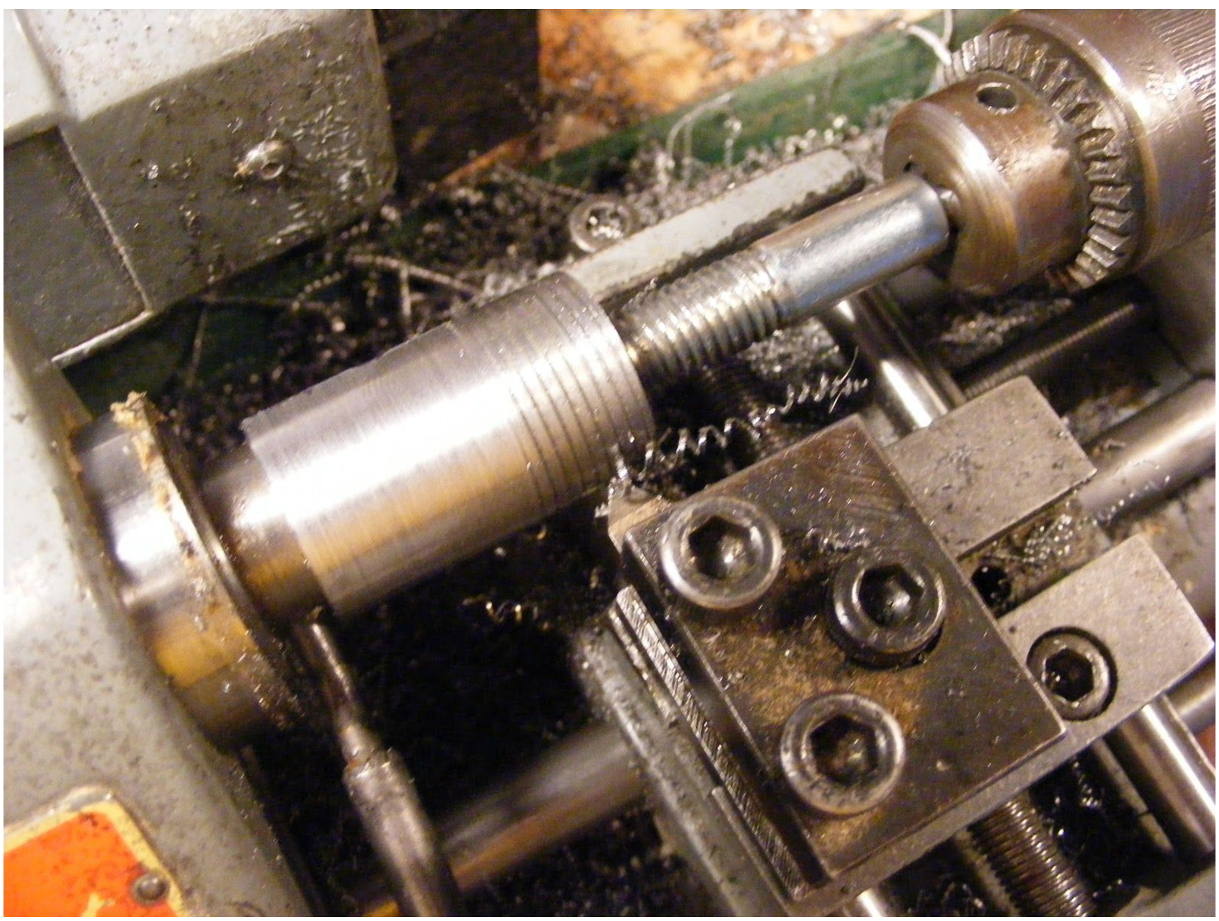
The tool must be lined up perpendicular to the spindle axis in use and the tip should be at center height.

A sharp tool will make cutting the threads easier so give it a bit of a hone along the cutting edges.

Starting the M22x1.5 Threads

The piece has been turned down to 22mm and we are going to put 1.5mm threads on it. In the drill chuck is what used to be a standard, hardware store M10x1.5 bolt, decapitated, and turned down to something that will fit into the drill chuck. You could also fit the 3-jaw chuck onto the tailstock and use that to hold the bolt. Lock the tailstock and loosen the quill on the headstock. Mount your threading tool and feed it slightly into the work, rotating the spindle by hand. As it turns, the bolt engages the pilot threads on the inside of the workpiece and moves it smoothly to the right at 1.5mm/turn. So we are making M22x1.5 threads, which is what is on the inside of the collet nut. We are also cutting them accurately concentric with the spindle axis, which is required if the closing nut is going to squeeze the collet concentrically.

Removing a chip of the size shown takes a fair amount of torque on the spindle. I did it a half turn at a time by sticking the tommy bar into the spindle cross hole and twisting it a half a turn at a time. No need to back out the tool when you get to the end - just turn the spindle backwards with the tool in the thread. If it's lubricated it will back out reasonably easily with the handwheel - er... pulley. Don’t forget to re-clamp the headstock quill when you are finished.

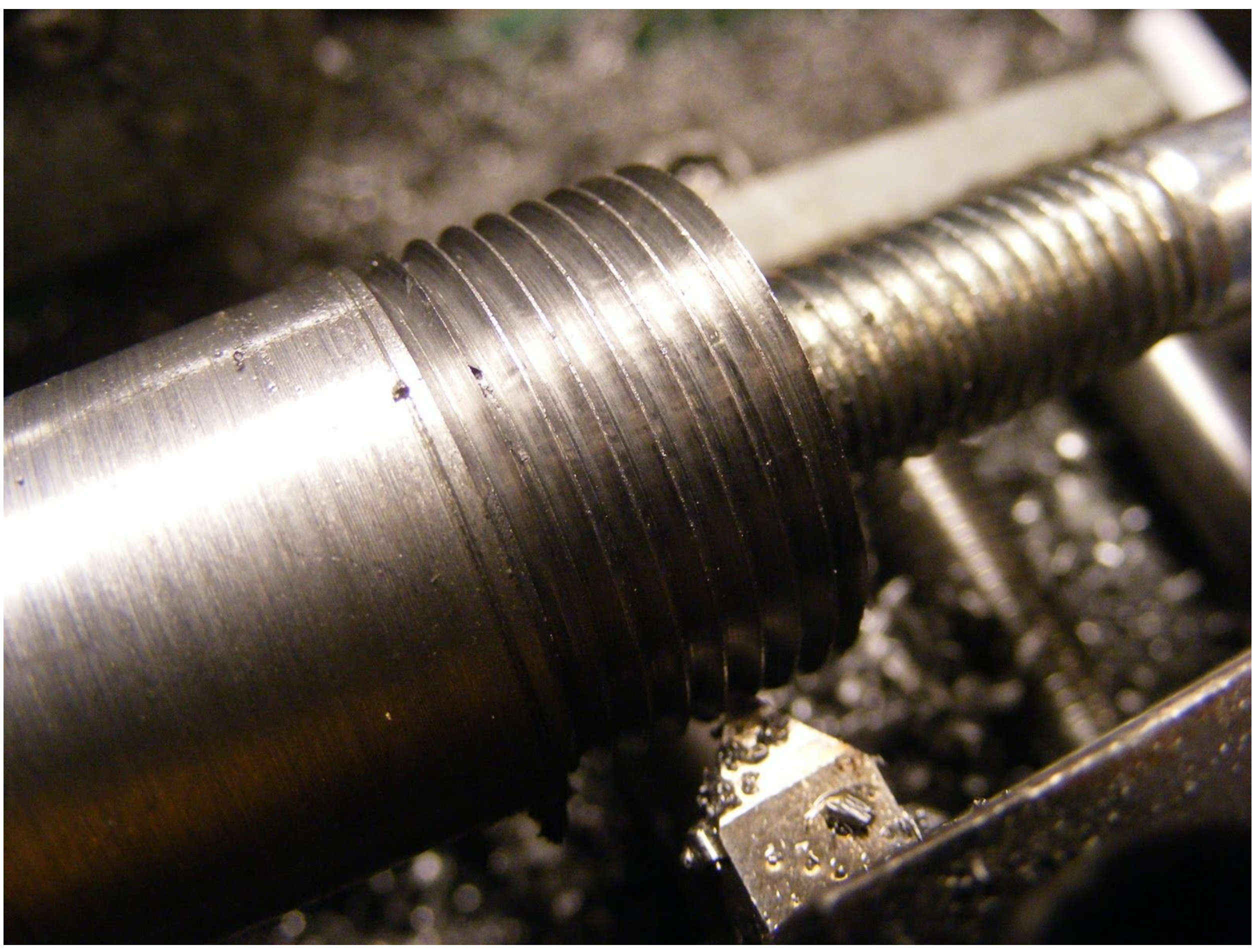


Threads Finished!

Keep taking light cuts to deepen the threads until they look like this. The ridges are not supposed to be sharp but to be 1/8 as wide as the thread pitch. It gets to be a fair amount of work when you have the tool all the way into the cut and you are cutting the entire face of the thread groove. You could advance both the cross slide and the carriage in the appropriate ratio to get the tool to cut on just one side. The ratio is tan(30) = 0.577 units of carriage motion for each 1 unit of cross slide motion, if you want to try that.

Actually, I thought the threads were finished when I took this picture but I had to go back and do another pass to get the nut to fit on smoothly. Before testing for fit, you should take a fine file and smooth off any burrs that may have developed on the ridges of the threads.

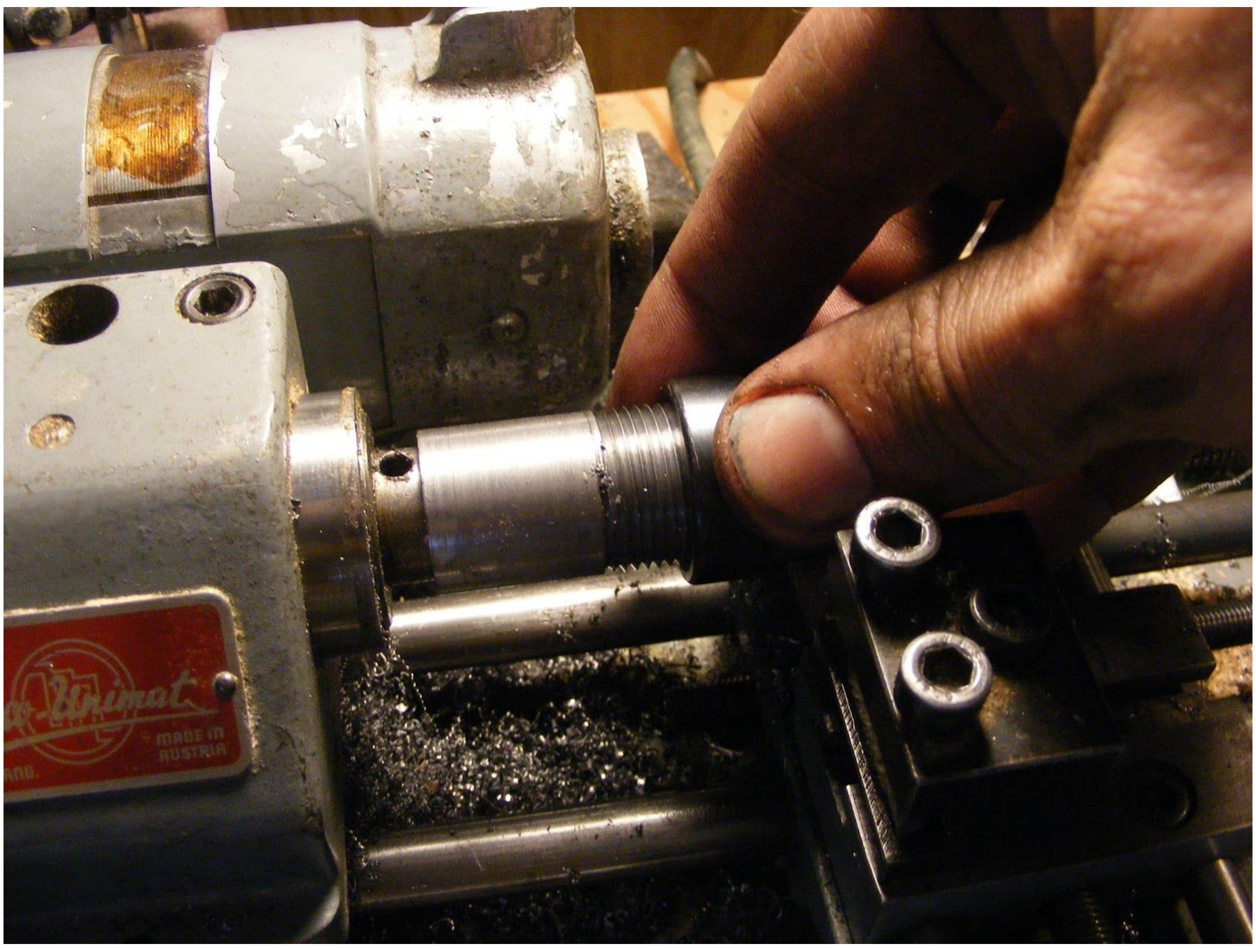
Threading would be a lot less work if you were working in brass or aluminum!



Closing Nut Fits!

This commercially-made ER-16 closing nut fits nicely on these threads. Because of the way we cut these threads we can be quite confident that they are concentric with the spindle axis. This is important because the closing nut has a conical inside surface that squeezes the collet into the holder. If the threads weren't concentric then the conical surface wouldn't be concentric and the collet would be distorted as it was being pushed into the holder.

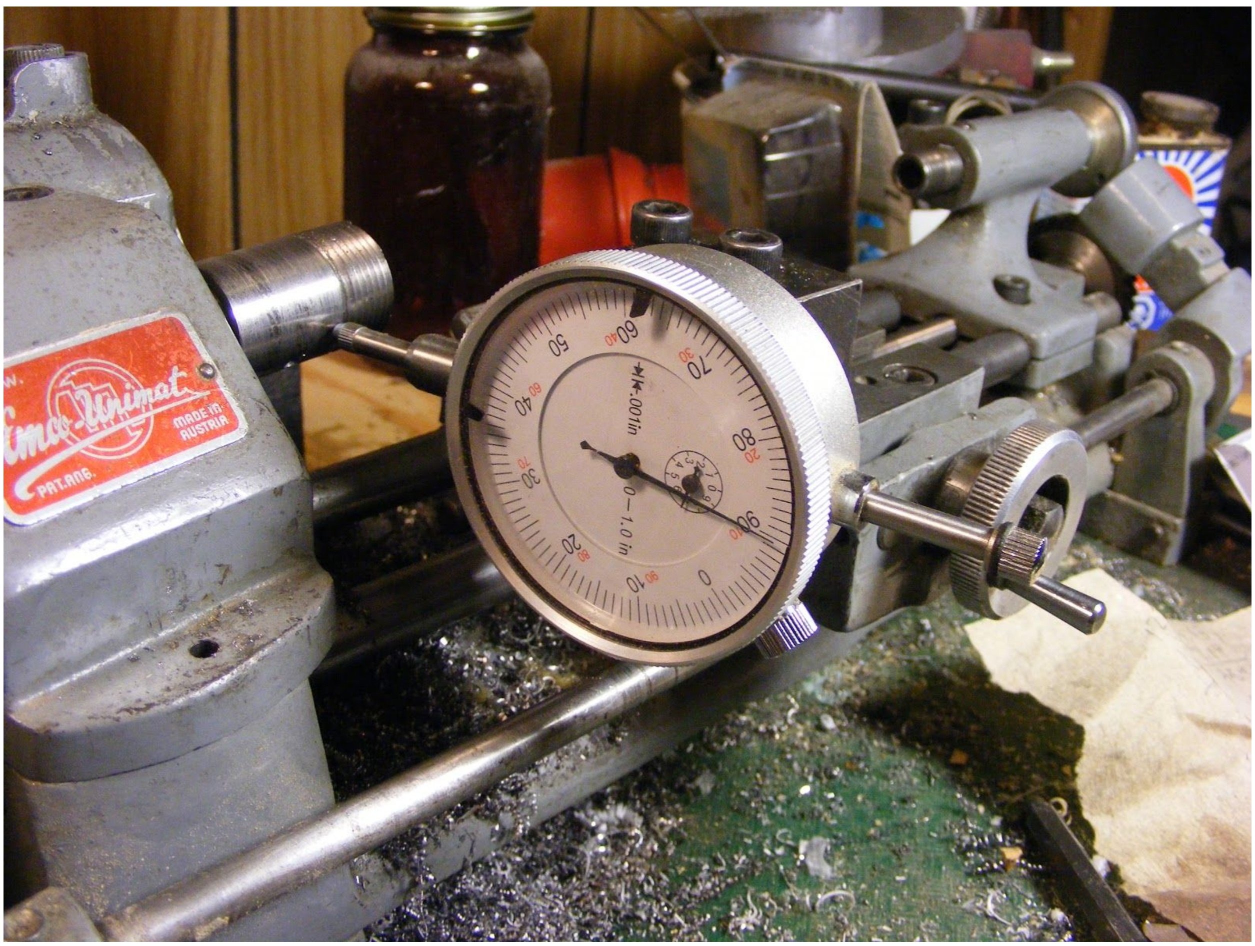
If you had an M22x1.5 die by some miracle, you could use it to cut these threads but you would have a real struggle to get them concentric enough, I think.



Setting the Cone Taper

Now we have to put in a conical bore on the inside of the holder. The angle of the cone is precisely 8 degrees from the axis. On the Unimat, this is done by rotating the headstock toward the rear by 8 degrees. You can set this angle with trigonometry and a dial indicator. The tangent of 8 degrees is .1405 - there now, the trig is all finished.

All this really means is that, as the carriage moves to the right, the angle makes the spindle axis move away from the carriage at a particular rate. Mount an indicator to the carriage and run its point along something cylindrical, which can be the outside surface of our workpiece. We turned it nice and cylindrical, remember? You could also run the headstock quill out and use that - it should be aligned with the spindle axis.



If the spindle axis is at the correct angle, the indicator then must move .1405mm for each 1mm the carriage moves. I had room on the workpiece to move the point of the indicator 20mm lengthwise, so it should move 2.81mm = .111 inch crosswise when I have the angle right.

For the best accuracy, the axis of the indicator must be perpendicular to the ways. I have the dial clamped in the tool holder. This setup was only barely possible with this indicator so you might have to rig up something else to hold the dial properly. It must be held firmly - there is no room here for errors caused by flexing in the setup.

Here’s how you converge on the correct angle once you have set it as good as you can get it with a protractor or whatever:

1. Wind the carriage left as far as you can and still have the point of the indicator on the workpiece.
2. Wind the carriage to the right and stop on the 0.0 mark on the handwheel.
3. Zero the indicator.
4. Turn the handwheel to move the carriage 20 turns to the left, stopping on 0.0.
5. Read the indicator, which should have moved 2.81mm, or .111 inches.
6. If the indicator reads less, then the angle is too small, so tap the headstock to a slightly larger angle. If it reads more, then tap it back.
7. Go back to step 1.

Keep going around this loop until you get it exactly right. Be sure that you allow for backlash on the carriage by always approaching the handwheel marks from the same direction every time.

The accuracy of this angle is really important. If it does not match the angle on the collet with high precision then the collet will not close equally tightly at the front and the rear, which means that the workpiece could wobble around. I don’t think there is any way to get the headstock angle set to sufficient accuracy without using an indicator like this.

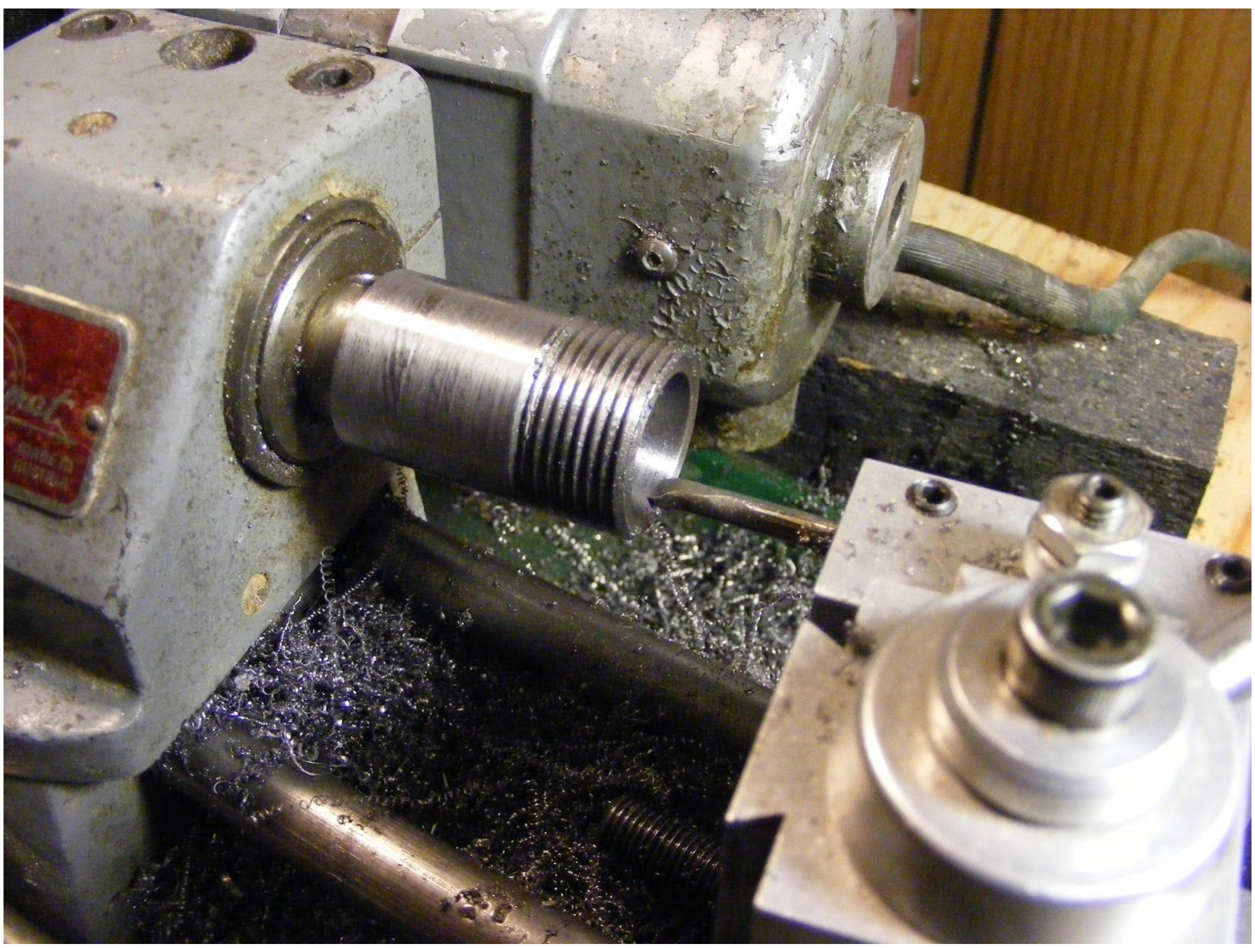
When you have the angle right, tighten up the headstock clamp and check the angle one more time in case it slipped while you were tightening it.

Boring the Cone

I'm using a little homemade boring bar here to bore out the cone. Keep going until the opening is 16mm across, the standard for ER-16 collets. Precision is not required here as long as the angle of the cone is exactly correct. The collet is going to slide as far into that cone as it needs to to jam down on whatever is in it so the precise diameter of the opening is not really important, within reason.

It is important that the tool be accurately at center height. Otherwise, the slope of the cone will be curved and not match the straight cone of the collet.

Once you have finished the cone I suggest that you polish it lightly with a little fine abrasive paper to remove any burrs or roughness you may have left in there. While you are at it you can polish the outside surface a little, too, to make it look spiffier and get off any burrs.



Trying it Out

Trying a 5mm collet there. This is just about right. It sticks out the right amount. When the collet has been pushed in far enough to close the slots completely, the edge of the extraction groove should be close to the end of the collet holder.

Look at all those lovely chips! There is quite a bit of metal to take out of there.

Collet with Tool

Here is a milling cutter mounted in the collet! The run-out proved to be very good - I can't measure it with my .001" dial indicator.

You can buy special wrenches that are supposed to make it difficult to squeeze the collet too tightly. But I just use a crescent wrench and don't worry about it.

You can also mount it on the tailstock for holding drills, like 1mm drills, which tend to break if they are not right on center. I'm thinking that I will make a specialized one just for the tailstock because I frequently drill down the axis of round stock and having the drill bit on center makes for a better hole. My drill chuck is OK but not really accurate enough for small drills.

It might also be fun to make an ER-40 collet chuck the same way, which goes up to 26mm capacity. Always another project!

Material and Supplies

ER-16 Closing Nut	My vendor: http://www.ctctools.biz/er-clamping-nuts/ (but many others)
ER-16 Collet Set	My vendor: http://www.ctctools.biz/collet-sets/ (but many others)
Steel, Al, or Brass stock	Workpiece
M10x1.25 bolt	Provides guide threads
HSS tool blank	To grind into the threading tool

Tools

M12x1.0 tap	Spindle threads
Dial indicator	Measure cone angle, align stock
Micrometer or Caliper	Various measurement tasks
Center drill	Make center hole
“Q” or 8.5mm drill bit	Hole for M10x1.5 guide threads
Cut-off or other narrow lathe tool	Dress shoulder contact area flat
Dead center	Spacer between spindle and workpiece