Making Clock Wheel & Pinion Cutters

When making hand made clocks or in repair work an odd size cutter is sometimes needed. Sometimes just one pinion is required and does not justify the cost of a commercial cutter. I have been making my own form relieved wheel cutters for years but shied away from making pinion cutters. Now that I am finished with commercial work I can try out all the ideas I have never had the time to try before. I have designed the making of the cutters with the owner of the small lathe in mind, there are many makes and models of small lathes on the market today and most of the parts of the tool can be modified to suit. Many years ago I made a fly cutter for making the reverse wheel pinion on a longcase clock. These pinions are made of brass but I pressed the cutter into service to do a trial run on a steel pinion. I wanted to use free cutting steel that I have in the workshop but I could not find it at the time (I'll find it later when looking for something else) and used a steel bolt instead. This was a blessing in disguise as the results of my efforts were most rewarding. The steel bolt was a nasty (sticky) sort of steel and not easy to machine with a fine finish. The pinion blank was set up in the pinion cutting machine and the cutter, centred. I took smaller bites of the pinion than if I was using a commercial cutter. I chose the most brutal and unforgiving way to cut the pinion with this carbon steel fly cutter, dry! What I was looking for was a distortion or leaning of the pinion leaf. I only cut 2 gashes to produce one test leaf but the results were most encouraging. The finish was not as good as a commercial cutter but there was no leaning of the leaf, which surprised me! I have read the articles by D Unwin and Duplex on this subject and thought I would combine some of the ideas of both into a system of making cutters. Unwin uses 4 tooth cutters and Duplex 12. I used the Duplex idea for making a drilling template and Unwins idea of a 4 tooth cutter. Both of the articles will make good wheel cutters but using a taper slide will ease the making of clock pinion cutters. I settled on a bore of 7mm as used in a lot of commercial cutters, and a diameter of 1 inch!

I have tried to design the parts, so that no complicated set ups are needed. I could have used the 4 jaw chuck in some instances but realize that not everyone has this item. The threaded parts could be made on the lathe but ready made threaded bar is cheap to buy. For the small amount that is needed you can even use the thread from a couple of bolts. The device is designed around the Unimat lathe and has a 14mm x 1mm thread that screws direct to the lathe nose. This keeps the cutting forces nearer the bearings and of course you can modify the design to suit your own make of lathe. The first items to be made are the cutter blank holding tool and drilling template. I used an off cut of 2" x ½" inch brass for the holding tool but any metal will do and after turning the face true I formed a recess in the base to prevent rocking. Reverse in the chuck and true the top face. This has to have a good finish as the cutter blank sits on this surface. Drill and tap 6mm and depending on the base thickness allow about 5/8” of the 6mm thread above the surface. Apply Loctite to the threads and run a nut up to the surface, tighten with a spanner or long reach socket, set aside for a few hours. When the Loctite has cured, chuck the base and turn the nut down to leave a 7mm diameter sleeve, clean the end of the 6mm thread.

The drilling template is made from 3/16” thick steel plate or part off a 1 inch diameter slice on a larger lathe. Take a light cut to true the surfaces and take off the corners before parting. Having set the disk in the 3 jaw chuck I used my drilling spindle to spot 4 x 1/8” indexing holes on a radius of -375” and while in the chuck a 7mm hole was drilled and bored all at one setting. You could use the milling/drilling fixture for this. The disk was placed onto the base and spotted through with a 1/8” drill to show where to turn a groove for the drill to run into when in use. A 6mm brass/steel nut was made from hexagonal stock and while in the chuck a 7mm diameter shoulder was turned too a length of -100”. This will be used for centering the cutter blank onto the drilling template.

The main body of the eccentric turning fixture is made from 1 inch diameter steel bar and it helps if you have access to a larger lathe for forming the 14x1mm thread. It can be done on the Unimat but it takes longer to do. If you have to use the Unimat I would suggest you hold the bar in the 4 jaw chuck.

My piece of steel bar came from the scrap bin and has a smaller diameter at the front but a full 1 inch dia would be better, the length of the device is 1 ¼”.

Drill a 4-1mm Tommy bar hole on the side and screw the bar onto the lathe, true all the surfaces and remove from the lathe. Measure ¼” from the centre of the bar and drill and tap 6mm for a depth of 5/16”. Loctite a 6mm stud into the device about 5/8” high. Place the drilling template onto the eccentric turning tool and use the nut with the 7mm shoulder. Rotate the disk until one of the holes is opposite the 6mm stud and drill a 1/8” hole for a locating peg, about 5/16” deep. Drill another hole about 3/32” right through, if the peg should shear off in use it can be removed with a punch from the inside. The peg should be just less than 1/8” high which will take the smallest thickness of cutter blank, secure with Loctite. A lot of suppliers sell gauge plate by the square inch and as the cutter blank will end up a sort of square shape with rounded edges it makes sense to preserve this shape. Set up the blank into the drilling template and drill 1/8” right through in all 4 places and remove from the tool. Give all the holes a slight counter sink on each side and rub down with emery or wet and dry paper to remove any burrs.

Having set the cutter blank in the device I did a trial cut and the lathe was not happy with the intermittent cutting. I have read a great deal on this subject by other authors and they have always resorted to using a toothed belt for the final drive. This was another job that needed to be resolved and I had gathered the necessary parts over the years for such an occasion. My lathe was bought new in 1986 and the motor could not handle the demands of a commercial situation and gave up within a year. Some of the newer lathes on the market are equipped with motors that provide a constant torque at slow revs and so no modifications might be necessary.

Once the drive was sorted out it was back to making the cutters! I find that when doing these sorts of repetitive jobs that it is all too easy to go into auto pilot mode, so a good idea is to use stops on both axis of the lathe. My version for the Unimat has a two tier system for the cross and taper slide and a two way idea for a longitudinal stop. One of the suppliers that I have used for many years sells gauge plate in a 6″ x 2″ strip at a very reasonable price and this is enough to make 12 cutters. (It might be a good idea to make the cutter blanks in small batches as at this point they all start out the same.) Place a cutter blank into the eccentric turning tool and use a sharp hss turning tool to remove the unwanted metal, work to the stop or the dial gauge. What is needed is a square shaped blank with rounded edges. Remove the ordinary tool post and install the taper turning slide. The Unimat taper turning slide is not designed to be swung round this far and there are no setting marks on the cross slide but this is easy to remedy. If you don’t want to mark your lathe just use a strip of masking tape on the cross slide. Set the slide parallel with the lathe axis and mark the tape with a pen at the 30deg mark and step round until you have enough marks to swing the taper slide round to 15deg either side. You might have to make an extension piece for the cross slide to avoid the hand wheels clashing. A -8 module, 8 leaf cutter was needed for an up date of a clock I made years ago and from the table of figures this turns out as, Tooth height = 86 thou, radius of form tool = 33 thou and cutter tip width =36 thou. The HSS lathe cutting tool is ground to a small parting tool shape and given a radius of -033″. I used my Metric drill gauge and used the 1-7mm hole to eye in the radius. I plan to make a grinding jig for this task.

An 8 leaf pinion cutter has an inclusive angle of 30deg, so set the taper slide to 15deg and bring the cutting tool up to the side edge of the blank. Turn the lathe by hand and when the tool touches the blank, swing the blank out of the way and advance the tool the required amount. Set the depth stop or note the longitudinal dial reading. My blank was 200thou thick, so -036″ from -2″ = -164″, div x 2 = -082. Again, offer up the cutting tool to the face of the blank and advance the taper slide tool -086″, (the tooth height) again set the depth stop or note the dial reading. Lock the cross slide or the settings will be lost!

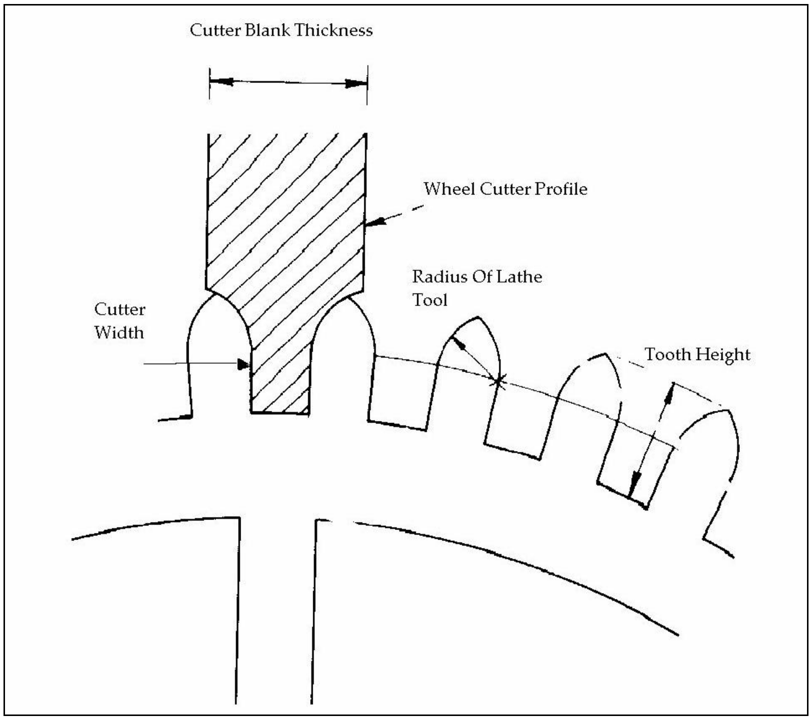
Retract the tool before starting the lathe and take small cuts until both slide stops prevent further cutting. I used cutting oil to ease the burden on the small lathe tool. When all 4 faces have been turned, remove from the tool and take off the burrs with 400 grit paper.

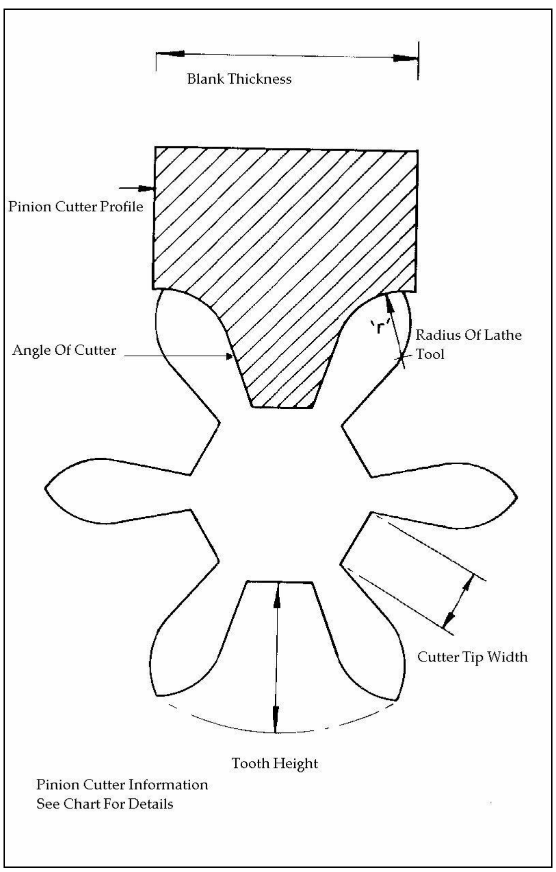
Reverse the cutter blank and place in the tool, turn the remaining 4 faces.

A jig is needed for making the radial faces of the cutter. A scrap piece of 1/8″ brass plate is held in the lathe tool post. A 6mm stud was fitted and as before the drilling template was used to locate a 1/8” diameter peg. Place the cutter blank into the holding jig using the nut with the 7mm shoulder. Install a slitting saw in the lathe and line the radial face of the cutter blank by eye, make a plunge cut of about 3/16” depth, I used neat cutting oil for this, applied with a small paint brush. After each saw cut the cutter was taken from the jig and any burrs were removed by rubbing on 400 grit paper. The saw blade was changed over for one of 1/8” thickness and used to remove the waste portions of the blank. This can be done with a hand held hacksaw and a file to remove the bulk of material. I have left a small portion of the original 4 dividing holes as an aid to future re-grinding of the cutters. Mark the cutter with any relevant information e.g. -8 8L then harden and temper to a pale straw colour. When tempering small flat pieces such as these it is a good idea to lay the part onto a bed of sand and heat from underneath. When the desired colour is reached the part is plunged vertically into cold water. The last part of the making of the cutters is to grind the cutting faces. You can buy special cup or knife shaped grinding wheels for this kind of work but they can be expensive. An ordinary fine grain wheel can be adapted for this task, they are easy to make but extremely messy using a diamond. If you have a tool and cutter grinder it would be easy to make a fixture to grind the cutting faces. Cover the lathe bed with cloths and set the cutter into the holding jig in the tool post. Line up the cutter face with the grinding wheel and lock the longitudinal slide, plunge the cutter into the grinding wheel (don’t take of more than 1/2 thou at a time) and grind all 4 faces at the same setting. Unlock the slide and take off another ½ thou, continue until all 4 faces are equal. As an experiment I used a small cut off blade 2mm thick to sharpen the cutter, it seemed to work just the same as a larger wheel. The article has dealt with the making of pinion cutters which are more difficult to make than wheel cutters. When making wheel cutters you don’t have to use the taper slide. I have given charts that have all of the information needed for making wheel/pinion cutters without needing to know all of the technical terms associated with this subject. Most good horological books have this information.

While I was finishing this article I received the book Wheel & pinion Cutting in Horology by J Malcolm Wild. On page 147 is a version of the tool I have just described. Malcolm has kindly given me permission to quote the wheel and pinion information from his book. Anyone who is serious about wheel or pinion cutting, either professional or amateur, should have this book for the wealth of knowledge contained in its pages.

Another mention must be made to David Robertson (USA) who read and compared all of the articles and gave corrections where necessary.


Cutter Blank Thickness
Wheel Cutter Profile
Radius Of Lathe
Tool
Cutter
Width
Tooth Height


Blank Thickness
Pinion Cutter Profile
Angle Of Cutter
'r'
Radius Of Lathe
Tool
Cutter Tip Width
Tooth Height
Pinion Cutter Information
See Chart For Details

Wheel cutter making Data In Inches

Module	Lathe Tool Radius	Cutter Tooth Width	Tooth Height	Cutter Blank Thickness
-4	-025″	-025″	-046″	-065″
-45	-028″	-028″	-052″	-080″
-5	-031″	-031″	-058″	-080″
-55	-034″	-034″	-063″	-090″
-6	-037″	-037″	-069″	-090″
-65	-040″	-040″	-075″	-110″
-7	-043″	-043″	-080″	-110″
-75	-046″	-046″	-086″	-125″
-8	-049″	-049″	-092″	-125″
-85	-053″	-053″	-098″	-156″
-9	-056″	-056″	-104″	-156″
-95	-059″	-059″	-110″	-170″
1-0	-062″	-062″	-115″	-170″

Pinion Cutter Making Data In Inches

Module	No of leaves	Angle of cutter	Radius of lathe tool	Tooth height	Cutter tip width	Blank thickness
-4	6	40 deg	-017″	-038″	-016″	-127
	7	34 deg	-017″	-043″	-016″	
	8	30 deg	-017″	-043″	-018″	
	10	21-5 deg	-017″	-045″	-018″	
	12	18 deg	-013″	-046″	-019″	
	16	13-5 deg	-013″	-046″	-022″	
-45	6		-019″	-043″	-018″	-127
	7		-019″	-048″	-018″	
	8	As above	-019″	-049″	-020″	
	10		-015″	-050″	-020″	
	12		-015″	-051″	-022″	
	16		-015″	-051″	-025″	
-5	6		-021″	-048″	-020″	-127
	7		-021″	-053″	-020″	
	8	As above	-021″	-054″	-022″	
	10		-016″	-056″	-022″	
	12		-016″	-057″	-024″	
	16		-016″	-057″	-027″	
-55	6		-023″	-053″	-022″	-127
	7		-023″	-059″	-022″	
	8	As above	-023″	-060″	-024″	
	10		-018″	-062″	-024″	
	12		-018″	-063″	-027″	
	16		-018″	-063″	-030″	
-6	6		-025″	-058″	-024″	-127
	7		-025″	-064″	-024″	
	8	As above	-025″	-065″	-027″	
	10		-019″	-067″	-027″	
	12		-019″	-069″	-029″	
	16		-019″	-069″	-033″	
-65	6		-027″	-062″	-026″	-127
	7		-027″	-069″	-026″	
	8	As above	-027″	-071″	-029″	
	10		-021″	-073″	-029″	
	12		-021″	-074″	-032″	
	16		-021″	-074″	-036″	
-7	6		-029″	-067″	-028″	-138
	7		-029″	-075″	-028″	
	8	As above	-029″	-076″	-031″	

Module	No of leaves	Angle of cutter	Radius of lathe tool	Tooth height	Cutter tip width	Blank thickness
	10		-022″	-079″	-031″	
	12		-022″	-080″	-034″	
	16		-022″	-080″	-038″	
-75	6	40deg	-031″	-072″	-031″	-178
	7	34deg	-031″	-080″	-030″	
	8	30deg	-031″	-081″	-033″	
	10	21-5deg	-024″	-084″	-033″	
	12	18deg	-024″	-086″	-036″	
	16	13-5deg	-024″	-086″	-041″	
-8	6		-033″	-077″	-033″	-178
	7		-033″	-085″	-032″	
	8	As above	-033″	-086″	-036″	
	10		-026″	-090″	-035″	
	12		-026″	-091″	-039″	
	16		-026″	-091″	-044″	
-85	6		-035″	-081″	-035″	-178
	7		-035″	-091″	-034″	
	8	As above	-035″	-092″	-038″	
	10		-028″	-096″	-038″	
	12		-028″	-097″	-041″	
	16		-028″	-097″	-047″	
-9	6		-037″	-086″	-037″	-178
	7		-037″	-096″	-036″	
	8	As above	-037″	-098″	-040″	
	10		-029″	-101″	-040″	
	12		-029″	-103″	-044″	
	16		-029″	-103″	-040″	
-95	6		-039″	-091″	-039″	-178
	7		-039″	-101″	-038″	
	8	As above	-039″	-103″	-042″	
	10		-031″	-107″	-042″	
	12		-031″	-109″	-046″	
	16		-031″	-109″	-052″	
1-0	6		-041″	-096″	-041″	-178
	7		-041″	-107″	-040″	
	8	As above	-041″	-109″	-044″	
	10		-032″	-113″	-044″	
	12		-032″	-115″	-049″	
	16		-032″	-115″	-055″	

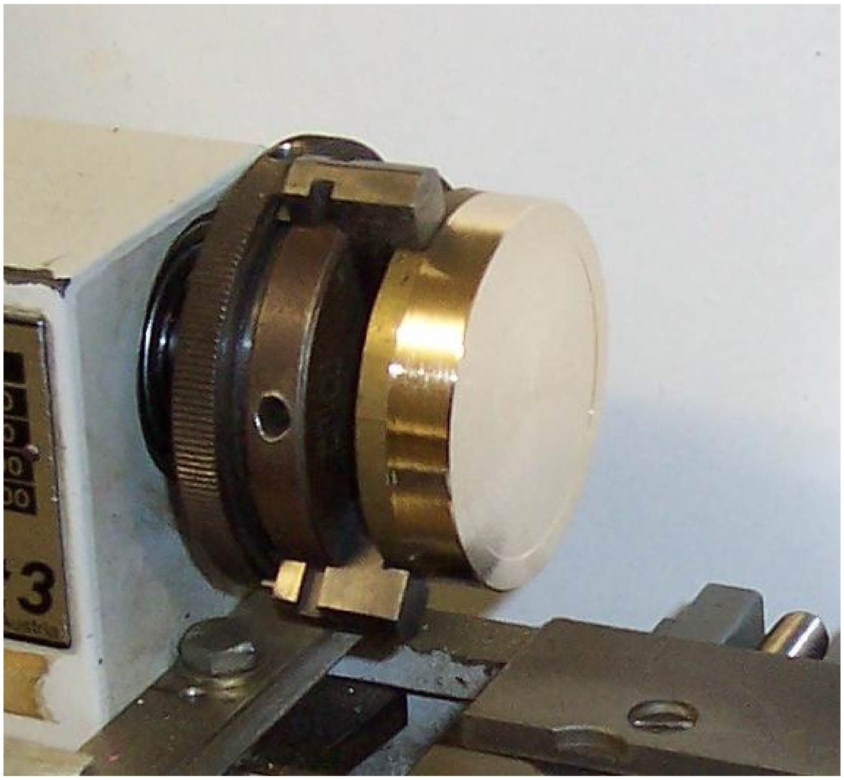


Figure 1
Base relieved to prevent rocking

Figure 2
6mm Studding secured with Loctite and a 6mm nut

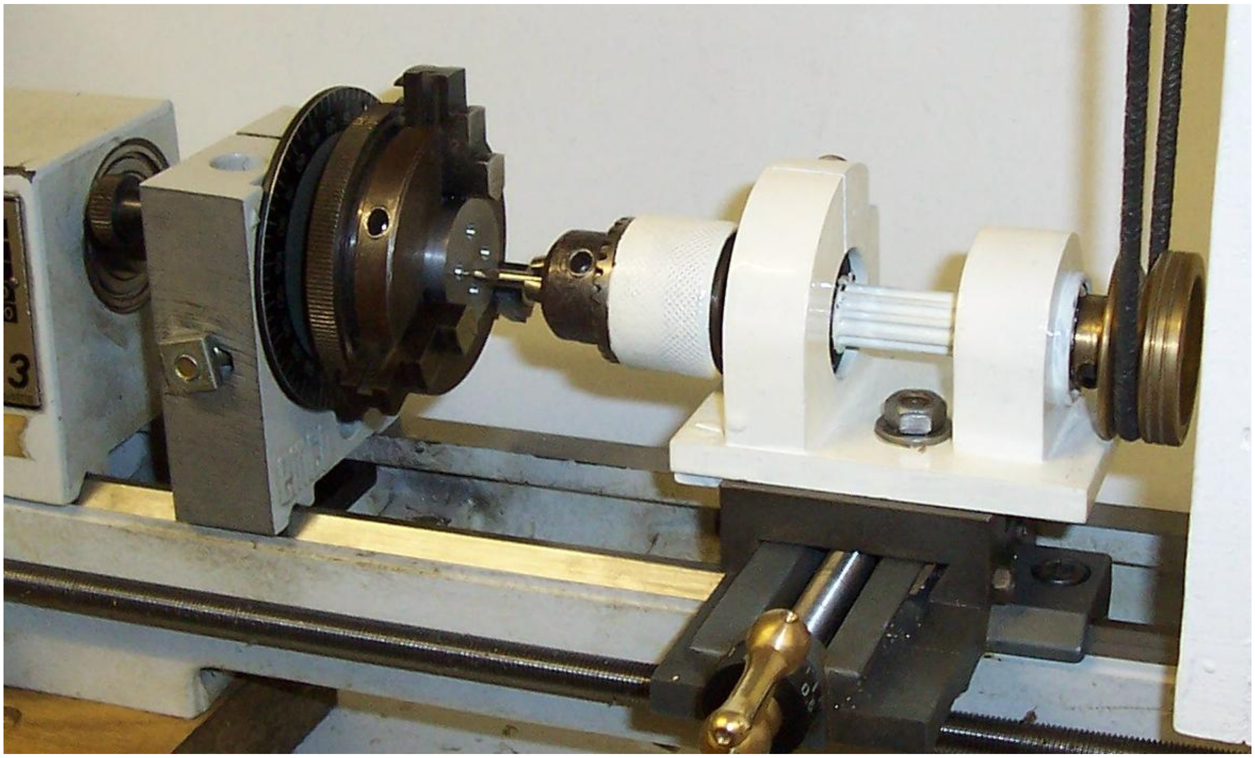


Figure 3
Drilling the 4 holes on the indexing disk.

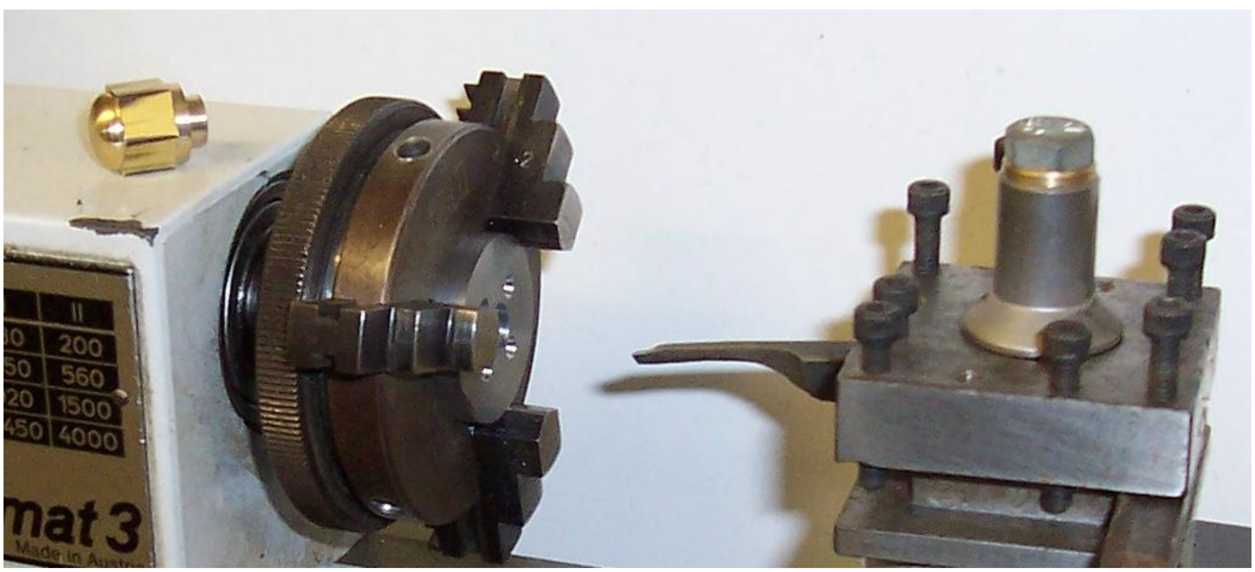


Figure 4
Boring the 7mm hole and using the 7mm collar as a gauge

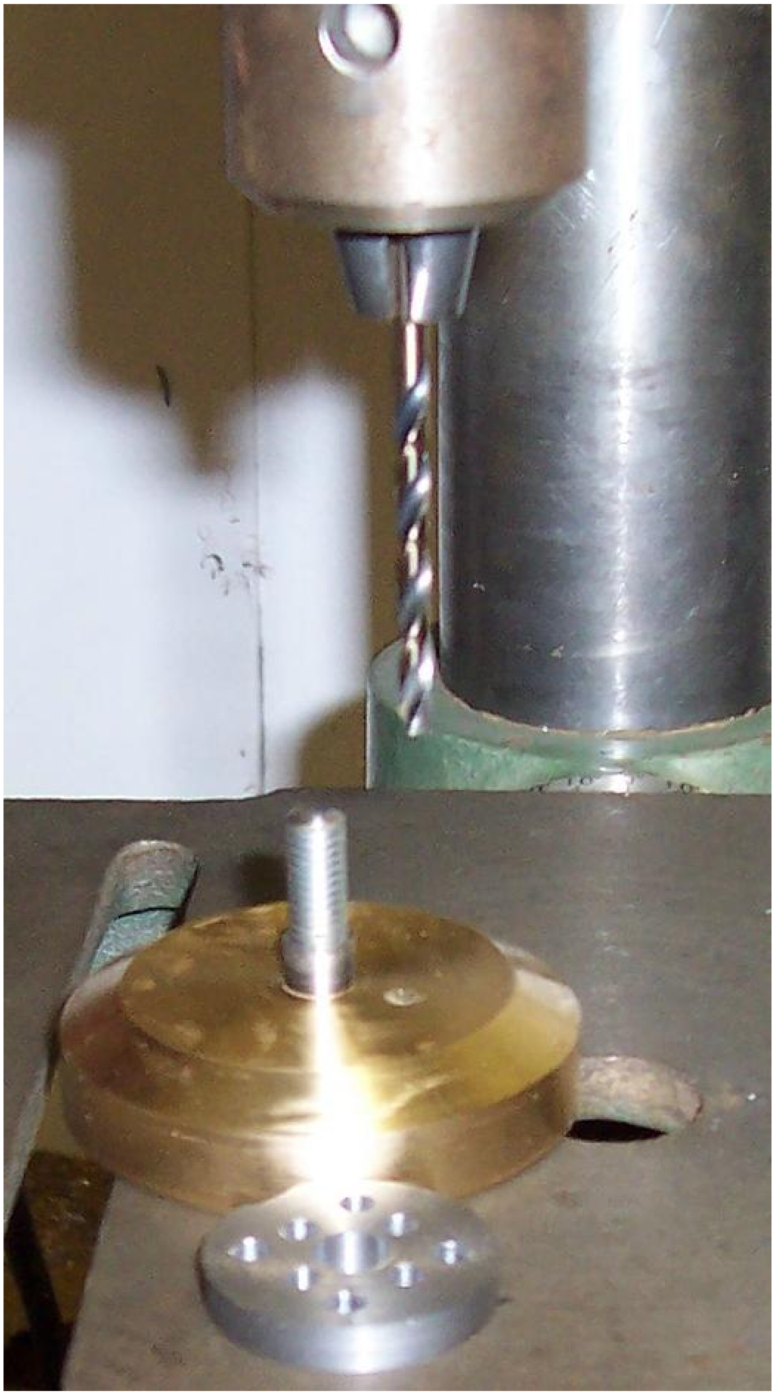


Figure 5
The 6mm nut has been turned down to leave a 7mm sleeve and spotting through the index plate. Please note that the index plate has an extra set of holes, these were later filled with iron wire

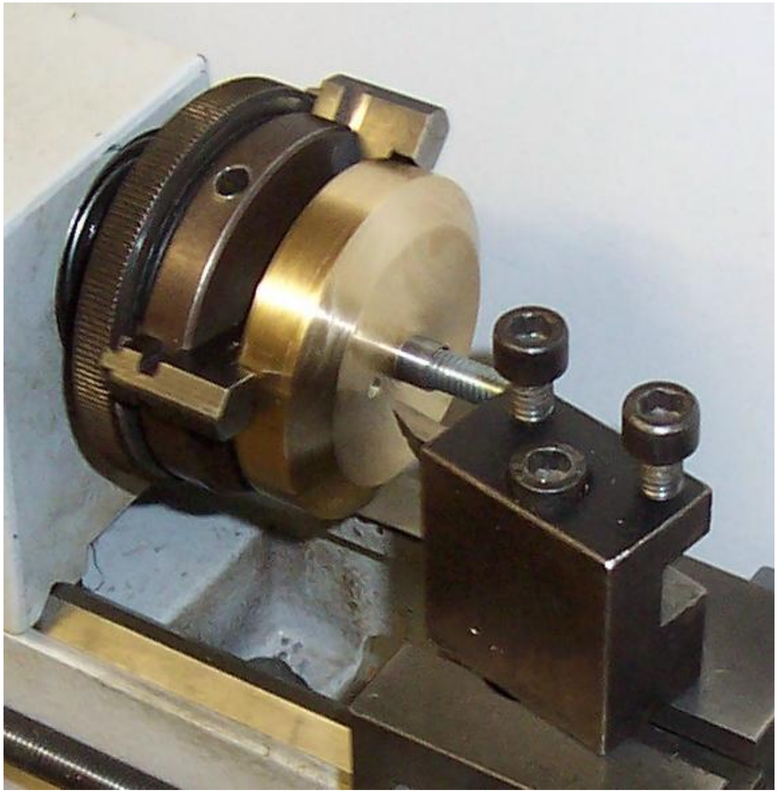


Figure 6
The base, mounted in the lathe and showing the drill mark

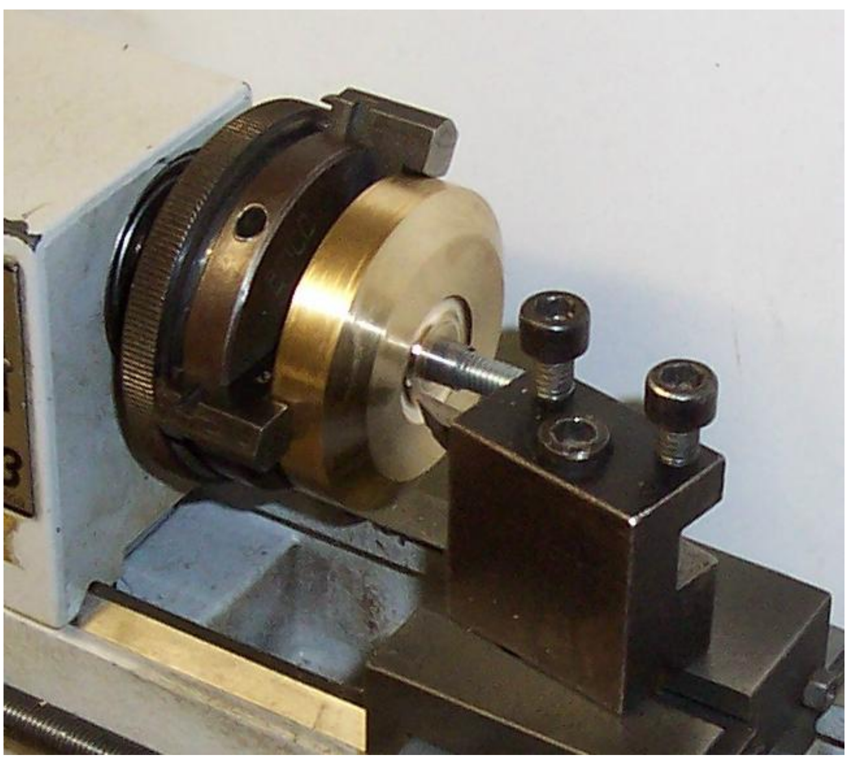


Figure 7
Turning the drill run out groove

Figure 8
Drilling the 4 holes 1/8” diameter on a cutter blank

Figure 9
Tapping the main body of the tool 6mm, using a tapping aid and a finger plate on the drill press

Figure 10
Drilling the 1/8” hole 5/16” deep for the locating peg

Figure 11
Drill right through with a 3/32” drill to aid peg removal, should it shear off in use

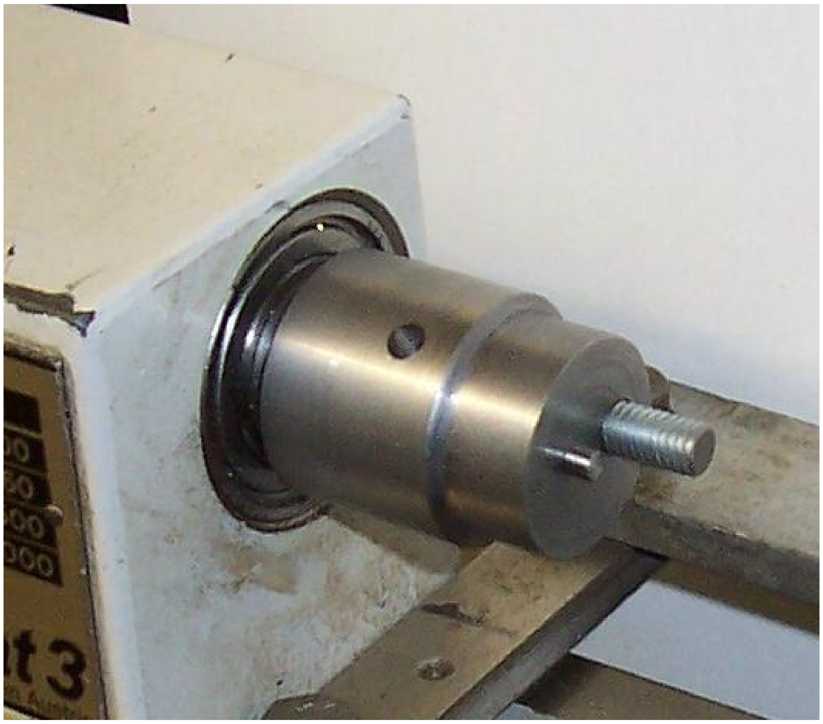


Figure 12
The tool screwed to the lathe

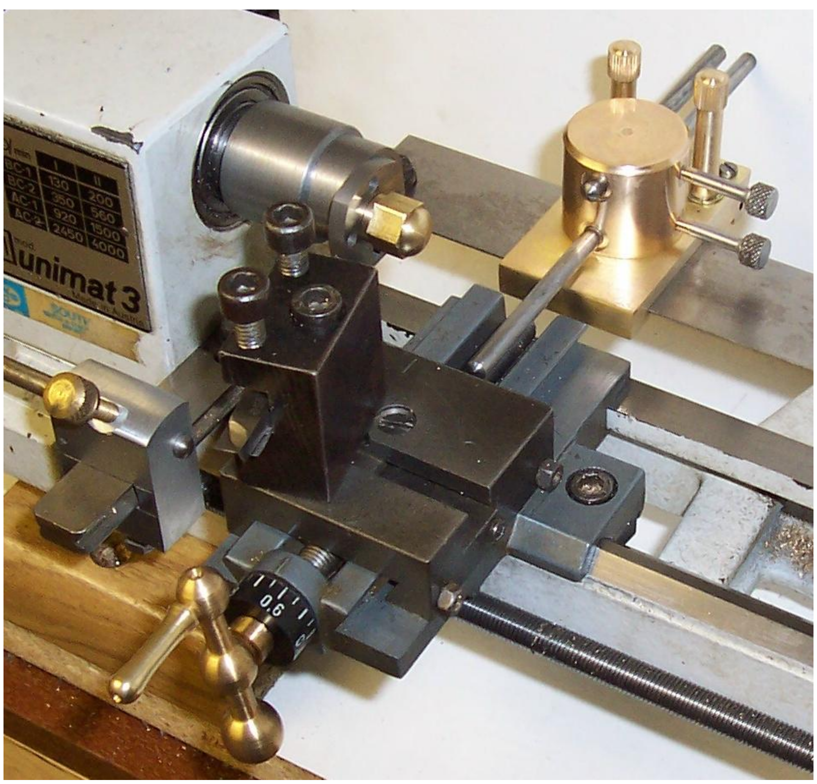


Figure 13
A 1 inch square cutter blank set up in the tool and turning the surfaces true using the depth stop

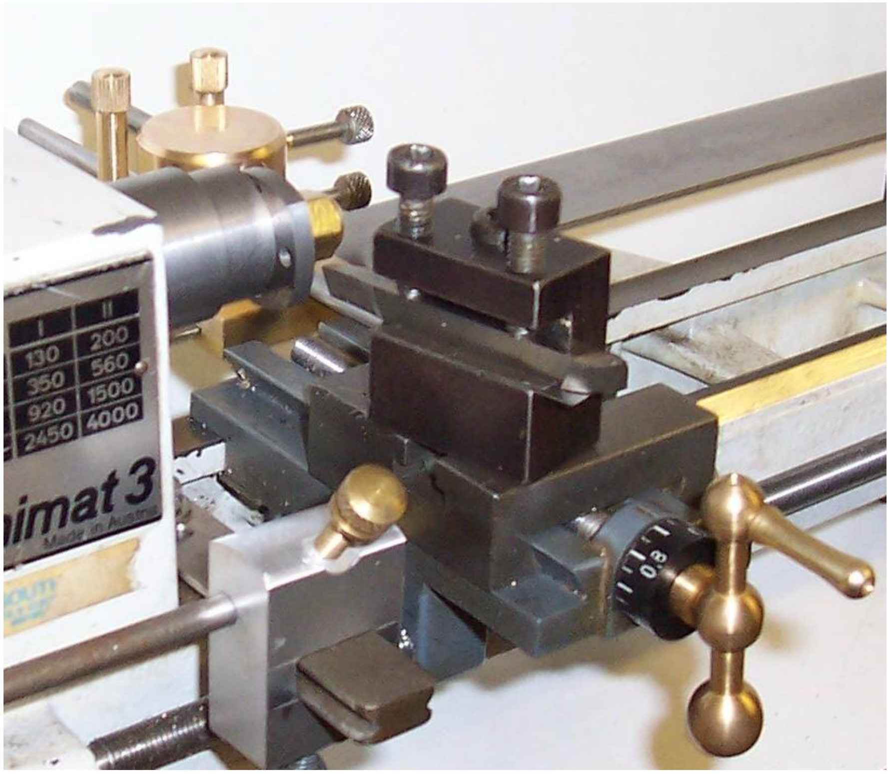


Figure 14
Side view showing the ¼” offset of the cutter blank

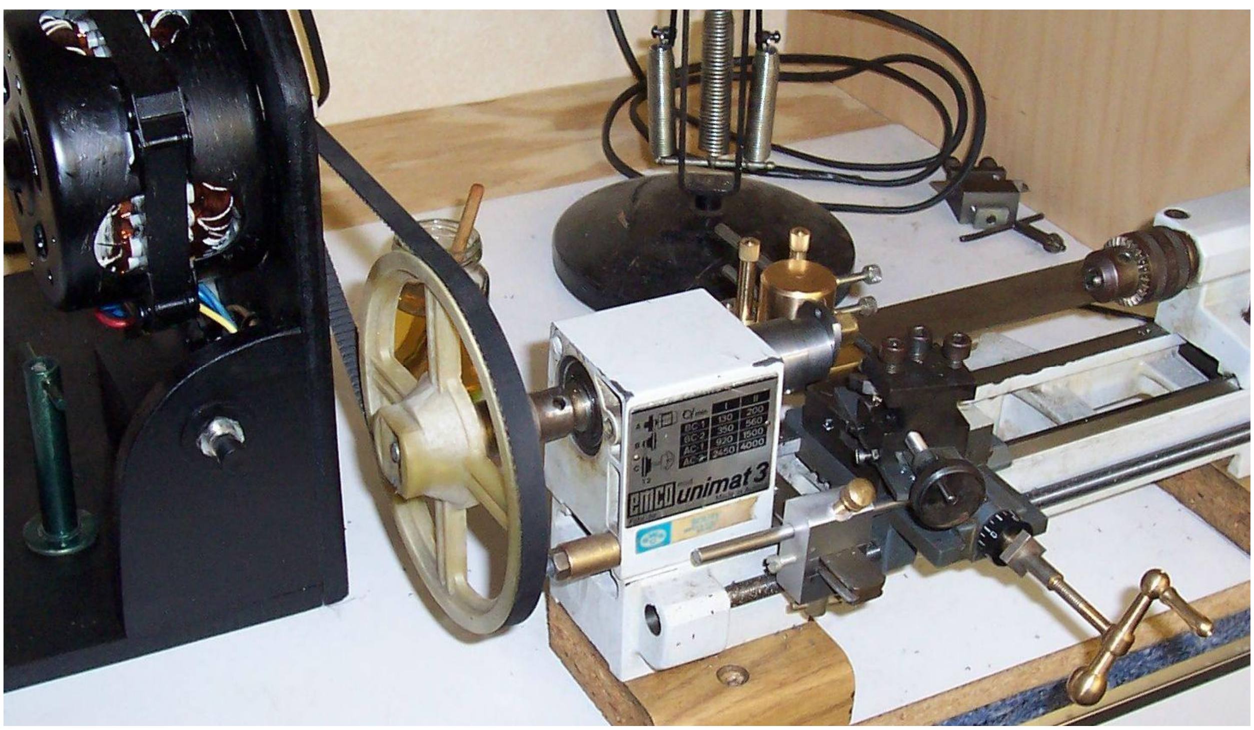


Figure 15
Setup for making pinion cutters. Slow speed with positive drive. Taper slide set to angle, depth stops in place, cross slide locked

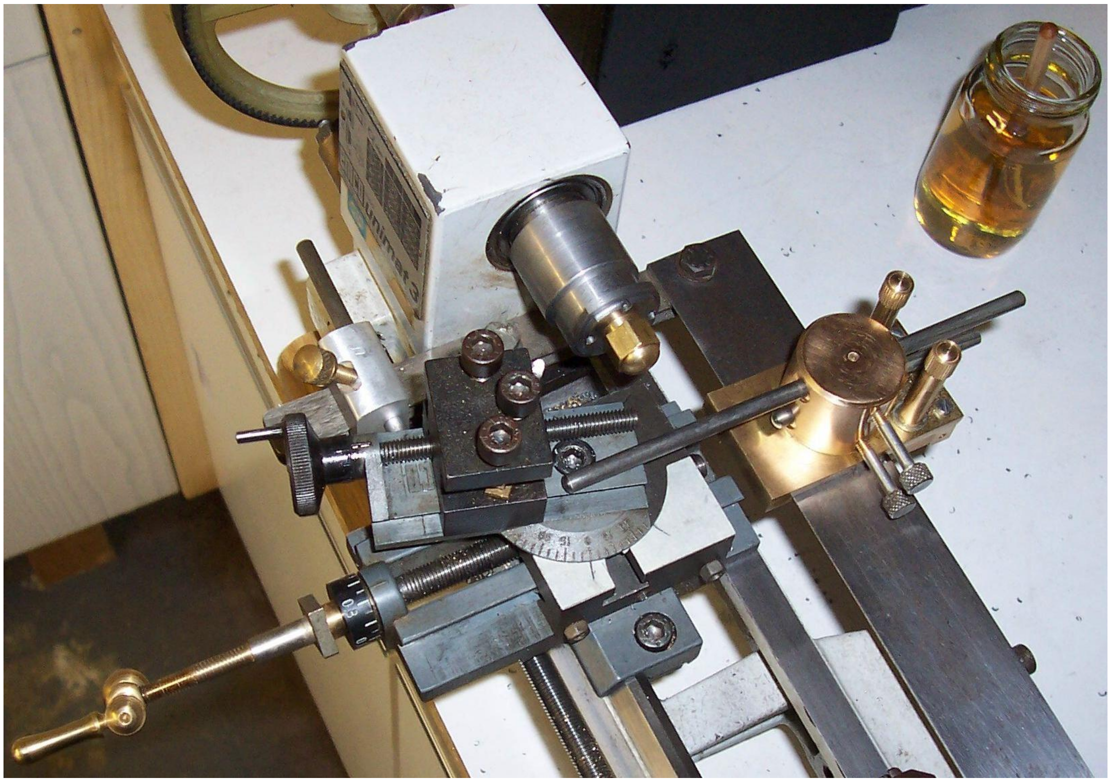


Figure 16
Overhead view of 15 showing masking tape on the cross slide with reference marks

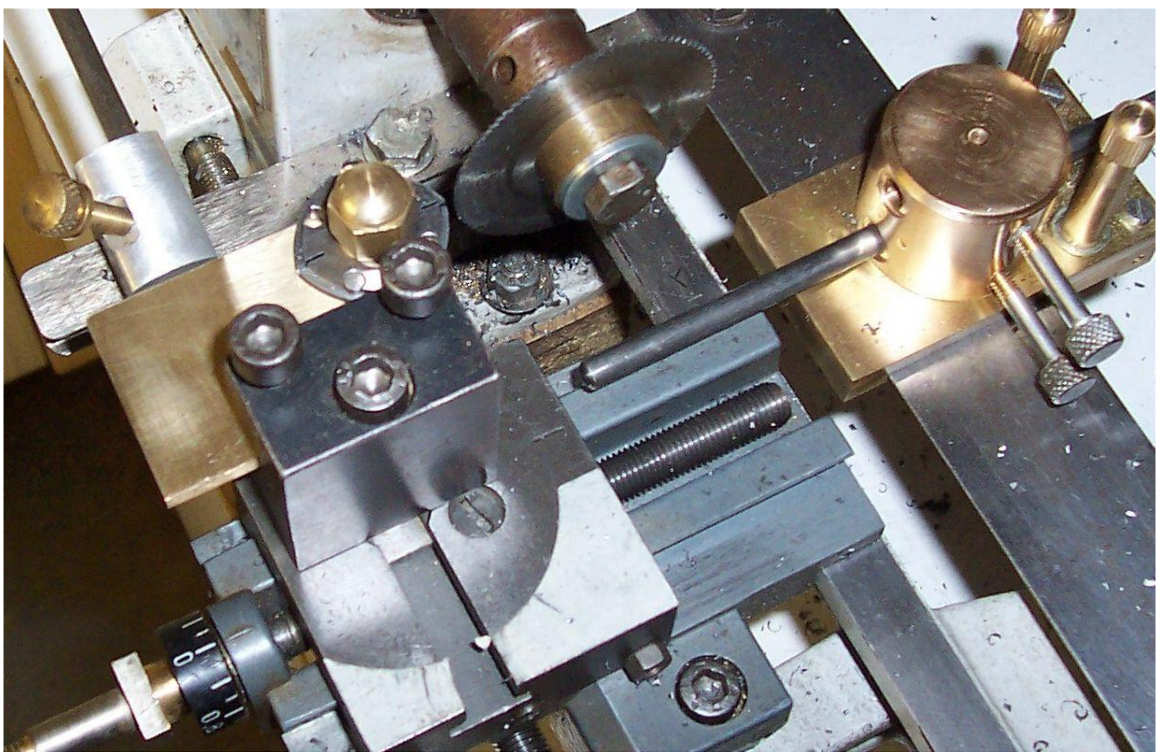


Figure 17
Forming the radial faces of the cutter with a slitting saw

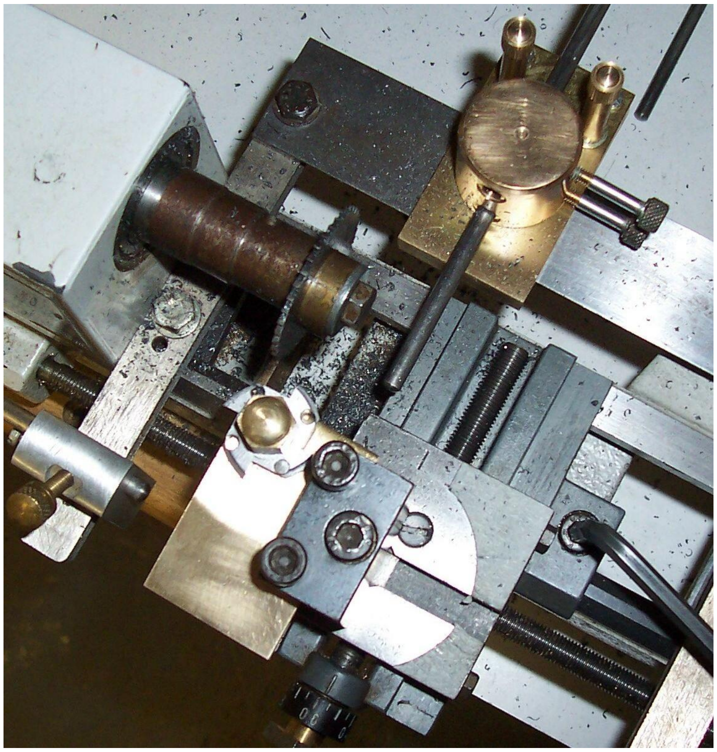


Figure 18
Removing waste

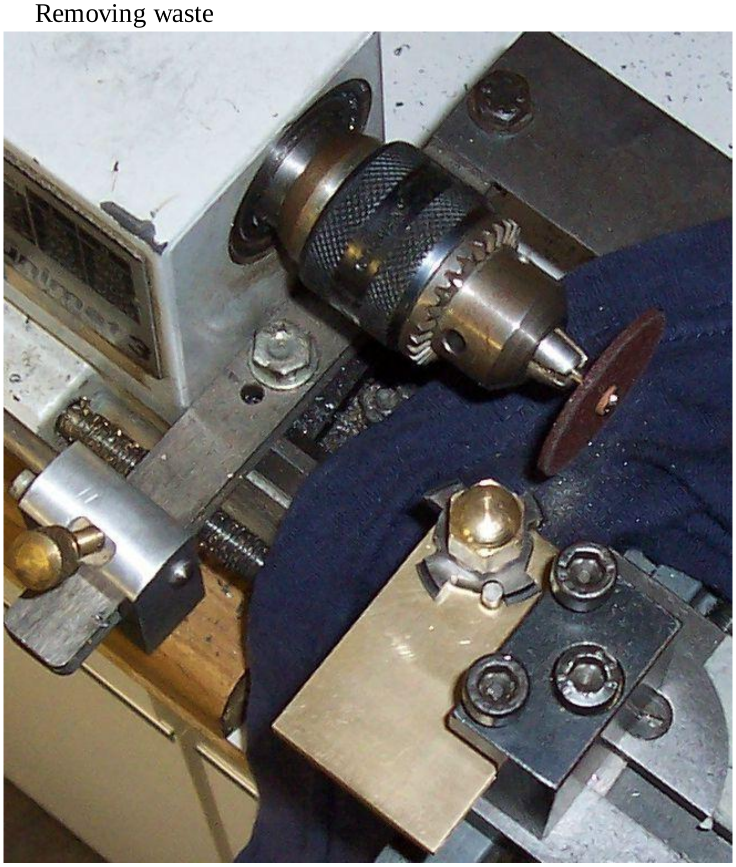


Figure 19
Grinding the cutter faces

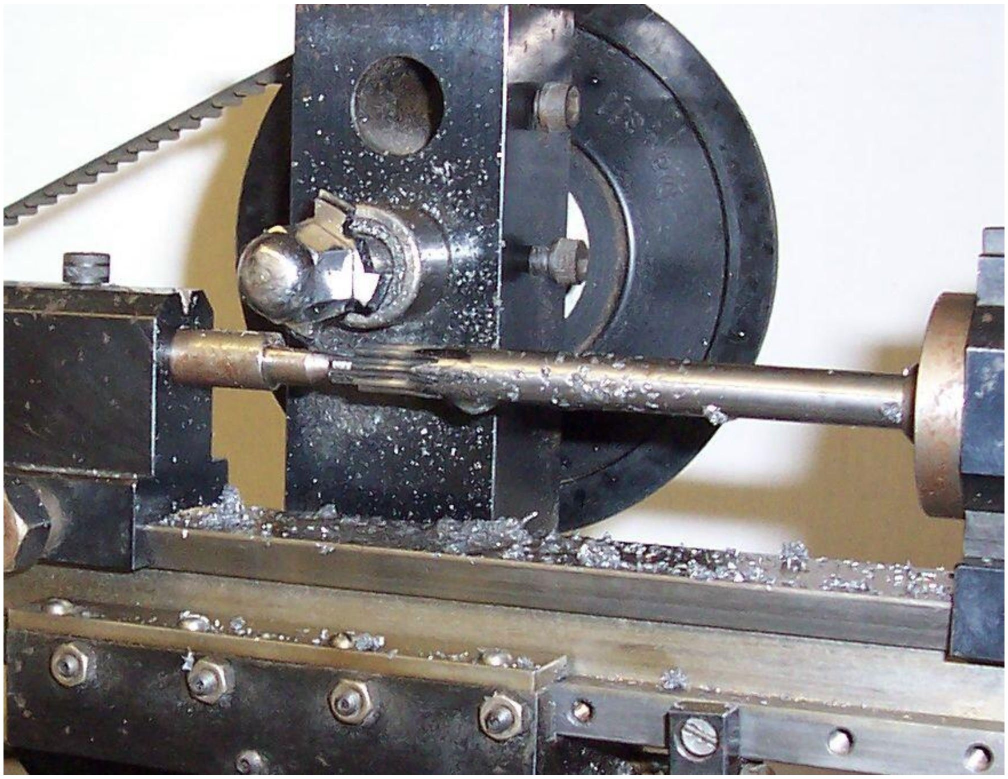


Figure 20
Cutter in use in my Chronos pinion mill