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On the Editor's Bench

Thanks for the Welcome

I'd like to thank the many people who have wished me well in my new role as editor. I've only met a few of you face to face, although it turned out that I had previously met at least one well-wisher on a visit to his club. I hope to meet many more readers in the future. As well as attending the big exhibitions (I'd love to mow the lawn, but I really have to go to Harrogate...) I hope to drop in on a few clubs around the area. As far as I know I haven't got a doppelganger, so if you see me at an event, ME club or one of our suppliers, please say hello.

Editor's Block

On the Editor's Bench at the moment is a 'bench block', carved from a decent sized mild steel offcut. Apparently jewellers use bench blocks for hammering wire flat, and theirs can be as simple as a nicely finished chunk of armour plate. Of course, mine is a fancy engineer's bench block. Knurled around the outside, drilled with several holes of different sizes and with a v-groove across the top. It is supposed to be invaluable for all sorts of jobs. I put a rather fuzzy picture of mine on the ME forum, in the forlorn hope the machining marks wouldn't show. The encouraging response was "I made one like that 20 years ago, but I haven't found a use for it yet". Well, I have found a use – a nice paperweight to keep the editorial in-tray under control.

I haven't found as much time for the workshop as I'd like recently, but one other little job I have done is a new, smaller, drive pinion for the little shunter pictured last time. I was about to start on a new 18-tooth gear when I found a 17-tooth one I'd put to one side after making a hash of a collar on it. With a bush fitted and the collar turned off, it was ideal. Hopefully the resulting increase in pull will get me right round the Derby SMEE track, if I'm able to get back there soon.

Rust Never Sleeps

Spring has well and truly sprung, but fair weather is not always good news for the workshop. Spring showers, warm days and chilly nights can be an ingredient encouraging one of our traditional enemies – rust! Seven years ago former *MEW* editor Dave Fenner started a simple experiment with rust preventing oils, this month you can read about his findings, as well as his advice on preventing – and treating - the 'orange peril'.

I'm fortunate to have a well-insulated concrete workshop, with small windows, which makes rust an occasional irritant rather than a major challenge. Others of us are less fortunate. If you have any advice of your own on keeping rust out of your workshop, please write in to Scribe a Line.

Model Engineer Exibition 2014

This year's Model Engineer Exhibition will be held over the 12th, 13th and 14th December. What a marvellous opportunity to do all your Christmas shopping in one place? Last year's exhibition was big success with numbers up and excellent feedback from visitors, exhibitors and traders. The new 'Maker Fayre' section was very popular and I'm delighted to confirm that Marc Barto has agreed to organise its return again this year. For those of us who want to learn more about topics such as 3D-printing this is a great opportunity.

Finally, I know there is outstanding work being done to produce workshop tooling – if you have something you're proud of or that would be of interest to you fellows, please consider entering it in the workshop tooling section. Let's show the modellers what the toolmakers can do!

Neil Wyatt
neil.wyatt@mytimemedia.com

HARROGATE

The SMEE Digital Workshop in action.

Hopefully this issue should be reaching you just before the Harrogate show in May. Lou Rex has threatened to pin a large red badge to me, so if you see me wearing it, do come up and say hello. One thing I'll be looking out for is the SMEE's 'Digital Workshop'. This is a recent initiative by SMEE members who have an interest in all things digital in their workshop. I may not have any CNC equipment, but another of my hobbies is microelectronics, so I'm very keen to see what they have been doing, particularly with AVR chips and Arduino boards. If that makes no sense to you at all, I'm assured there will be plenty of traditional engineering in evidence as well!

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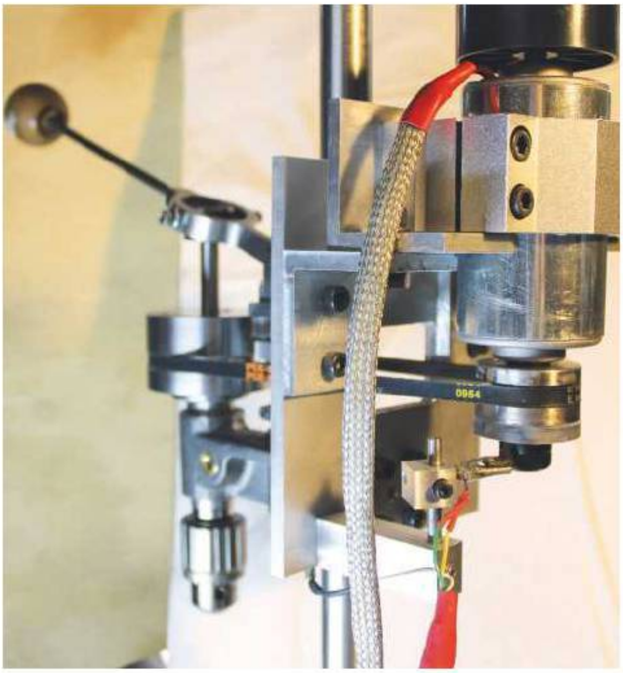

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ON THE COVER

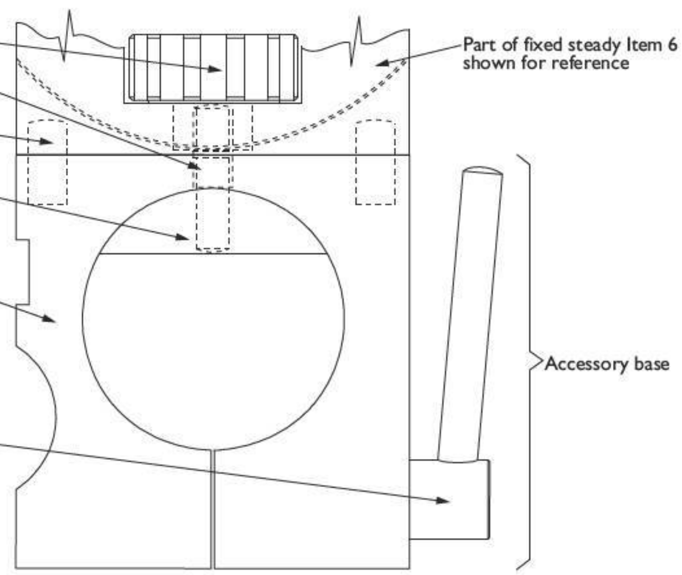
Former *MEW* editor, Dave Fenner, with his latest project; restoring a rusty Porsche 911 Targa.

A Fixed Steady for the Hobbymat Md65

Alan Wain was unable to buy a fixed steady for his Hobbymat lathe, so he built one to his own design, the method of attachment also providing other useful functions.

The Hobbymat MD65 is a useful little lathe but, like any product, it does have its limitations. One that I have found irritating is the lack of a fixed steady and this really came to the fore when I planned to manufacture a collet chuck to fit a Jacobs taper. The length of this combination is too great to achieve the required concentricity without support. A temporary steady could serve but would still need attaching to the lathe bed somehow. For those not familiar with the Hobbymat, the bed is of round section with a flat top (D shaped, I suppose) so the single bolt clamping method common to most lathes is not possible. Searching the internet, the only reference to a fixed steady that I could find associated with this machine was a photograph of an aluminium casting with a U bolt that looked far better suited to keeping a TV antenna in place. Although I had considered this method of attachment, it looked fiddly to set up and far too Heath Robinson to be very effective. No, a better method was needed.

Fig. 1



General Arrangement

Design

As previously stated, the Hobbymat has a round bed with a flat top. The cross-slide base and tailstock are bored to a sliding fit on the bed and kept in alignment by anti-rotation pads, segments of what looks like nylon bonded inside the tops of the bores. The lower side of each bore is slotted axially to allow adjustment of fit and locking onto the bed by forcing and setting screws acting upon the slot. If this method is satisfactory for the tailstock, then it must surely be sufficiently sturdy for a fixed steady. However, to fit the steady, the tailstock and saddle would have to be removed, which would make fitting even more tedious than the U-bolt idea. To me, the best solution seemed to be a base permanently fitted to the bed and stowed under the chuck when not in use, positioned and used to mount the steady when required. Other uses for the base that quickly sprang to mind include a carriage stop and dial gauge bracket. A session of measuring, and measuring again, provided enough information to design the arrangement in **fig 1**, which only shows the bottom of the actual steady frame. **Photograph 1** shows an initial test of the completed steady. The drawings reflect the measurements taken from ***my*** lathe, I would advise anyone embarking on this project to check their own machine and adjust measurements accordingly.

What I call the accessory base is the key part of the project. Except for the bore diameter and nylon pad, dimensions are not critical to operation. Material for the body of the base is cast iron, in common with the cross-slide base and tailstock. Base dimensions above, below and to the rear of the bed bore were kept the same as for the cross-slide base, as much for aesthetics as mimicking the shape of the existing castings. I would have preferred to replicate the front protrusion also but the only suitable piece of cast iron to hand wasn't large enough. A fixing screw was not considered necessary, owing to the limited width, so only a pinch bolt is used to clamp the base in position along the bed. The nut that secures the steady to the base may seem overly complex but is necessary to minimise the stud height to satisfy the stowage requirement. I elected to fit the dowels to the base rather than leave alignment holes that would inevitably have gathered swarf that would be difficult to remove from the base in its permanent home. Blanking plugs could have been made, of course, but discipline is needed to use them!

The detail of the actual steady is of minor consideration. I originally intended to adapt Harold Hall's design (**ref. 1**), but instead opted to do my own thing and avoid the complication of constructing a frame that opens. The width of the fingers on mine was dictated by the piece of 0.375 inch square phosphor bronze bar that I had in stock. I show the size as 10mm in the drawings, so as not to offend readers who hate to see metric and imperial dimensions mixed.

Construction

The following account details my method of construction, which is not necessarily best practice. I have little doubt that the job could have been done far more professionally and probably more easily, which I am sure will be the case if anyone chooses to follow this design. With my bench drill temporarily out of use for 'modification', the whole job was carried out on a Hobbymat lathe which, to say the least, proved tedious at times.

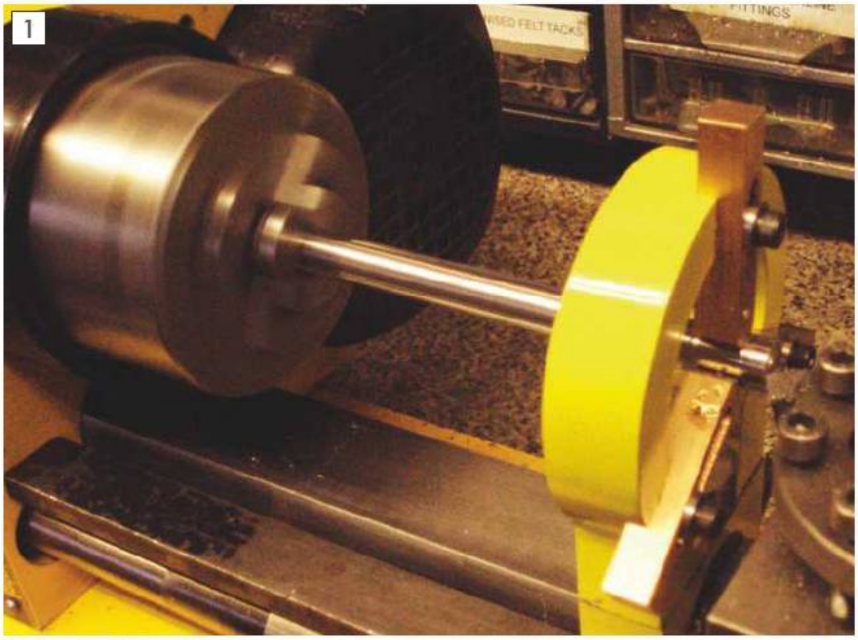
Gauge and jigs

I will cover these items first, although I made them as required.

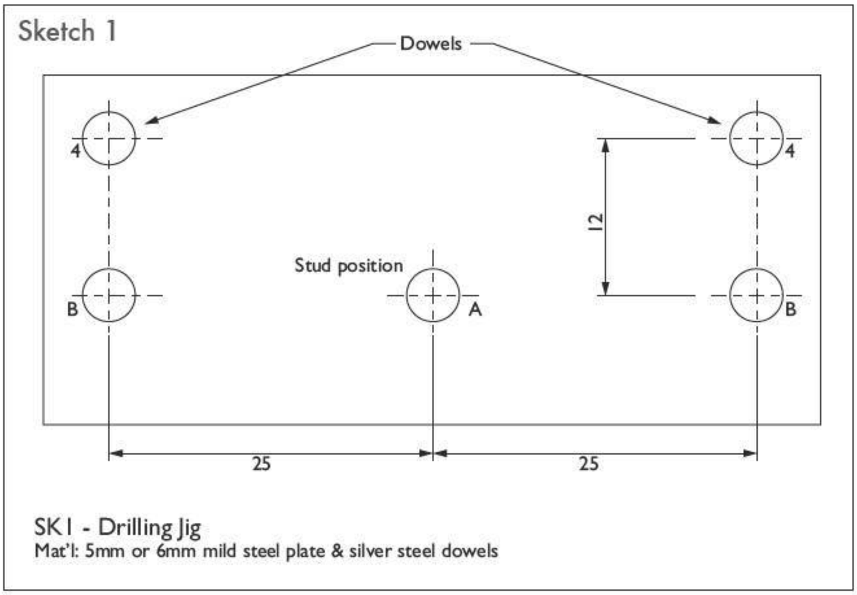
If inside measuring instruments are available, a plug gauge for the 40.0mm bore isn't absolutely necessary but is a useful aid and doesn't take long to make. Face and turn 25mm of a 50mm (ish) length of mild steel bar as accurately as possible to 40.0mm diameter, reduce the diameter of the end 5mm to 39.5mm to signal the nearness to finished size. Job done.

Without the luxury of a mill, I deemed a drilling jig, **sketch 1**, essential to ensure that the fixed steady and any other accessories I may wish to make in the future will fit the accessory base accurately. This is just a piece of plate with perpendicular holes drilled as accurately as possible and two dowels glued in with one of the stronger anaerobic adhesives (I used Truloc 231) protruding equally through both sides. The size of holes is not that important; I chose 4.0mm but holes 'B' could be larger. Given that drills tend to cut oversize, the dowel holes are best drilled slightly undersize and reamed for best fit. I made a 'D' bit from the same length of silver steel used for the dowels. As an aside, I would recommend anyone who hasn't made a 'D' bit to have a go; you will never regret it. Just make sure that it IS silver steel you are using; it is very frustrating to make a lovely tool, only to find that it won't harden! Getting back to the job; when finished, mark the intended orientation and top or bottom so that it is always used the right way around, and the right way up when drilling accessories to mate with the base. Identify its purpose somehow and store it safely for future use.

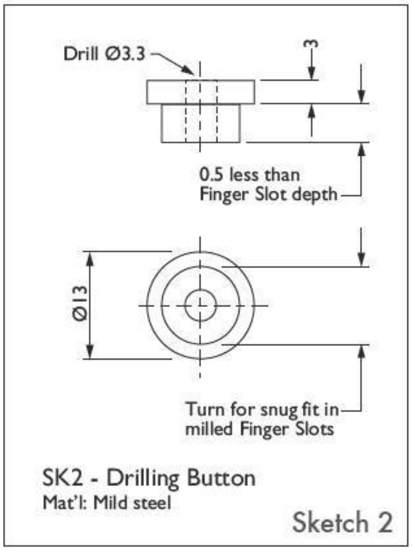
Although covering this now, the drilling button, **sketch 2**, is really best left until after the finger slots have been milled, when a good fit is easier to achieve by trial and error. This is used to centralise the tapped holes for the finger screws in their slots in the body of the steady. It is a simple turning and drilling job on an odd



Testing the steady.



Searching the internet, the only reference to a fixed steady that I could find associated with this machine was a photograph of an aluminium casting with a U bolt that looked far better suited to keeping a TV antenna in place.

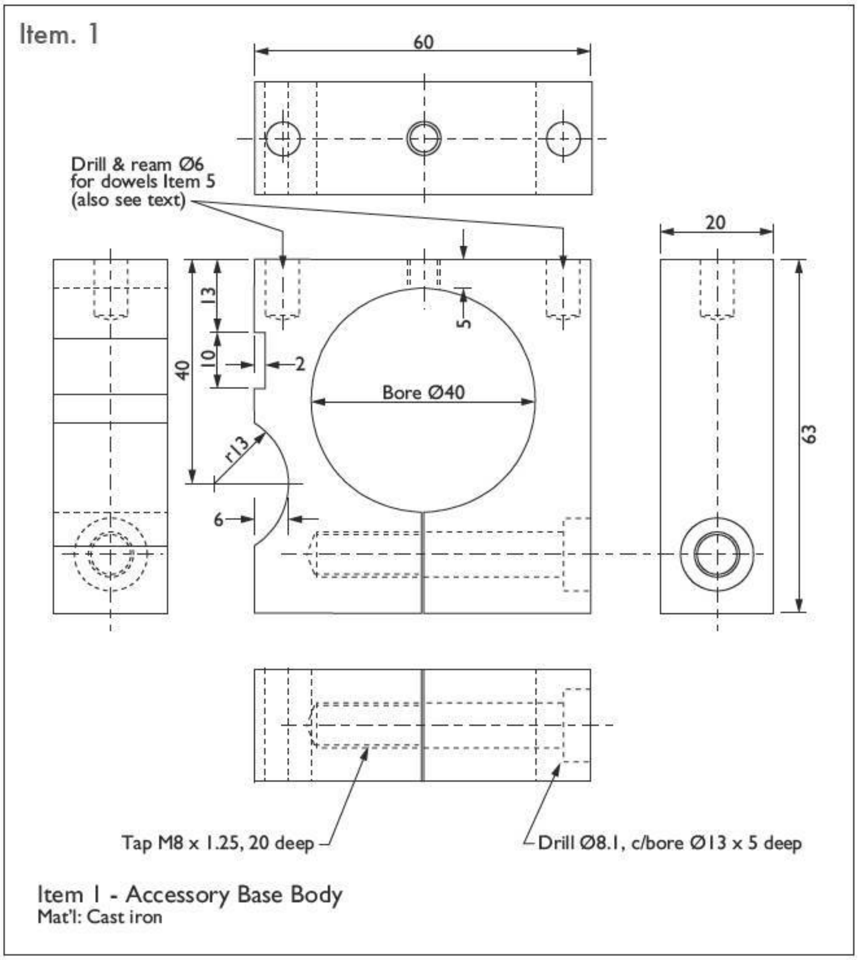


end of steel that is too small for anything else. The hole is 3.3mm because that is the tapping size for M4; change the size to suit whatever finger screws are used.

Item 1 - Accessory base body

After marking out the outside dimensions, saw away surplus material to leave a slightly oversize rectangle. Don't cut too close to the lines and try to cut as square as possible. Machine in the four-jaw chuck until all faces are square to each other before finally machining to size. I started by 'facing' the two flat surfaces until they were parallel, then took quite some time to machine a little at a time from each edge, checking for square, re-chucking and machining a bit more etc.

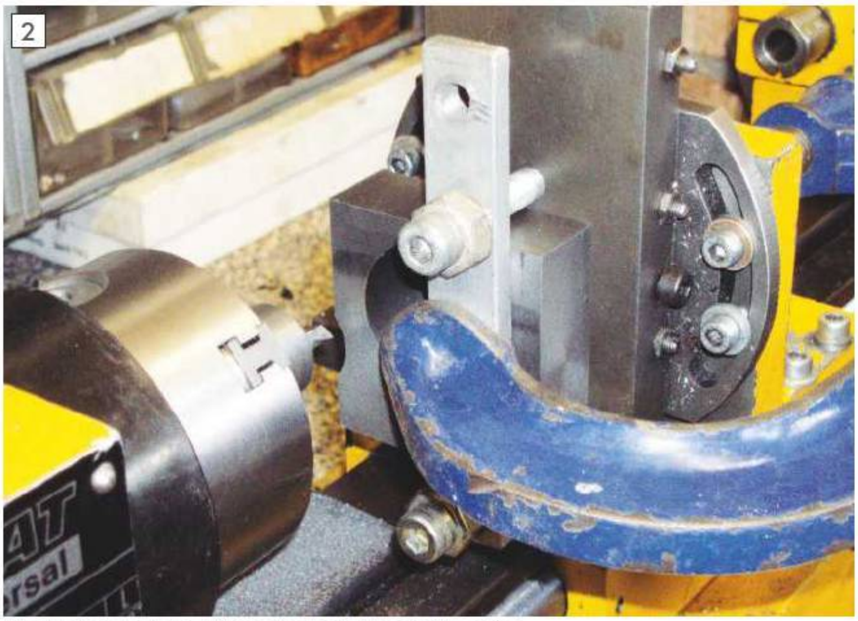
Using what is to be the top edge as a datum, scribe the centre and continue this down the front face to mark the centre line of the 40.0mm bore, then scribe, and centre-punch the centre position of the bore. Centre-drill this punch mark; in my case, I did this with the work positioned and clamped to the Hobbymat angle plate on the cross-slide. Set up again in the four-jaw, using a centre in the tailstock to support the work whilst the jaws are adjusted; I adjusted the final position by easing the pressure of the centre, turning the chuck and observing the tiny gap between work and centre with a loupe. Because the edge of the finished bore is only 5mm from the top edge, sufficient packing is essential under this jaw to prevent the boring tool contacting the jaw as the bore nears finished size, the packing also serving to protect the top edge. After drilling to the largest size of drill available, rough out the bore until it starts to look near to size. Offer up the thin end of the plug gauge prepared previously and reduced the depth of cut to around 0.05mm per pass until the smaller diameter of the gauge enters the bore. From there, reduce the depth of each cut further and continue boring, taking one or two spring cuts at each setting, until the major diameter of the gauge just enters. In my case, even after taking so much care to arrive at the right size bore, the gauge still entered a little more easily than I had intended.



With the bore complete, mark out and drill the pinch-bolt hole, in stages, to 6.7mm diameter. I know that M8 tapping size is 6.75 but the drill will more than likely cut oversize anyway. Open out the pinch-bolt hole to 8.1mm diameter and 31.0mm deep, then tap the deeper part of the hole M8 x 1.25, finishing with a plug tap. The counter-bore I cut using a 13mm end mill. I carried out all of these drilling, tapping, counter-boring operations from the headstock, with the work clamped to the angle plate; it may have been easier to put the work back into the four-jaw, in which case, the counter-bore could have been bored. The depth of the counter-bore isn't critical or even essential; it just hides where the clamp screw would mess up the paint finish.

The clearance cut-outs for the leadscrew protective tube and leadscrew guard (called 'spindle guard' in the handbook) can be either milled or filed; I chose to mill them. Mark out their positions and shapes if filing, or just the centre heights if milling, using the top edge as the datum. Be careful to keep marking out within the boundary of the cut-outs where it will be machined or filed away.

To machine the leadscrew cut-out, clamp the work overhanging the rear edge of the vertical slide (top slide mounted on the angle plate), using a square off the bed top to ensure vertical. Use bolts in the tool clamp mounting holes through a suitable length of drilled flat bar as a clamp. Adjust the top slide to align the scribed cut-out centre height to a centre in the headstock then lock the top slide. I doubled up on security for this operation and used a G-clamp to keep everything in place. A 26mm end mill is not something the average Hobbymat owner is likely to have, me included, so I used a home made fly cutter set for 13mm radius to machine the cut-out. Set the cutter to the edge of the



Machining clearance for the leadscrew protective tube.

work and zero the cross-slide dial (taking up the backlash). Traverse the work using the leadscrew and advance the depth of cut for each pass using the cross-slide, until the required depth of 6.0mm is reached, i.e. six full turns of the cross-slide hand-wheel. By taking only shallow cuts, this was a surprisingly drama-free operation for the Hobbymat and didn't take very long. **Photograph 2** shows this in progress, along with the crude clamping arrangement. Filing would suffice but the home made fly cutter is easy enough to make, does a nice job and will find other uses.

I used a 10mm end mill to machine the shallow rectangular cut-out for the leadscrew guard, with the work mounted vertically and the edge being machined towards the chuck. Once set to the correct height, again to a centre in the headstock, traverse with the cross-slide and control the depth with the leadscrew. To mount the work I used a machine vice that came with the lathe. This so-called 'machine vice' is not brilliant so I used a stub of ½-inch silver steel against the moving jaw to mitigate lift and gently tapped the work flat to the base of the vice. For those without a machine vice, the work could be clamped directly to the angle plate but it would be more tedious to set on centre height whilst keeping the work vertical. Once again, very shallow cuts are necessary because the Hobbymat lacks rigidity for milling. Fortunately, not too many passes are required to reach the 2.0mm depth required.

The next operation on the base is to cut the axial slot into the underside. Choose your favourite (or only) method for this; mine happened to be a hack-saw, using two blades in the frame to achieve the width required. Finally, break all sharp edges.

Fit a suitable length M8 cap head screw into the pinch-bolt hole to test the clamping action onto the plug gauge; the fit on mine was very satisfactory, despite my fear of it being oversize. Leave the gauge clamped inside the bore for the final operations, drilling the dowel and stud holes.

Using the centre line previously scribed, mark and lightly centre-punch the centre of the top edge for the stud position; this must be truly over the centre of the 40mm bore. Centre drill, then drill 4.0mm or whatever size you chose for your drilling jig. Ensure that this hole is truly vertical hence the effort spent in making sure the job was square to begin with. Using the same size drill, centre the drilling jig (Sketch 1) onto this and firmly clamp to the face by the dowels. With the correct size drill in the chuck, drill through both outer holes in the jig. Remove the jig and individually align each hole again to open them up to 6mm for the dowels, preferably finishing with a reamer or the aforementioned 'D' bit. At this stage, also open up the stud hole to 5.0mm, counter-bore 6.0mm for the first 0.5mm and, finally, tap M6.

Item 2 - Anti-rotation pad

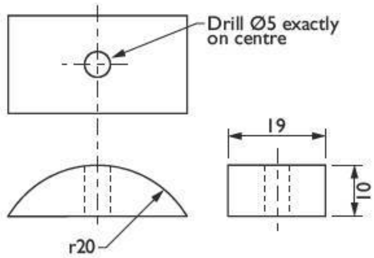
Face and then turn the end of a piece of black nylon bar as accurately as possible to 40mm diameter for a length of approximately 25mm; mark this end with a pencil to identify the side which is square to the machined diameter. Either part off at 20.0mm long or, as I did, hack-saw off and reverse in the lathe to face to 20.0mm length. Mark out a segment with a 10.0mm height and saw off oversize. The disc will make more than the one pad, so it is worth putting the remaining material somewhere safe in case it is needed in the future.

Set the top slide parallel to the bed and remove the tool clamp. Retract the top slide for minimum overhang and lock. Use one of the tool clamp holes in the top slide to clamp the blank, pencil mark down, overhanging the end of the top slide with approximately 1.0mm clearance to machine down to the 10.0mm mark. Ensure that it is clamped securely and cannot twist under the clamp. Fly cut the flat base of the anti-rotation pad, taking quite small cuts so as to minimise deflection that could result in an out-of-square base. Measure the height frequently, resetting the lead screw dial accordingly, and aiming for a final cut to arrive at exactly 10.0mm height.

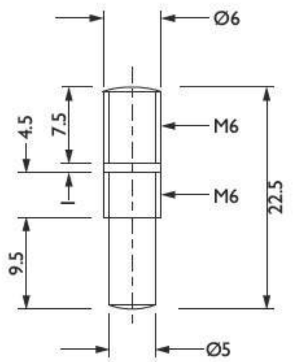
Assuming you now have a segment of nylon to the correct dimensions, mark the longitudinal centre on the curved top. I did this with a digital calliper from each side to give two very close parallel lines. Set up the machine vice on the vertical slide, once again setting vertical with a square off the top of the lathe bed. Mount the pad vertically in the machine vice, using parallel packing below the base to allow the top to stand clear of the vice jaws by around 3mm. With a centre in the headstock, adjust the cross-slide position to centre between the previously marked parallel lines and lock the cross-slide. Now for the critical part; adjust the vertical slide to set the maximum height of the pad to lathe centre height, using the well-documented method of trapping a short ruler or other piece of flat steel between the centre and the work. I checked the distance from the face of the chuck to the ruler using inside callipers, adjusting until equal. Lock the vertical slide but check again for correct position, in case anything moved. Centre-drill and drill through 5.0mm. Very lightly countersink the resulting hole, just sufficient to take off any burr. Remove from the machine vice and de-burr the hole where it exits the base.

Item 3 - Nut

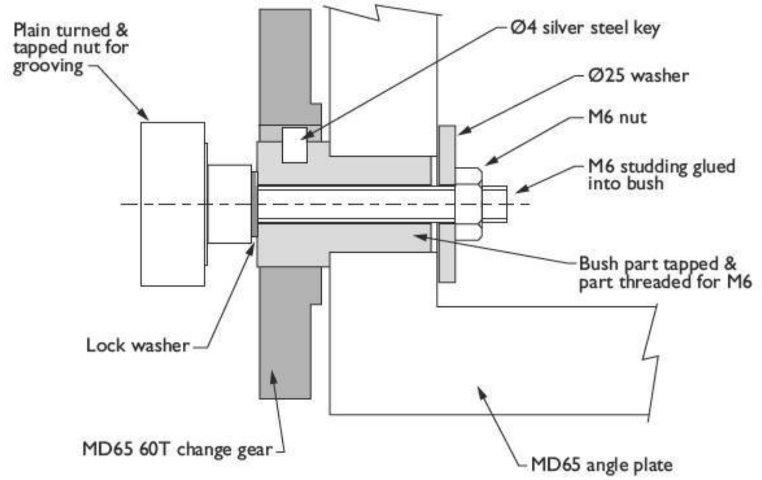
This item may seem out of sequence but, if made now, can be used to assist with making the stud. The nut is a simple turning, drilling and tapping job, which I will not describe, but some form of gripping surface on the large diameter is advisable. A knurling tool is on my wish list but nearer the bottom than the top; as an alternative, I elected to machine grooves in the nut as shown on the drawing but I don't have a proper dividing device either. To work around this, I devised



Item 2 - Anti Rotation Pad
Mat'l: Black nylon
Item. 2



Item 3 - Stud
Mat'l: Mild steel
Item. 3



Sketch 3 - Dividing Arrangement
Sketch 3

the rudimentary arrangement shown in **Sketch 3.** The angle plate supplied with the Hobbymat has a 15.75mm hole on centre height. I made a stepped bush to fit this and the 20.0mm bore of a 60T change-gear, making a key for the change gear from a short stub of 4mm silver steel glued radially into the larger diameter. The stud through the bush, washer and nut serve to mount the work and lock the bush to the angle plate. The detent I made from a piece of steel sheet, suitably bent and screwed to one of the holes in the angle plate provided for mounting the top slide.

With the nut firmly screwed onto the protruding stud with a lock washer, the grooves were machined by advancing the work onto a 6.0mm end mill, whilst the depth is preset by the cross-slide. This arrangement did the job (**photo 3**) but is not ideal because the milling cutter tends to unscrew the work piece, as I found the hard way. To do the job again, I would probably use a much smaller cutter and more divisions to reduce the torque on the work.

To be continued...

REFERENCE

1. Using a Lathe Steady, Harold Hall, *MEW* 174, March 2011)

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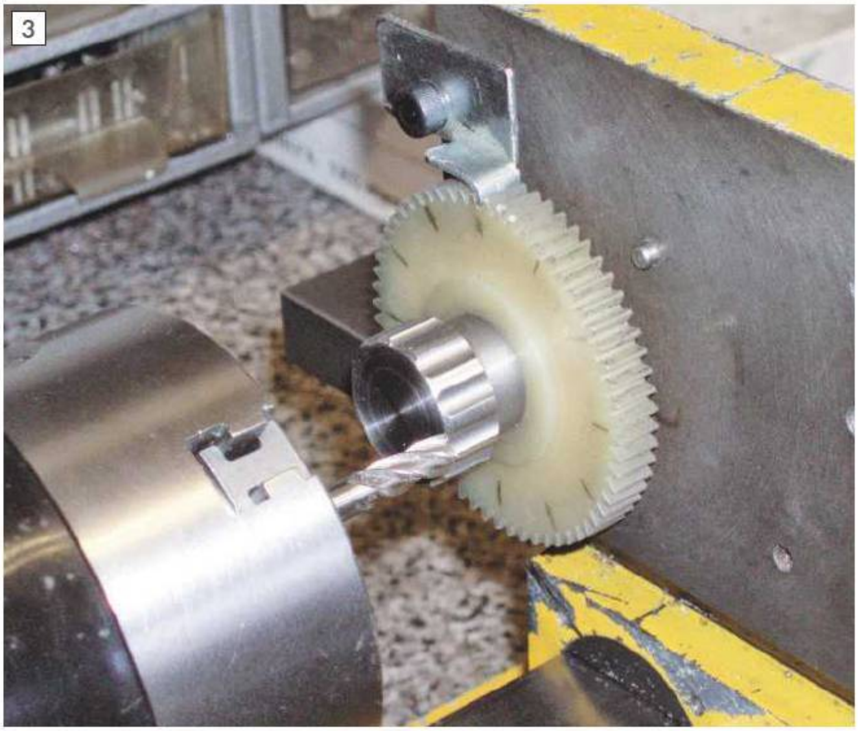

Machining grooves in the nut.

A Toolmakers Hammer Revisited

Derek Spedding makes a tasteful and effective tool from one of our earliest free plans.

Way back, over 20 odd years ago, in one of the early *MEW* editions, (issue 8 December 1991-January 1992), there appeared a free pull out drawing for an excellent Toolmakers Hammer by Derek Winks. It was intended for setting out centers for drilled holes with a dot punch in locations where it was impossible to use a conventional optical center punch.

At the time I resolved that one day I would set some time aside to make one of these handy little tools as much for the looks as the functionality. Recently after 5 years of retirement and eventually having a little spare workshop time, due to being hemmed in by snow, I finally managed to get the time to build one (**photo 1**).

I had saved a lens from a broken jewellers eyepiece sometime over the intervening years and built a housing for it in brass as per the drawing. The lens was housed between 2 o-rings to give it partial shock resistance (**photo 2**).

All of the construction followed the original instructions with allowances for metrication and available materials from the scrap box. The handle was turned and shaped from a piece of unknown hardwood that I found in the depths of my shed.

If you Google 'toolmaker's hammer' you will find an American all metal version that does the job, but has no where near the ornamental antique look of Derek Winks' version.

I have found it so useful I don't know how I managed without it. Like most of us the story was getting the punch in the right place on the scribe lines with the help of a magnifying glass, then putting down the glass, trying to hold the punch in position then feeling around for the hammer, picking up the hammer and – just before striking – the punch slips out of position. Repeat the operation several times with much bad language until you get it right - only to find that you are not quite spot on!

None of this now! Line up the punch through the lens and with a leisurely tap of the hammer all is done. All done in one operation, accurate - and ready to finish with the heavy centre punch.

Maybe it's time to re-issue the drawings for this most useful tool and possibly a family heirloom to boot. ■

1

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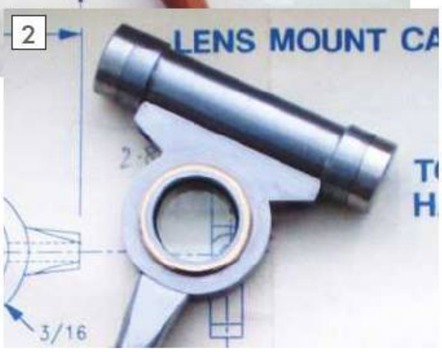

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Design and CNC Machining of Straight Tooth Bevel Gears

This article discusses the design and CNC machining of straight tooth bevel gears. The project arose as a consequence of the two 4 inch scale traction engines I am building. I did not agree with some of the dimensions given on the drawings for the bevel pinions, gears and differential centre. Before spending time machining the bevel gears and differential centre it seemed sensible to understand the design of the bevel gears and thus be able to confirm, or reject, the dimensions given on the drawings. Little did I know how long the exercise would take!

Andrew Johnston took up the challenge of machining some large bevel gears for 4 inch scale traction engines.

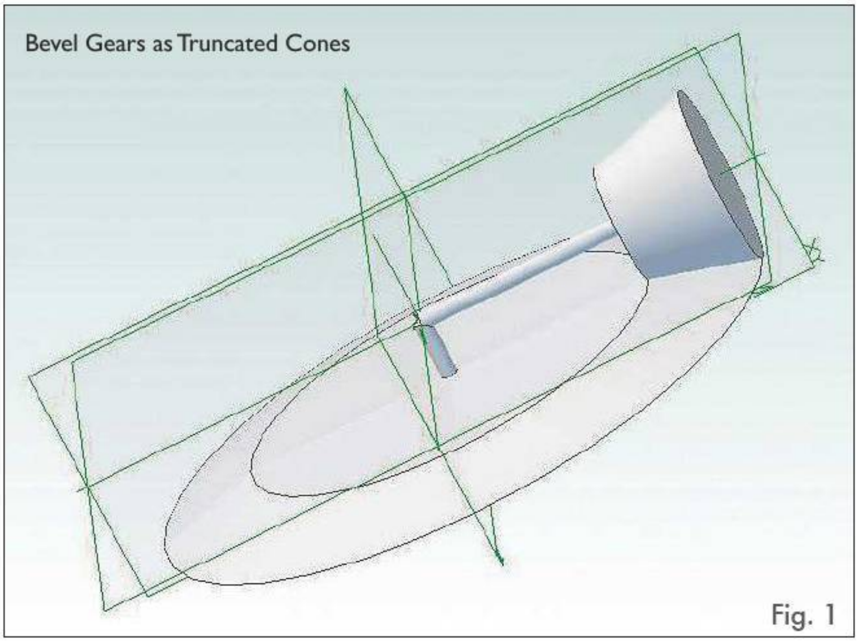


Fig. 1

Description of Bevel Gears

Spur gears can be represented by two cylinders that just touch, with diameters equal to the pitch circle diameter (PCD) of the gears, and lengths equal to the width of the tooth. In this article gears are described in terms of diametric pitch (DP), as the drawings I am working with for the traction engine are imperial. The diametric pitch of a gear is the number of teeth that would be on a gear with a pitch circle diameter of 1 inch. The larger the DP the smaller the teeth. For instance a spur gear of 20DP would have 20 teeth on a gear with a PCD of 1 inch, but a gear of 40DP and a PCD of 1 inch would have 40 teeth.

This article is limited to straight tooth bevel gears whose axes intercept, in the most common case, at 90 degrees. Bevel gears can be represented by two truncated cones whose axes intersect at 90 degrees and whose outer diameters are determined by the pitch circle diameters at the outer end of the respective bevel gears. These diameters are defined by the number of teeth and their diametric pitch, in exactly the same way as for spur gears (**fig 1**). This is an important point; straight bevel gears are designed using the diametric pitch at the outer end of the gear. The tooth shape of the bevel gear is based on the involute curve, in a similar way to spur gears. However, unlike a spur gear the tooth size varies across the width of the gear. Since two cones can represent the bevel gears, meeting where the axes intercept, the size of the tooth varies from a maximum at the outer edge of the gear to zero at the point where the axes intersect. It is important to understand that the shape of the tooth does not vary, just its size, in proportion to the distance along the cone. As the tooth gets smaller its load carrying capacity decreases, so for practical purposes the face width of a bevel gear is usually limited to less than a third of the cone distance. In **fig 2** a section of a bevel gear is shown, illustrating the main parameters.

Design of Bevel Gears

In the same way as for spur gears the design of straight tooth bevel gears starts with the diametric pitch (DP) and the number of teeth. This will define the reduction ratio and the diameter of the pitch cone at the outer face. This is the pitch circle diameter (PCD). The number of teeth on the meshing gears also defines the angle of the pitch cone. The gears we are concerned with intersect at 90 degrees, and hence the angle of the two pitch cones will add up to 90 degrees.

In the case of the traction engine differential the drawing specifies 6DP gears, a pressure angle of 20 degrees, with 10 teeth on the pinion and 36 teeth on the gear. The 10 teeth specified for the pinion is less than the normal minimum of 12 teeth, and will lead to some undercutting of the teeth, required for clearance. Full size traction engines often had 8, or fewer teeth, but as the bevel gears were sometimes used 'as cast' the problem of machining undercut teeth did not arise. Small numbers of teeth were used on the pinions to minimise the overall width of the differential.

The PCD of a gear (D) is defined by D=N/P for the bevel gear and d=n/P for the pinion, where P is the diametric pitch of the gear, and N and n are the number of teeth in the gear and pinion respectively. These give PCDs of 1.667 inch for the pinion and 6 inch for the gear.

The angle of the pitch cone (A) for the gear is given by tan(A)=N/n. For the pinion it is give by tan(a)=n/N. For the differential this gives the angle of the pitch cone as 74.47 degrees for the gear and 15.52 degrees for the pinion. This particular differential has 3 pinions equi-spaced around the gear. It is important that the number of teeth on the gear is divisible by three, with no remainder. Otherwise the three pinions will not sit equally spaced around the gear, each in the same orientation, and will not therefore mate with the second gear wheel.

Having determined the PCD we can then calculate the addendum (J) and the dedendum (K) of the teeth at the outer edge. The addendum is the height of the tooth above the PCD, and is given by 1/P. In this case it is 0.167 inch. The dedendum is the depth of the tooth below the PCD. In theory this is the same as the addendum, but is usually give extra depth for clearance. Depending upon the preference of the designer it can be 1.157/P or 1.25/P. In this case I used the later value, for reasons which will become apparent later, and the value is 0.208 inch. Adding the addendum and dedendum gives the whole tooth depth (W) in this case 0.375 inch.

Following on from these calculations it is possible to calculate the face and root angles. The face angle is important as it allows a blank to be machined. The root angle is needed to set up the blank at the correct angle when using traditional machining methods. First the addendum angle, θa, and dedendum angle, θd, have to be calculated. These are given by: tan(θa)=J/E and tan(θd)=K/E
where E is the pitch cone distance given by E=D/2sin(A)
From these, and the pitch cone angles, the face angles and root angles can be calculated:

Face angle = pitch cone angle + addendum angle
Root angle = pitch cone angle – dedendum angle

Finally we need the outside diameter (OD) of the gears in order to be able to machine blanks. The OD is given by the PCD plus twice the addendum multiplied by the cosine of the pitch cone angle, thus: OD = PCD + 2 x J x cos(A)

For the differential gears this gives an OD of 1.987 inch for the pinion, and 6.089 inch for the gear. Here I disagreed with the drawings, as they give an OD of 2.000 inch for the pinion and 6.050 inch for the gear. I took most of my design calculations from a book 'Gear Design Simplified' (**ref 1**).

Machining of Straight Tooth Bevel Gears

It is not possible to machine a straight tooth tbevel gear on the equipment normally found within a home workshop. Traditionally straight bevel gears were machined on a Gleason bevel planer, which uses two reciprocating blades, like a shaper, following a template to generate the tooth form.

The are two manufacturing approximations for straight tooth bevel gears that are to be machined on a horizontal milling machine, using involute cutters in a similar way to spur gears.

In the first method an involute cutter is chosen according to the DP at the outer edge of the gear and for a number of teeth given by the number of teeth on the gear divided by the cosine of the pitch cone angle. This is unlike spur where the DP and the number of teeth alone is used. The reason for this will be discussed later. The blank is set up on a dividing head such that the root angle is parallel to the table. The involute cutter is centralised over the axis of the gear blank and a series of cuts made appropriate to the number of teeth. The blank is then rotated and translated at right angles to the gear axis, first one way and then the other, and two further series of cuts made. The objective of this is to widen the tooth at the outer edge while leaving the tooth width at the inner edge, formed by the first pass, unchanged. There are two problems with this method, one theoretical, and one practical. The theoretical problem is that since the involute cutter has the correct 'curve' for the tooth at the outer edge, it is incorrect at the inner edge. The tooth at the inner edge is not curved enough, and needs to be corrected by hand. The practical problem is that the involute cutter is not a standard cutter as used for spur gears. The cutter will have the same tooth form as an involute cutter of the same DP and number, but it will be narrower, so that it can pass through the narrow end of the tooth. To distinguish these cutters from conventional spur gear involute cutters they were often stamped with the word 'BEVEL'. These special involute cutters for bevel gears do not now seem to be available commercially.

In the second method, known as the parallel depth tooth method, the calculations are based on the DP at the inner end of the gear. As the name suggests the method approximates the tapered tooth form by one of parallel depth, although the tooth still tapers in width along the length of the tooth. Again, three passes of the cutter are required, but crucially, since the calculations are based on the DP at the inner end, a standard involute cutter can be used.

Given that it was not possible to machine bevel gears using the special bevel involute cutters as I could not obtain them, I resolved to re-design the differential using parallel tooth bevel gears. After some calculations, using a spreadsheet to play with gear tooth numbers and DP, I came to the conclusion that while it was possible to design such a differential, it would lead to a huge re-design of all the surrounding parts, with consequent knock on effects for the whole drive train.

This left the problem of how to machine true bevel gears. It occurred to me that I should be able to machine the bevel gears using a CNC mill with a 4th axis. Like a conventional mill the CNC mill has three orthogonal axes X, Y and Z. The 4th axis is a rotary axis. By convention a rotary axis aligned along the X axis is labelled A.

CAD

Before using the CNC mill to machine the bevel gears I needed to create an accurate 3D representation of the bevel gear and pinion, including the exact tooth shape. A quick trial in Alibre (my 3D parametric CAD software) showed that a sketch approximating the tooth form could be used in conjunction with a point at the origin to create a 'loft'. In 3D CAD a 'loft' is a shape formed by a linear transition from one shape to another shape, an arbitrary distance away. If one of the shapes is a point then the 'loft' reproduces the shape of the first shape but linearly decreasing in size. In practice there seemed to be a bug in the software, in that it wouldn't generate a 'loft' from a sketch to a point, despite the manual saying it could. Instead of a point I had to use a 5 thou square at the origin. The errors in the tooth form due to this are smaller than the resolution of the CNC mill, so for all practical purposes can be ignored. The 'loft' could then be replicated using a circular pattern. Finally the 'loft' can be truncated and a base added to produce the actual gear. Simple in theory; but then the question arose, exactly what is the form of the gear tooth? Obviously, it's an involute, but what is an involute curve and which bit of it is used? Mathematically an involute is a curve formed from another curve by unwinding a taut string. Gears use the involute of a circle. In parametric form the involute curve of a circle is defined by:
$x = a(\cos(t)+t\sin(t))$ and $y = a(\sin(t)-t\cos(t))$
where a is the radius of the circle and t is the angle in radians. The involute of a circle is usually visualised by a string wound round a circle and then unwrapped, the end of the string tracing out the involute. But which part of the involute is used? It turns out that the first

Features of a Bevel Gear

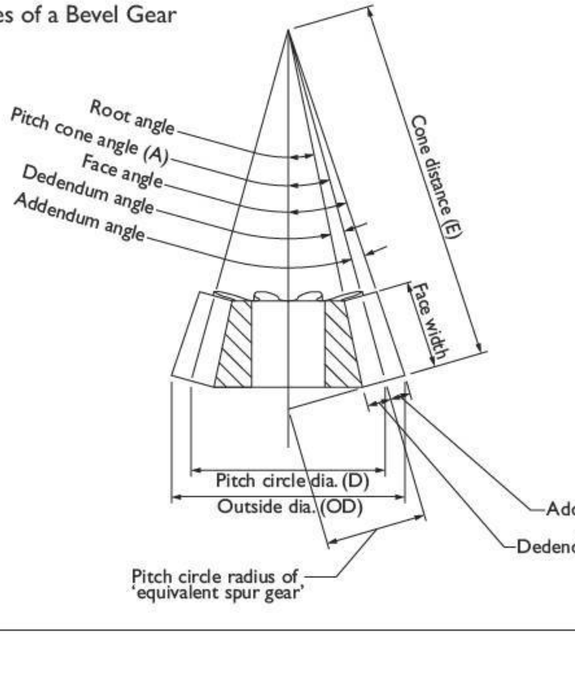
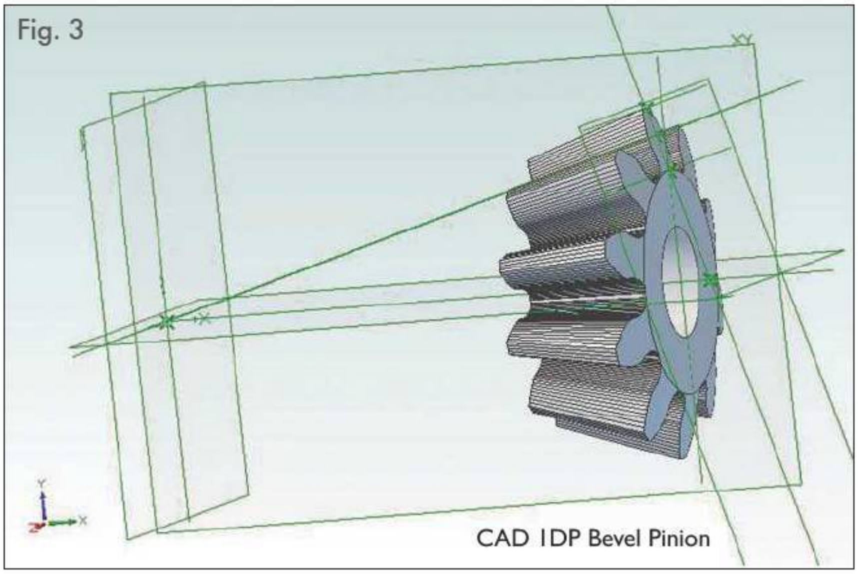


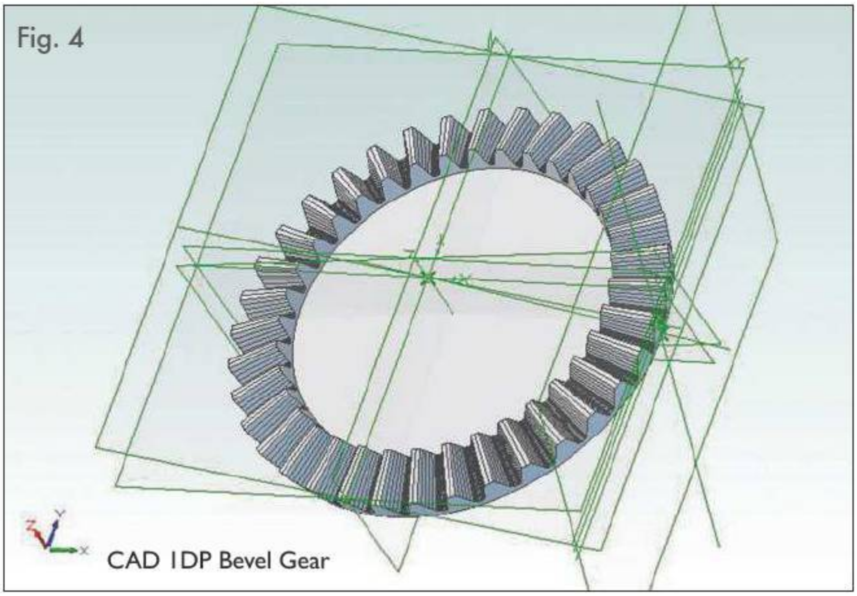
Fig. 2

Fig. 3



CAD 1DP Bevel Pinion

Fig. 4



CAD 1DP Bevel Gear

part of the involute is used, from a circle known as the base circle for a particular gear. The diameter of the base circle is defined as the PCD times the cosine of the pressure angle. The pressure angle of a gear is the angle between a tangent to the PCD and a normal to the involute. To run together gears must have the same pressure angle, as well as diametric pitch. Common pressure angles are 14.5, 20 and 25 degrees. A pressure angle of 14.5 degrees is common on older gears, whereas 20 degrees is normally used now.

In theory constructing an involute should be simple. Draw the base circle, mark a series of equally spaced points on the circumference and draw tangents from said points. The length of the tangent corresponding to the arc length from the start point is then marked. Finally the points are joined up to give an approximation to the involute curve. In practise this proved to be rather more fiddly than expected in my CAD software. Finally, after several attempts I abandoned the idea. Fortunately I then found on the internet a DOS program that generates the tooth forms for a 1DP spur gear from 10 to 200 teeth with selectable degrees of accuracy. The program generates gears with a dedendum of 1.25/DP, hence my previous choice of the value for the dedendum! Having generated a series of gears from 10 to 200 in DXF format I then selected the 10 and 36 tooth gears and imported the DXF files into my CAD system. After a bit of fiddling I managed to get a sketch of a single tooth imported into the 3D part of the CAD system and then to generate the complete gears in 1DP.

At this point I discovered I had made an error in the design. The shape of the involute for a bevel gear is not directly related to the number of teeth on the bevel gear but to the number of teeth on the 'equivalent spur gear'. The 'equivalent spur gear' is set at the face angle to the axis of the bevel gear and thus is larger in diameter than the bevel gear (see fig. 2). The number of teeth (N') on this equivalent spur gear is given by:

N'=N/cos(A)

For the 10 tooth pinion the equivalent number of teeth is 10.3 and for the 36 tooth bevel gear it is 134.5. For the pinion we can stick to the tooth shape for 10 tooth gear, but for the gear we need to choose the tooth shape appropriate for a 135 tooth gear. This has the effect of making the teeth on the gear much less curved than might have been expected from the number of teeth on the gear. The use of a different number of teeth, based on the concept of the 'equivalent spur gear', is known as Tregold's approximation. To create the pinion and gear it is necessary to put the sketch of the tooth shape on a plane at the face angle of the gear and at the correct distance from the origin. The CAD model of the 1DP pinion is shown in **fig 3** and of the 1DP gear in **fig 4**. Also illustrated in these figures are the axis and plane constructs needed to get the tooth outline in the correct place to form a 'loft' to the origin.

Once the pinion and gear have been modelled as a 1DP gear it is simple within the CAD system to get the equivalent 6DP gears. All dimensions are scaled by the inverse of the DP required, ⅙ in this case. Before starting machining I took the opportunity to make an assembly of three pinions and two bevel gears to check that the distances between the gears, and other parameters, accorded with the drawings and with what I thought they should be (**fig 5**). My 3D CAD system also has a motion simulator that allows the gears to be rotated by assigning rotational speeds to each gear. This allowed the mesh of the gears to be checked, at least qualitatively, to ensure that there were no gross errors in the assumptions about the tooth shape.

Finally the gears were modelled with bosses and cutouts as per the original drawings. From the CAD I was able to confirm most of the design data on the drawings, but I disagreed with the outside diameters and the heights of the teeth, and thus the sizes of the gear blanks.

CAM

Having modelled the gears in 3D it is then necessary to create machining strategies and to generate the CNC tool paths. Let us take the pinion first. Looked at end on the teeth would require a long cutter to reach all the way down, if the pinion was bolted to the mill table. Thus it seemed sensible to machine the pinions along their rotational axis, rotating the pinion as required. This requires four axes on the CNC mill, three linear and one rotary. In fact, with the strategy I chose the Y axis always stays at zero. By making some sketches in the CAD model I was able to confirm that a 4mm ball nose cutter would be able to machine the root radius of the teeth on the pinion. So the whole pinion can be machined using a 4mm ball nose cutter. It seems sensible to let the machine do the maximum amount of work; hence we start with a cylindrical blank whose diameter is the maximum diameter of the pinion, and whose length is the maximum of the pinion. The outer diameter is calculated as part of the design process. The length is more difficult to calculate as it is dependent upon the face length of the pinion rather than being an inherent property of the gear. However it is easily obtained from the CAD model. A two stage strategy was adopted for the pinion; first rough out the shape of the teeth using a relatively coarse rotary

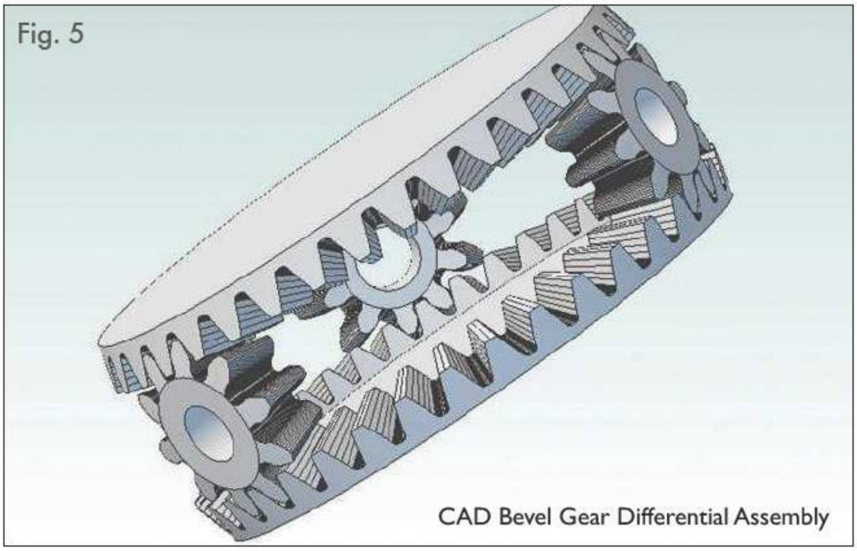
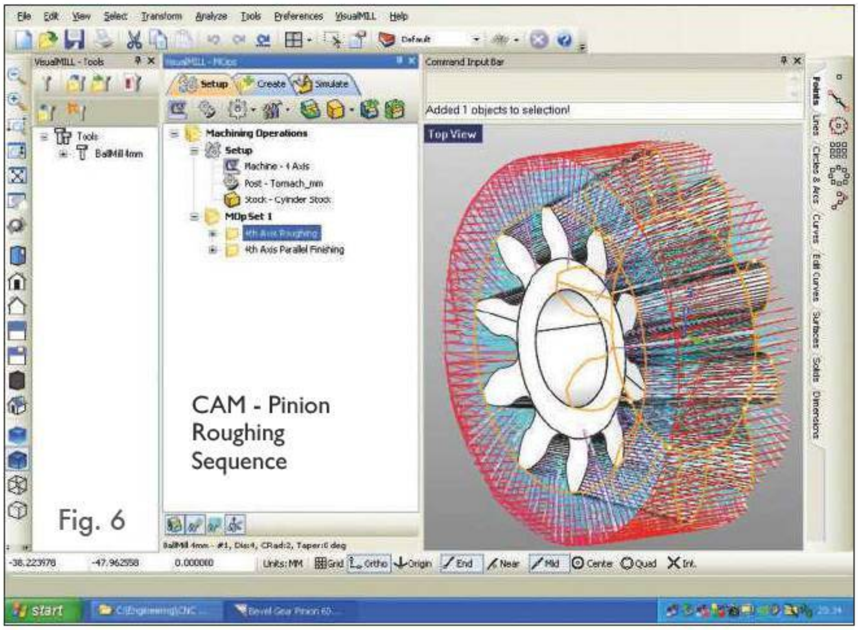


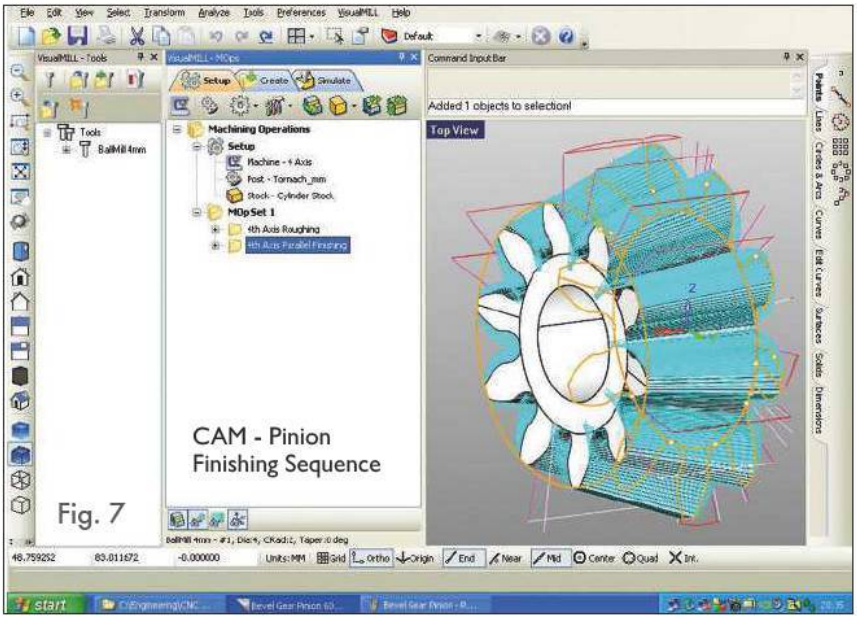
Fig. 5

CAD Bevel Gear Differential Assembly



CAM - Pinion Roughing Sequence

Fig. 6



CAM - Pinion Finishing Sequence

Fig. 7

step and linear step down. This is shown in **fig 6**. Secondly the profile of the teeth is formed using a finishing pass along the tooth profile with a fine step over, as shown in **fig 7**. The three-flute cutter is programmed to run at 5000rpm with a feedrate of 400mm/min, giving a chip load of 0.027mm/tooth.

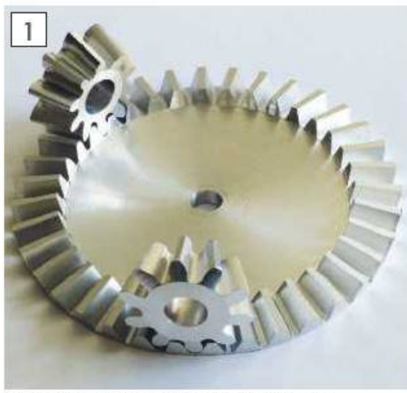
The machining strategy for the gears follows a different path. Since the gears are fairly flat, a standard length cutter can be used without the need for a rotary axis. The gear can be bolted down to the mill table and the X, Y and Z axes moved in synchronism to form the radial teeth. Sketches on the CAD model indicated that a 2mm cutter is needed to form the radii at the bottom of the teeth. A similar philosophy to the pinion was adopted, first roughing cycles and then a finishing cycle. It would take an inordinate amount of time to rough out the gear using a 2mm cutter, so the initial CAM program used a 4mm ball nose cutter for the roughing and a 2mm ball nose cutter for the finishing, and to form the correct radius at the bottom of the teeth. This strategy was modified in the light of practical experience gained by machining prototype bevel gears.

Machining Aluminium Prototypes

Before machining the actual gears in cast iron a partial set of gears in aluminium were machined to check out the tool paths and to assess the finish obtained by various stepovers during the finish profiling cuts. Machining of the bevel pinions went according to plan, except that the initial finishing stepover of 0.3mm proved to be a little coarse. This was reprogrammed with a stepover of 0.1mm, which gave an acceptable finish. Finishing of the tapered inner and outer faces, to give the correct face width, and finishing the central boss, was done manually in the lathe, using the same split mandrel as was used to hold the pinion for CNC machining.

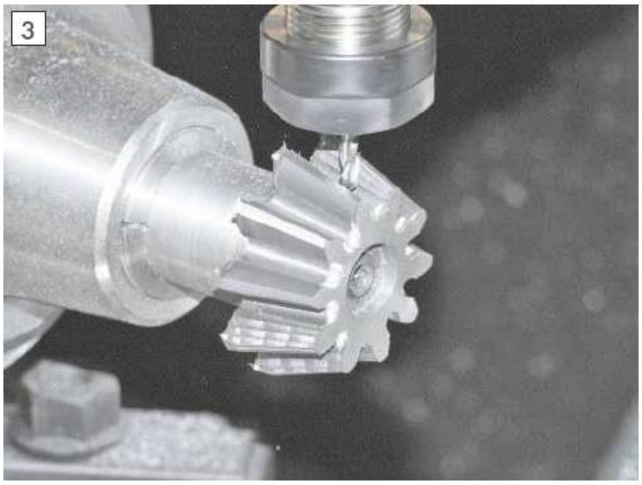
The machining of the prototype bevel gear proved to be a bit more problematic. The roughing cut with a 4mm cutter was fine, but after several broken 2mm cutters and much experimentation with speeds and feedrates it became clear that too much metal was being left at the bottom of the gaps between teeth for the 2mm cutter to cope with in one pass. So a first profiling cut with a 3mm cutter was included followed by the final profiling cut with the 2mm cutter. The prototype gears are shown in **photo 1**.

1



Prototype Aluminium Bevel Gears.

CNC Mill Setup and Cast Iron Blanks.



Pinion Machining Photo 4: Outer Bevel Gear Machining.

Outer Bevel Gear Machining.

Inner Bevel Gear Machining,

Two Sets of Completed Bevel Gears.

Complete Set of Parts for One Differential.

Machining the Cast Iron Gears

Blanks for the cast iron pinions were machined from a bar of round cast iron, to specification GR17. The cast iron was machined dry. The arrangement of the 4th axis for machining the pinions, and all the blanks are shown in **photo 2**. Machining of the pinion blanks was straightforward, using the same speeds and feeds as for the aluminium prototypes. The machining of one of the pinions is shown in **photo 3**. The cutter has finished a couple of teeth; the difference between the roughing and finishing cuts can be clearly seen. Machining time was 2 hours and 38 minutes per pinion.

The blanks for the gears shown in photo 2 were machined from castings. However, due to an error in dimensions on the blanks, and the fact that one casting had a blow hole, I ending up recycling the castings and machining new blanks from cast iron round, as for the pinions. The cast iron bevel gears were machined dry using the same parameters as for the aluminium prototype, with one change. When machining the first gear it became apparent that the material left on the tapered inner face of the teeth by the 4mm and 3mm cuts was too much for the 2mm cutter, which would break part way round the gear. Since this material would be machined away on the lathe after the teeth had been cut on the CNC mill anyway, the blanks were modified to machine this inner angled face before cutting the teeth. This eliminated the problem of broken 2mm cutters. The cutters for the gears were run at 5000rpm, with feedrates of 500, 400 and 300mm/min for the 4mm, 3mm and 2mm cutters respectively. Machining times were 2 hours 26 minutes, 2 hours 37 minutes and 2 hours 33 minutes respectively. The beauty of CNC milling is that once set up and running one can go and do something else. However, watching the cutter forming a tooth out the of the blank can be rather mesmeric. Machining of the outer of the two bevel gears in the differential is shown in **photo 4**. This shows the 3mm cutter, the cutter is progressing anti-clockwise as illustrated by the different patterns on the nascent teeth to the right and left of the cutter. Cutting the inner of the two bevel gears with a 3mm cutter is shown in **photo 5**. This gear has a large central boss on which the differential centre that carries the pinions rotates. Since the cutter is only forming the teeth it remains clear of the central boss. However it is a good idea to program the safe height of the cutter for rapid moves to be above the height of the boss and clamp.

Two sets of completed bevel gears and pinions are shown in **photo 6**. The faces of the teeth have been machined at the correct angles, other machining done and bronze bearings fitted as required. **Photograph 7** shows the complete set of parts for one differential, which started the whole project, including the differential centre and second shaft spur gears.

Conclusion

I have been pleased with the way the bevel gears turned out. They mesh well and all parts of the differential fit together properly. I didn't keep an accurate log of time, but I estimate that for the gear design, CAD and CAM, time spent was about 60 hours. It took another 6 hours to design, make and adjust the 5C collet chuck backplate for the fourth axis on the CNC mill. The total cutting time was many hours, but of course I spent most of this doing other things, so it doesn't really count. I now have a better understanding of the design and machining of bevel gears, which is half the fun! ■

REFERENCE

1. 'Gear Design Simplified' Franklin D. Jones & Henry H. Ryffel, Industrial Press, Third Edition 1961, ISBN 0-8311-1159-3

News from the Trade

Visitors to Arc Euro Trade Ltd. will be aware that there is some building activity going on at their premises. Looking at some of the Heras fencing at the property, as well as the warehouse next door may give the impression to some that the warehouse is closed.

It's actually business as usual at ARC. They have just acquired the warehouse, which gives them increased storage space. They are carrying out work to secure the boundary, along with some renovation work on the inside. This work will be ongoing for some time.

So far Arc have brought in all the goods which were being kept in outside storage. This allows them to service visiting customers who wish to take a machine away with them immediately more easily. At present there is no clear idea for how the additional warehousing will be used.

In the coming months there will be also be additional parking available to customers visiting ARC, on the front of the new warehouse.

Arc's existing building and the new warehouse on the right.

I've just received a copy of GLR Kennions' new catalogue. The combination of these two familiar names brings a good selection of metals, fixings and fittings that suit the model engineer. They also have a lot of specialist items for the live steam enthusiast. Call 01279 792859 or email **glrkennions@hotmail.co.uk** for a copy.

Axminster's SX3 digi mill.

Axminster have refreshed their machine tools, with the most striking change being a new colour for their 'model engineer series' and larger 'engineer series' machines. Out goes the oxford blue and white, in with a colour you might describe as 'aqua'. Long gone are the days when you had a choice of battleship grey or battleship grey regardless of where you bought your machine!

One machine in the Engineer Series is the SX3 Mill Drill DIGI an advanced mill/drill with the added benefits of a digital read-out (DRO) system for the table position. All the other standard features of the standard SX3 version are present including a tilting head, digital spindle speed, down-feed read-outs and a thread tapping facility. It is used for courses in the Axminster Skill Centre. An interesting feature is that coarse vertical feed of the head is by a handle on the base with fine feed via a wheel on the head itself. The mill is priced at £2,299.94, including VAT.

Readers' Tips

We have £30 in gift vouchers courtesy of engineering suppliers Chester Machine Tools for each month's 'Top Tip'. Email your workshop tips to **neil.wyatt@mytimemedia.com** marking them 'Readers Tips', and you could be a winner. Try to keep your tip to no more than 400 words and a picture or drawing. Every month I'll chose a selection for publication and the one chosen as **Tip of the Month** will **win £30** in gift vouchers from Chester Machine Tools. Visit **www.chesterhobbystore.com** to plan how to spend yours!

BELOW: Geoff Harding's Milling Machine Readout.

Geoff Harding's handy wrinkle, for anyone who hasn't got a digital readout, wins our runner up prize of an *Art of Welding* book:

A Simple Milling Machine Readout

I little while ago I was pitching a series of holes in a line on my vertical milling machine as most of us will have done. Without a direct read out system it requires counting the revolutions of the table handle. A little aid I have added to my machine is a simple rule and a pointer.

The rule is supported on suitable brackets using the table stop groove and a pointer attached to the stationary part of the machine. In use the rule is zeroed by sliding the brackets along the groove (some machines already have a rule fitted but they are not able to be moved). Now I do not need to count the handle revolutions. The aid has an added advantage as I can read imperial measurements on my metric machine. Precise positions are finalized by the divisions on the hand wheel. For the other axis I clamp the rule to the magnetic dial gauge stand and fit a simple pointer over a table tee-slot.

Geoff Harding

CHESTER MACHINE TOOLS

No more than one prize with a value of £30 will be given each month. By entering you agree your entry can be freely published and republished MyTimeMedia on paper or electronically and may be edited before appearing. Unpublished tips may be carried forward to future months. You will be acknowledged as the author of the tip. There is no guarantee that any entry will be published and if no publishable tips are received a prize will not be awarded. The decision of the editor is final.

This month's winning tip comes from Tony Finn.

Pozilock collet chucks have a small cone centre set deep inside them, if you have a damaged one in your chuck, this tip could save you a lot of grief:

TIP OF THE MONTH WINNER!

Renewing the Back Centre of a Pozilock Chuck

If the back centre of your Pozilok chuck has got damaged, it's an easy matter to renew its profile, once you can remove it.

The back centre has a right hand thread, ⅜ inch BSW. To remove it you need a tool like the one in the photo, which I made from a piece of 22mm diameter bar about 60mm long. The slot is a clearance 10 mm wide and the centre of it is deeply recessed with a 10mm centre drill to clear the point inside the chuck. There are two flats on the other end for gripping it vertically in the vice.

Remove the closure nut (and any collet), but before putting the chuck to the tool, it is also necessary to retract the Allen grubscrew pin which stops the rotation of the collets, otherwise the tool will not engage. A spanner is used on the flats of the chuck and you may find that it takes some effort to get the centre free but, don't worry, it will unscrew!

After removing the centre, it is a simple matter to chuck it in the lathe, in a collet chuck if you have (another) one. With the top slide set over 30 degrees, true up the point to a 60-degree cone. I thought the centre might be hardened but it wasn't difficult to machine. The back centre doesn't need to be very large, as the centring holes in the back of the cutters are quite small, so a slight reduction in its height won't matter.

Reassembly is simply the reverse of disassembly, but don't forget to return the Allen grubscrew to its normal position. If the centre is beyond repair, it isn't a difficult job to make a new one.

Tony Finn

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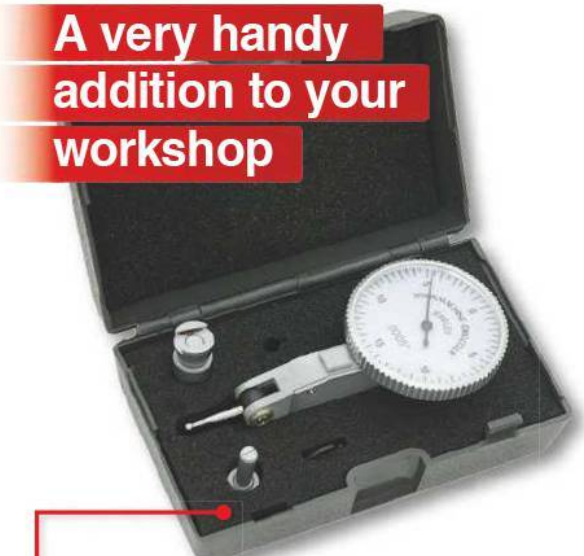

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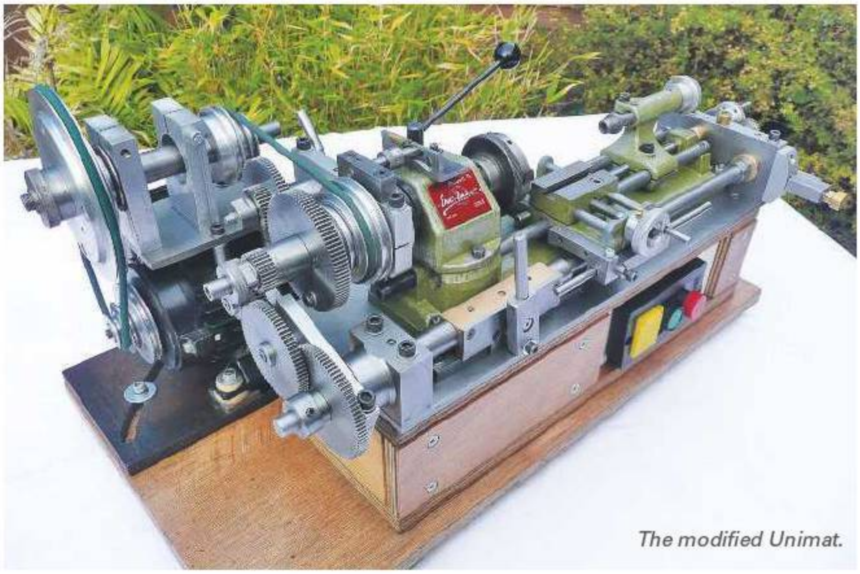
Unimat SL Lathe Modification Part 6

Drive Shafts & Dog Clutch

Terry Gorin adds an ingenious modification to allow screwcutting on his Unimat lathe.

Continuing my series on improvements to my Unimat SL1000, this time I move on to screwcutting drive shafts and a dog clutch. Most operations called for on the drawings will be self-evident to experienced readers and I have only commented on the method and sequence of specific operations.



The modified Unimat.

The sequence of power drive to the cross slide in the majority of conventional screwcutting lathes is via tumbler gear, gear train and leadscrew. The latter, being connected to the cross slide via a half nut or dog clutch. The Unimat leadscrew, however, is centrally located below and permanently connected to the cross slide and any attempt to transmit power drive direct to the headstock end of the leadscrew would have destroyed the original design concept of the Unimat headstock, to be rotatable in high or low position. That's not the intent of these modifications. Power drive therefore has to be to the tailstock end of the leadscrew via an intermediate drive shaft. This was the basis of the power drive accessory marketed by Unimat, with belt drive from spindle to a drive shaft and dis-engagable drive via worm gear to the tailstock end of the leadscrew. This, however, did not provide the fixed-ratio drive to the leadscrew, necessary for conventional screw cutting. Power drive from the modified headstock spindle (**ref 1**) to a driveshaft could be by a conventional gear train, but the necessarily small sized components in a tumbler gear inserted between spindle and train would have been vulnerable to stress, noise and wear resulting from high spindle speeds. Tumbler gearing is not always necessary. The Cowells 90ME and Myford ML10 lathes both operate perfectly well with a dog clutch only. Any speed reduction benefit from worm drive to the leadscrew, similar to the Unimat accessory, was not necessary with a gear train and connection between driveshaft and leadscrew could be by simple spur gearing. Tumbler gearing, in essence, is spur gearing, therefore why not introduce tumbler gearing at this position? It would be rotating at lower than spindle speeds with less stress, noise and wear. Consequently, therefore, final choice, and sequence, of power transmission from spindle to leadscrew is via gear train, drive shafts and dog clutch, finally to tumbler gear and leadscrew extension.

The drive shafts with their front and rear bearings, together with the dog clutch, bolted to the lathe baseplate provide the supports for the gear train, tumbler gear and leadscrew extension, and were constructed first. The gear train, tumbler gear and final drive to the leadscrew will be detailed in later articles. **Figure 24** shows the final assembly of all drive shaft and dog clutch components with **photos 18** and **19** showing the complete assembly bolted to the lathe baseplate.

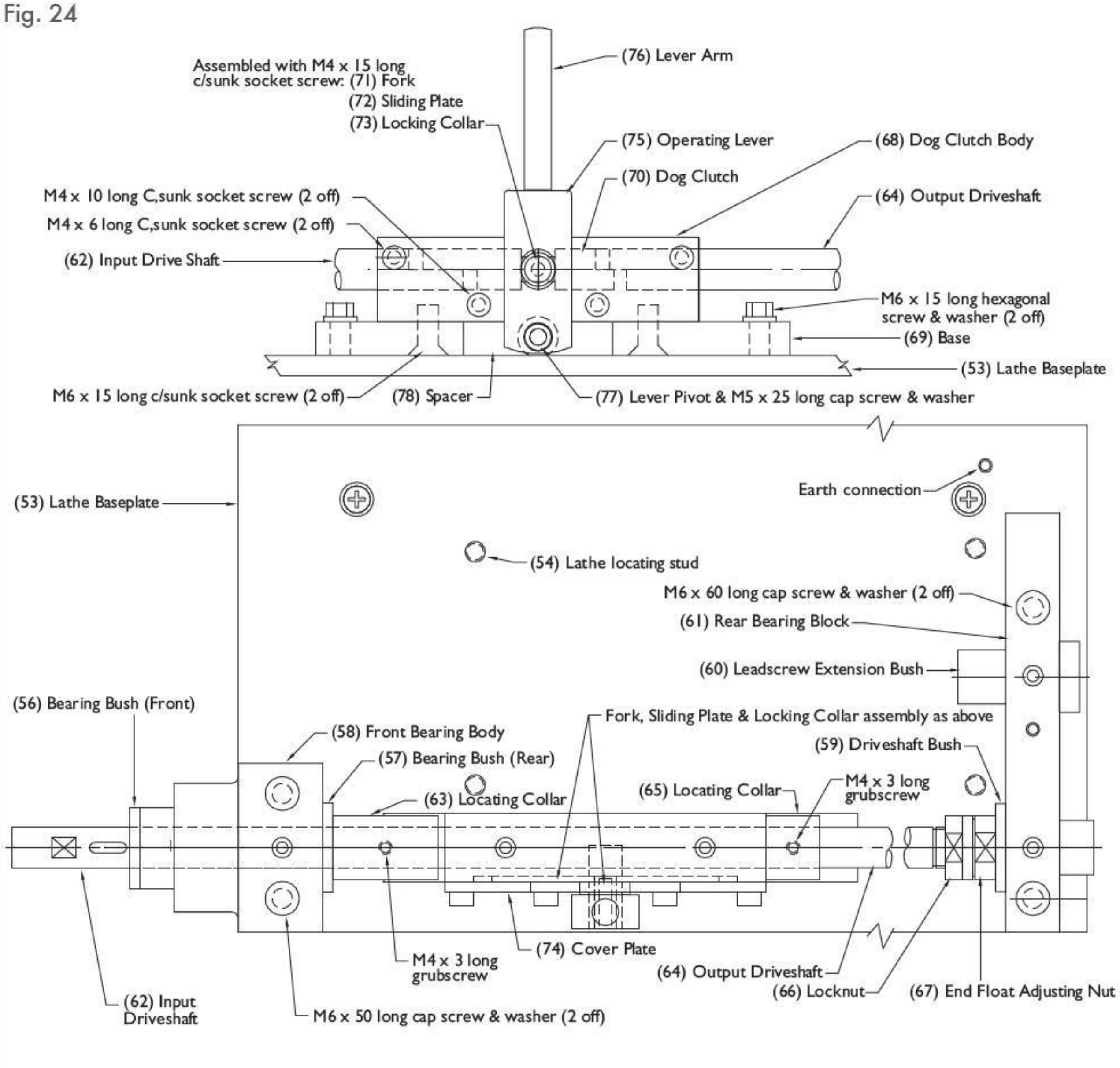
Drive Shafts and Bearings

Constructional details for the front and rear drive shaft bearings are shown in **figs 25** and **26** with **fig 27** detailing the drive shaft components. **Photograph 20** shows the completed components but with the bearing bushes already pressed into their respective bodies. The input (62) and output (64) shafts are supported at their outer ends by the front and rear bearings respectively with the dog clutch body, detailed later, supporting the inner ends of both shafts. Marking out and drilling of the clearance holes for the two securing bolts for each of the front bearing body (58) and rear bearing block (61) was done with great care. This ensured that, when bolted to their respective tapped holes in the lathe baseplate, the front edges of both body and block were flush with the front edge of the baseplate, see fig 24. Both were then removed from the baseplate and the bottom faces and front edges only then used as datum points for the remaining setting out dimensions.

Rear Bearing

With the Unimat bed bolted to its baseplate, the 77.5mm (#1) and 41mm (#2) dimensions, locate the centre of the 16mm diameter boring for the leadscrew extension bush (60), in the rear bearing block (61). They are respectively the horizontal distance of the Unimat leadscrew from the front edge of the baseplate and its vertical height above the top face of the baseplate. The tumbler gear, leadscrew extension and size and choice of gears had been designed at this stage, but not constructed. The 25mm horizontal (#3) and 25.5mm Vertical (#4) dimensions, shown for both rear and front bearings, are based on that design. They

Fig. 24



Drive Shafts And Dog Clutch Assembly

18

Driveshaft front bearing & dog clutch.

19

Drive shaft rear bearing.

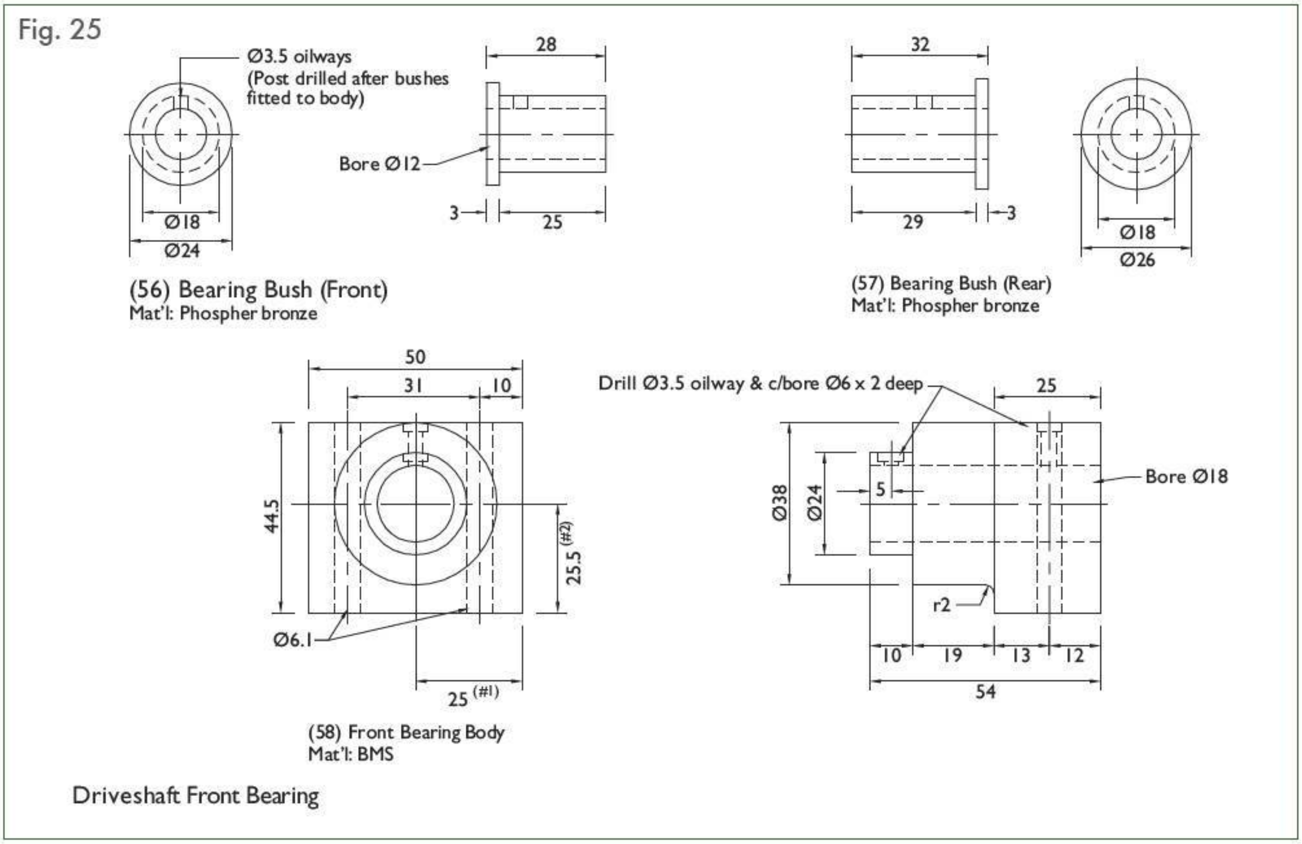


Fig. 25
Ø3.5 oilways
(Post drilled after bushes fitted to body)
Ø18
Ø24
28
Bore Ø12
3
25
32
29
3
Ø18
Ø26
(56) Bearing Bush (Front)
Mat'l: Phospher bronze
(57) Bearing Bush (Rear)
Mat'l: Phospher bronze
50
31
10
44.5
25.5 (#2)
Ø6.1
25 (#1)
Drill Ø3.5 oilway & c/bore Ø6 x 2 deep
25
Bore Ø18
Ø38
Ø24
5
r2
10
19
13
12
54
(58) Front Bearing Body
Mat'l: BMS
Driveshaft Front Bearing

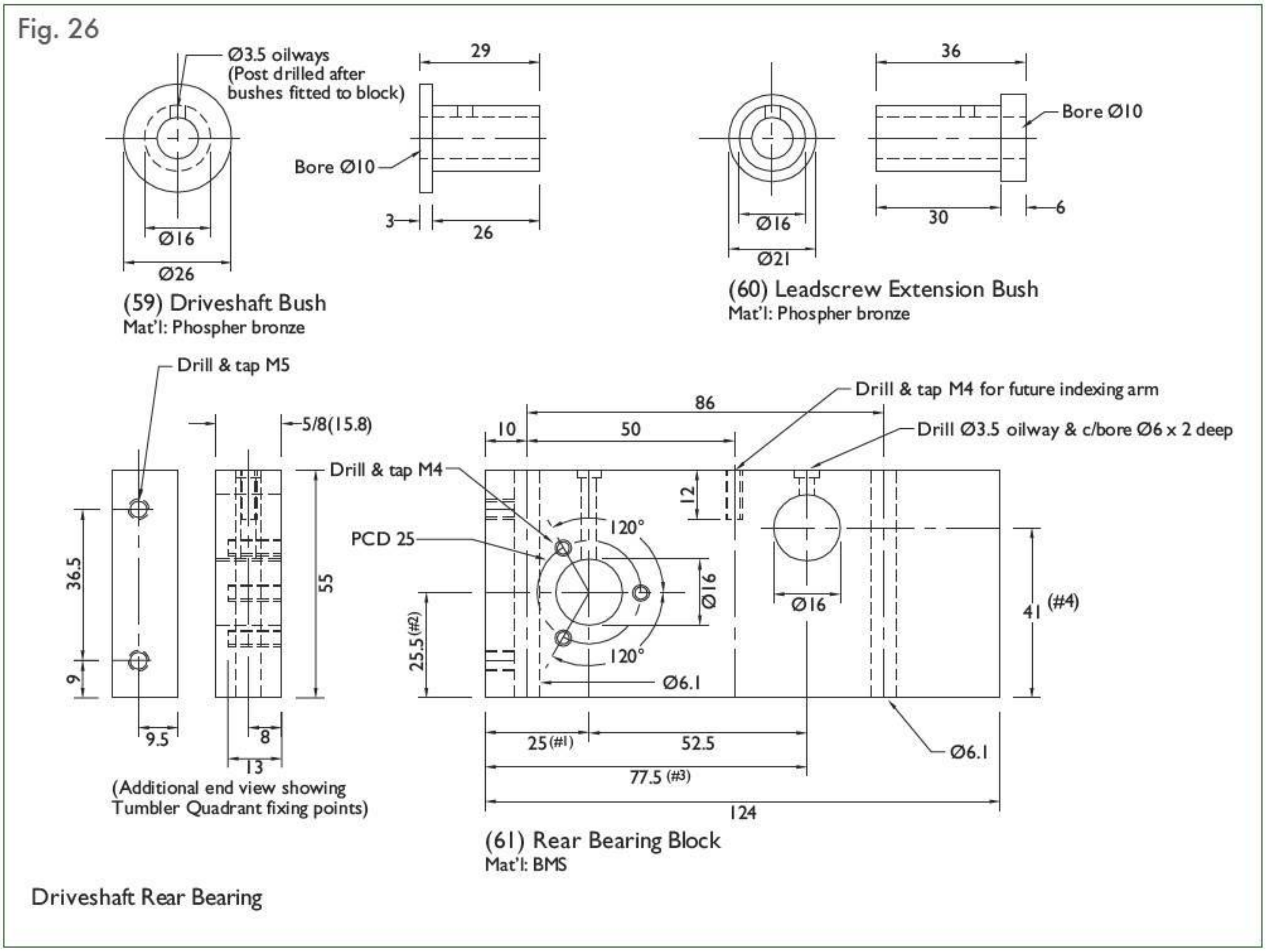
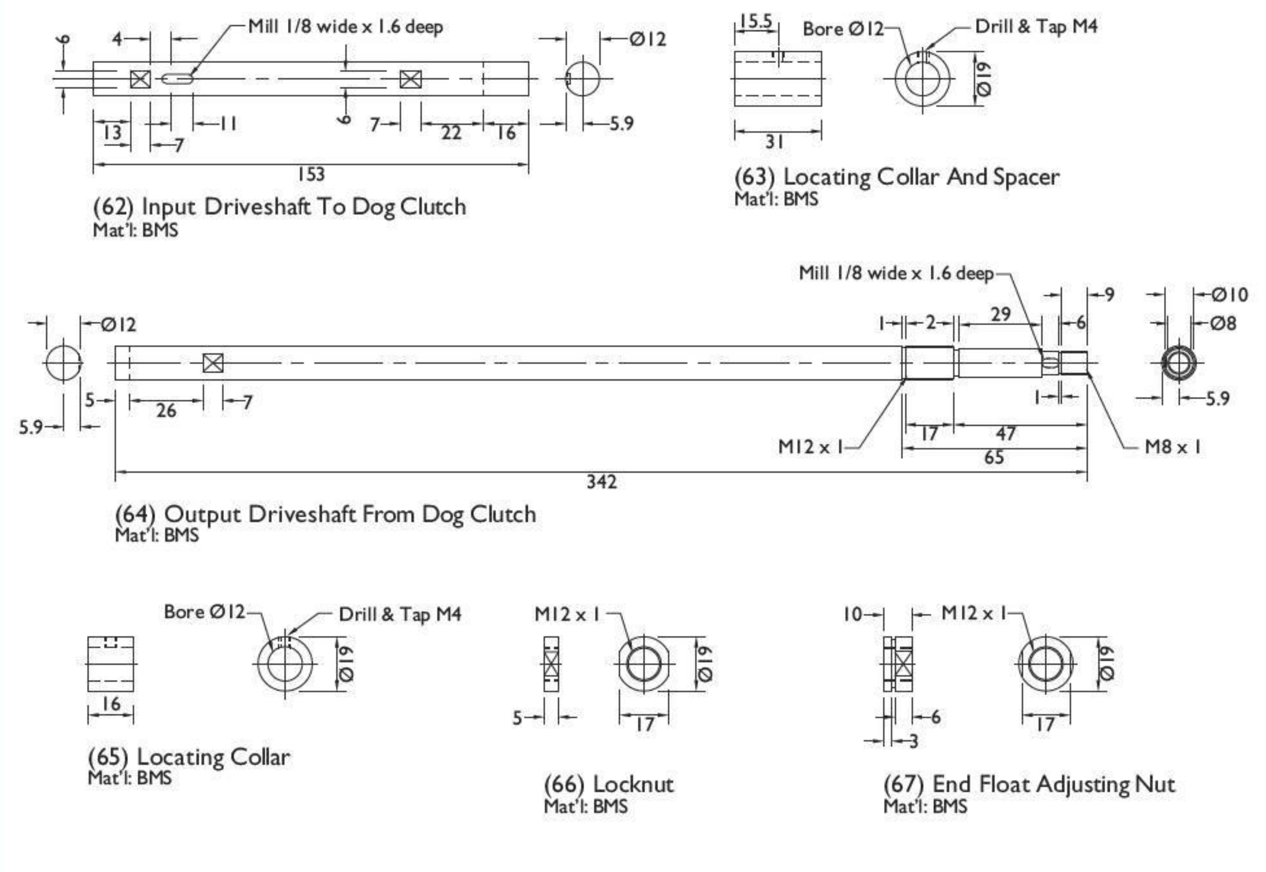


Fig. 26
Ø3.5 oilways
(Post drilled after bushes fitted to block)
Ø16
Ø26
29
Bore Ø10
3
26
36
Bore Ø10
Ø16
Ø21
30
6
(59) Driveshaft Bush
Mat'l: Phospher bronze
(60) Leadscrew Extension Bush
Mat'l: Phospher bronze
Drill & tap M5
5/8(15.8)
Drill & tap M4
36.5
9
55
9.5
8
13
(Additional end view showing Tumbler Quadrant fixing points)
86
10
50
Drill & tap M4 for future indexing arm
Drill Ø3.5 oilway & c/bore Ø6 x 2 deep
12
PCD 25
120°
Ø16
Ø16
41 (#4)
25.5 (#2)
120°
Ø6.1
25 (#1)
52.5
Ø6.1
77.5 (#3)
124
(61) Rear Bearing Block
Mat'l: BMS
Driveshaft Rear Bearing

Fig. 27



Driveshafts

locate the drive shafts so that the dog clutch is just clear of the Unimat bed and the tumbler gear and drive shaft and leadscrew extension gears all engage satisfactorily when fitted. Both borings to the rear bearing were carried out on the Myford with the block clamped to the vertical slide and the bore centres accurately located by manipulating the cross and vertical slide leadscrews. Not possessing an indexable boring bar, both borings were taken within a few thou of the nominal sizes by gradual adjustment/grinding of the boring bar bit. The leadscrew extension and drive shaft bushes were both turned from phosphor bronze cored bar to the sizes shown, but with the outer diameter of the sleeves machined to light drive fits to the previously bored bearing block. (In my haste to prove correct fits, all bushes in these modifications were fitted to their housings as soon as completed and hence photo 20 and others, show all bushes fitted!) Photograph 20 also shows how the sleeve of the driveshaft bush (59) protrudes from the back of the rear bearing block, as a trunnion on which the tumbler gear can rotate. The sleeve of the leadscrew extension bush (60) protrudes from the front of the block as support for the leadscrew extension. To ensure concentricity all sleeve outer diameters and shaft borings, for all bushes, were machined at the same chuck setting.

To be continued...

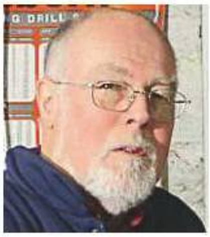
20

Bearing & driveshaft components.

REFERENCE

1. Unimat Modification, *Model Engineers' Workshop* Issue 211, page 25.

A Note on Rust



Dave Fenner's latest rust bucket prompts reflection on the topic.

Rust is a theme which has been touched upon on various occasions by different authors over the years in *MEW*. This is an attempt to draw together the contributions of others, add thoughts and experience of the writer, and invite others to add their considerations in the future.

Latest project, very rusty 1973 Porsche 911 Targa.

Historically my own workshop, for the past twenty-five years, has been a draughty agricultural barn, stone built with a tin roof. In general, it is impossible to heat, though I do have an Ambi-Rad propane powered radiant heater directed downwards at the well used workspace between mill and lathe. Rusting of tools and machinery has been a persistent problem, accentuated in the winter and spring months. My interest in dealing with rust was re-awakened by my latest automotive rebuilding project (**photo 1**). German engineering may have acquired an enviable reputation, however it is clearly no match for the rust fairy.

Cause of rust

For rusting to occur, three elements must be present; iron, oxygen, and water. The rate of rust formation may be accelerated if other chemicals such as salt or carbon dioxide are present. The formation will also follow the normal laws governing chemical reactions, in particular that the rate will increase at higher temperatures.

In the workshop setting, machines or tools will rust due to condensation forming on the surface. This would typically be caused by humid air in contact with metal surfaces at a lower temperature. Metal cutting machines are generally sturdily built usually from iron castings. The mass of cast iron cannot change temperature instantaneously, and so will lag behind movements in the ambient air temperature. With a falling temperature, the machine will stay above ambient, but when the mercury is rising, then the metal is cooler than the air, and moisture will condense on the surface, leading to rust. This effect can be accentuated if the workshop has a south facing window, as strong sun then heats the air quickly, while the metal remains cool, with the inevitable result.

Personal observation leads me to believe that automotive rusting is not nowadays as great a problem as it was a decade or two ago. Nevertheless, it does still occur, and in this country, is aggravated by the use of salt on roads in winter. There is also the phenomena known as stress corrosion and stress fatigue, which can come into play, which may cause the more highly loaded areas of bodywork to decay first. Thus for cars with a soft or removable top, the lower sections of the A and B posts where they join the sills and floor, are prime problem areas (**photo 2**). They are also likely to get wet on the inside, as soft-tops often leak.

For rusting to occur, three elements must be present; iron, oxygen, and water. The rate of rust formation may be accelerated if other chemicals such as salt or carbon dioxide are present.

Preventing Rust

When a steel structure such as a ship or oil platform, is immersed in water, a device known as a sacrificial anode may be employed. The anode is made from a more active metal, typically aluminium, magnesium, or zinc which corrodes preferentially. For pipelines a similar form of protection may be achieved by applying an 'impressed current', supplied by a DC power supply. Here again an anode is encouraged to corrode in preference to the structure. In both of these cases, the anode is electrically connected to the structure first by wire or direct contact, and secondly by water or moisture in the soil which acts as an electrolyte, thus forming an electrical circuit.

We may note that cars are not submerged in water and therefore such a system cannot work. In fact an internet search found a Wikipedia note that one seller in the U.S.A. of an automotive electronic rust prevention system was ordered in 1996 to cease marketing and pay $200,000 in customer redress.

Like cars, our machines and tools are not immersed in water, and so the short and simple answer is that either the oxygen or the water, or both, must be prevented from contacting the iron. For the workshop, a number of letters have featured in *Scribe a Line* testifying to the benefits of installing a dehumidifier. For a small to medium size shop, insulated to modern standards, this probably is the ideal first step in the solution. If the moisture can be removed from the air, then it cannot condense on the tools or machines. Heating, to maintain a near

Showing the gaping hole at the footwell/A post area.

Black underseal (left) and Waxoyl (right) which is available either black or clear (much less messy).

constant temperature will avoid the -cold machine - warm air' situation, again helping to eliminate condensation. The downside, for both of these approaches, is the initial capital cost and then the ongoing running cost.

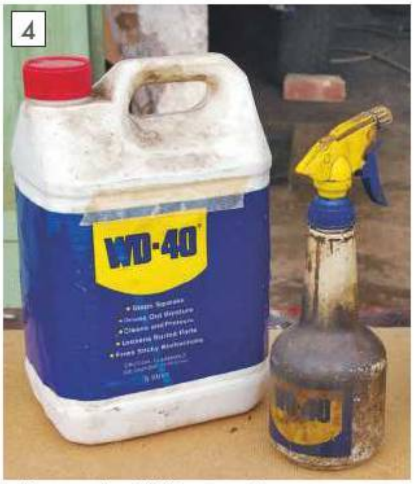
If the workshop shares garage space with the car, it probably does not help to bring the car in while still wet, as that simply adds to the moisture level within the garage.

If the machine temperature can be raised above that of the air, then condensation will not occur. There have been suggestions to add low powered heating elements to a lathe bed to give this effect. The counter-argument has been that if the heating is somewhat localised, then the accuracy of the machine could suffer.

A physical barrier preventing water contact may be achieved in a number of ways, and here the most obvious might be paint. Up until about 1980, cars would commonly rust away from the inside. It was about that time, that many manufacturing plants introduced electrophoretic dip coating, which ensured that all the surfaces (inside and out) of a bodyshell were given an adequate coat of paint. Later on, the attention of some manufacturers (notably Porsche and Audi) turned to the use of zinc coated steel, and in one case stainless steel (De Lorean). The latest trend is towards aluminium, but that is a different story. For the car repairer/restorer, products such as bitumen based underseal or 'Waxoyl' (**photo 3**) can offer a solution.

For many tools, and parts of machines, a coat of paint is just not a viable option, so some other form of barrier must be found. Some readers have recommended a quick spray with a water displacing fluid such as WD40 (**photo 4**) or Duck Oil, and this has certainly been used on occasion by the author. It would seem that these types of product are a mix of non-volatile viscous oil and lower viscosity volatile thinner, which allows the low viscosity mix to penetrate into crevices. The volatile thinner will then evaporate leaving an oily film, giving a measure of protection.

Some oils are marketed specifically for corrosion protection, and two which were marketed by Myford when in Nottingham were Rust Ban 393 manufactured by Exxon Mobil and Calpreve manufactured by Calder Oils. Litre packs of these are shown in **photo 5**. It would appear that Myford no longer handle these products, but they are more likely to be available from the respective manufacturers. Back in April 2007, a test was set up by the author, which was noted in Trade Counter – *MEW* issue 124, whereby three specimens were prepared and hung up in the workshop, where they have been weathering gently for nearly seven years. **Photgraph 6** shows the test pieces as



5 litre packs of WD 40 work out more economical than the small aerosols.

they are at the time of writing (February 2014) and it can be seen that No1 (unprotected) has rusted significantly, No2 (Rust Ban intended for relatively short term storage) has begun to rust, while No3, (Calpreve – higher viscosity and intended for longer term protection) shows no sign of rust.

Tools in boxes or cabinets may be protected by employing VCI (vapour phase corrosion inhibitor) emitters. As can be

One litre packs of Rust Ban 393 and Calpreve 91.

The three test pieces after seven years.

seen in **photo 7**, these are available as small tinlets containing a compound which gives off a vapour which in turn protects steel tooling. It is claimed that one emitter will give protection to a 100 litre volume for a period of two years. Silica gel packs, which work rather as mini dehumidifiers by absorbing moisture, may also be used, either purchased or salvaged from incoming packaging. These may also be periodically regenerated by gently warming in an oven to dry out.

Once it has rusted

Traditionally, when dealing with light surface rust on cars, the technique was to grind away the rust to give a bright bare metal surface for repainting. The downside of grinding is that it also tends to remove good metal causing thinning. It also leaves a freshly abraded surface which will corrode quickly unless protected. The chosen preparatory coat might well be an etch primer which is now readily available in aerosol form. An alternative approach is to remove the loose surface rust, then coat the surface with a rust converter, which chemically changes the surface to a stable compound which may then be overpainted. Jenolite (**photo 8**) is one such product which has been around for many years. Others have come to the market, and Practical Classics magazine conducted a comparative test of eight similar products in spring 2011. As a result, they selected three for particular note – Granville Heavy Duty Rust Cure – best budget buy; Bilt Hamber Hydrate 80 – recommended; and Rustbuster Fe123 – best buy.

Where the rust on a car has progressed to impair the structural integrity, then there is generally no option other than to cut back to good metal, then buy or make replacement parts or repair panels. In the home workshop, much can be accomplished using a Mig welder, tinsnips, folder and hammers. Adding a spot welder, bead roller and English wheel extends the range of capabilities.

For smaller parts, there are available fluids which are claimed to 'digest' rust, and I have had good results with RustAway (photo 8). Small parts are left submerged in the liquid for up to a day or so and the rust is converted to a black compound which is easily brushed away.

VCI emitters, these supplied by Enginewise.

RustAway and Jenolite. Note the effect on the label of the content of the latter.

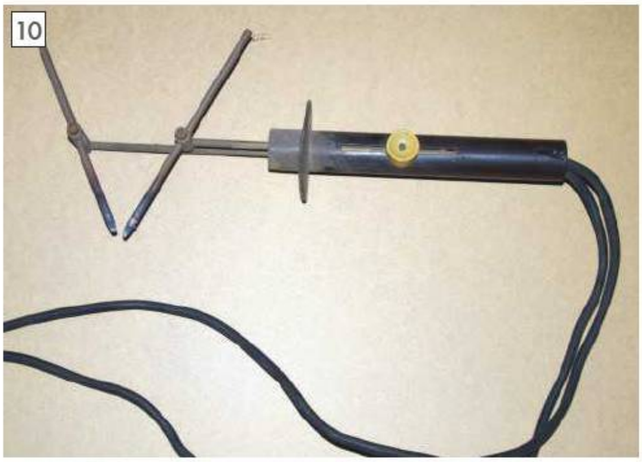
Another process which has been covered before in *MEW* is electrolytic de-rusting. **Photograph 9** shows two plastic tubs which have been successfully used to clean up steel car wheels. The tub on the right contains caustic soda, which softened the paint so that it could then be easily removed with a wire brush. The left tub, contains a solution of washing soda, has a steel plate anode at each side and a wooden frame to ensure that the negatively connected work piece does not touch the anodes. In my case, power is supplied by a variable voltage DC supply giving up to 24 volts, though a normal battery charger would probably be fine. Here the red rust is converted to a black gunge which can be readily scrubbed off. A criticism has been levelled at the electrolytic process, namely the possibility of hydrogen embrittlement, which might give rise to cracking. Hence for highly stressed parts, a de-embrittlement process should be considered.

Rusting of bolted assemblies poses a different sort of problem. In one earlier article, the author noted that the strength of a rusted joint could exceed that of the parent metal. Certainly M6 bolts are notorious for their tendency to shear when rusted. Conventional wisdom advises the application (possibly repeated) of a penetrating oil such as WD40. My own experience is that this only becomes effective once there is slight movement of the bolt, so that the fluid can be worked in and can then help to move the rust particles and lubricate the thread, when a forward-backwards motion can be applied to the fastener. I have also found that a sharp rap with a hammer can help fracture the rust bond. If access permits, then the application of heat can be an effective means of freeing things off. The ideal tool is an oxy-acetylene torch, but these generally require committing to a cylinder rental contract. A Tig torch works well, as does the old carbon-arc torch (**photo 10**) which can be run from a small arc welder. Often though the simplest approach may be to reach for the angle grinder, fit a thin cutting disc and cut away the offending fastener.

We might well ask why heat is effective here, and part of the answer will be that the nut expands giving a bit of clearance. Now I am no chemist, but I suspect that when heated, the rust changes form (somewhat like blue copper sulphate turning white) and in doing so loses volume or rigidity. Comments from others would be welcome on this point.

Finally, I would like to briefly digress with short and possibly relevant story. A number of years ago, I had been approached to look at reworking a batch of used turbochargers. A few samples were delivered to assess the job. Naturally the bolts and studs were seized. One or two were immersed in the caustic soda bath for a couple of days, and in one case the bolts were then successfully removed with relative ease. Others with a deeper knowledge of chemistry may care to comment on whether this was just coincidence or whether the caustic soaking played a genuine part in easing the rust. ■

Tub on right contains caustic soda, that on left has washing soda solution and is equipped with plate steel anodes. Both will need topping up with water for larger.



Twin carbon arc brazing torches were popular for car body repairs before revised MOT rules effectively banned brazed repairs.

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A beginners' guide to Home Metalworking Part 6

This time, David Clark looks at lathe tools.

As well as working in engineering, David Clark has set up and operated several home workshops. This regular series offers much sage advice for the beginner.

1

A selection of HSS tool blanks.

2

A boring bar ground from a round piece of HSS.

3

An offhand grinder with adjustable tool rest.

4

A recessed grinding wheel suitable for grinding on the side of the wheel.

TYPES OF LATHE TOOLS

HSS tools

There are two types of lathe tool that you might come across in the home-workshop. The first of these is High Speed Steel (HSS). HSS is steel that usually has a mixture of more than 7% molybdenum, tungsten, vanadium and chromium as well as more than 0.60% carbon. It is called High Speed Steel because it is capable of machining at higher speeds than the old carbon steel which softened when it got hot. HSS is normally supplied as square or round section tool steel in an already hardened state (**photos 1** and **2**). It cannot normally be hardened in the home workshop.

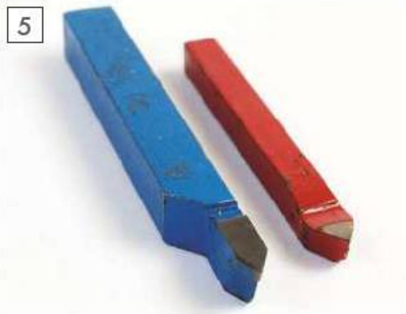
Tool grades

There are various grades of HSS. The ones you are most likely to come cross in the amateur's workshop are those designated with a T where tungsten is the major alloying element and those with an M meaning that molybdenum is the principal alloying element; those designated M are more resistant to wear than the T grades. The majority of HSS you are likely to come across won't be marked and will be a T grade.

HSS is easy to grind in the home workshop using an offhand bench grinder (**photo 3**). I recommend using a 46 grit wheel for roughing and 60 grit wheels for finishing. The wheels are used are usually aluminium oxide wheels (**photo 4**). The wheel specification recommended is as near as possible, A46K5V. This can vary a little bit depending on what you can obtain form your wheel supplier. I don't recommend a grit size smaller than 60 for finish grinding HSS tools as the wheel will probably glaze over and overheat the tool.

The other type of lathe tool you might come across is the tungsten carbide lathe tool. Tungsten carbide tools are supplied as steel shanks with 'brazed on' pieces of carbide (**photo 5** and **6**) or as a purpose made steel shank with a 'screwed on' tungsten carbide tip (**photo 7**). The brazed on tips can be sharpened in the home workshop and work out much cheaper than inserted tips. Inserted tips are usually made to the ISO standard and are usually interchangeable with various manufacturers' tool shanks. In the USA,

5

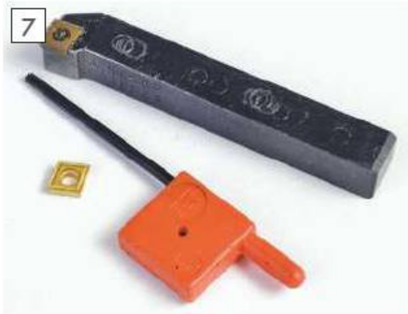


Two tungsten carbide brazed tools.

6

A mild steel mounted tungsten carbide boring bar.

7



An inserted tip turning tool.

›

A Mini-Thin grooving and parting tool with a selection of tips.

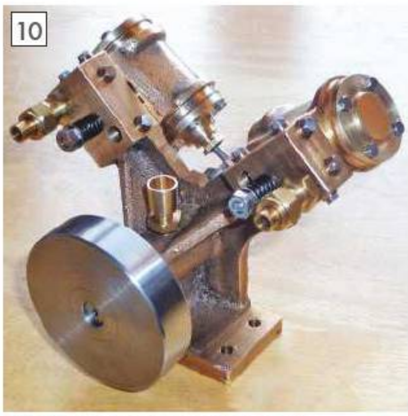
Turning a brass component with the Mini-Thin tool.

tips are usually to the ANSI standard and are not compatible with the ISO standard.

The tips are often capable of cutting on more than one edge by turning the tip round in its holder and, in some cases, the tip can even be turned over in the holder to bring other edges into use. Also, some tips can be used in two types of holder, each of which allows a different part of the tip to contact the work.

Tips are often supplied with special cuttings to lengthen their cutting life. There are four main coatings in use in industry. They are TiN (titanium nitride) which is a gold colour coating, TiC (titanium carbide) which is grey, TiCN (titanium carbo-nitride) varies from almost gold through a coppery colour to a silver blue colour and TiAlN (titanium aluminium nitride); the colour of TiAlN varies from black to bronze depending on the Titanium to Aluminium ratio in the coating.

One of the inserted tip tools I find most useful is the Mini-Thin grooving and parting off tool available as a kit from J&L Industrial (**photo 8**). It is not cheap but the tips last quite a long while and can be used for finish turning as well as grooving and parting off. I finished this multi-step brass cylinder end cap by turning with a mini-thin grooving tool (**photo 9**) Tips with a 60-degree inclusive angle are also available for metric screwcutting. This tool has a ½ inch shank and takes inserts that are screwed to the side of the tool. Although the tool will not part of large diameters, if the component has a hole through it, it will part off up to at least 5mm wall thickness so a bit of, say 16mm bar with a 6.5mm hole through it should not pose a problem. I find the Mini-Thin tool holder ideal when turning small brass and bronze fittings for steam engines. I used it to face, taper turn and part off 12 bronze washers to seal the steam holes on an oscillating steam engine with no problems at all (**photo 10**). The washers can just be seen under the hexagon headed bolts.



The bronze washers can be seen under the hexagon bolts.

The tip size

Tip size is designated by the largest inscribed circle that can fit into the tip while not going outside the boundary of the tip (**fig 1**). The larger the tip, the greater the depth of cut can be taken although this will be limited somewhat in the average model engineers' lathe. A rule of thumb is that the maximum depth of cut should not be more than two-thirds of the cutting edge length.

Carbide grades

The grades of carbide used in inserts are based on the toughness and ability to resist wear of the tip. You should use the tip manufacturer's technical guide to select the proper grade of carbide required to machine the material you are using. The type of cut being taken, for instance continuous or intermittent, should also be taken into account when selecting the grade of carbide to be used.

Corner radius

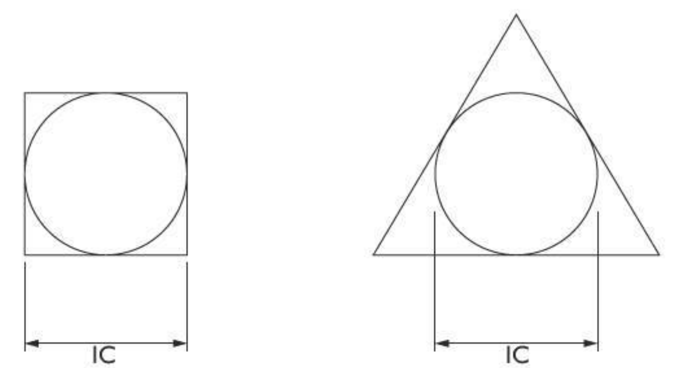
Carbide tips can be purchased with different corner radii for different machining conditions and metal removal rates. The corner radius selected will have an impact on the surface finish and the tip life. The larger the tip radius is, the stronger the insert will be and the longer it will last. However, the larger the tool radius is, the more rigid the setup needs to be to avoid chatter at the tool tip.

Grinding carbide tools

You can grind carbide tipped tools in the home workshop but it can be a bit of a slow process. You will need a silicon carbide grinding wheel which is often called 'green grit' because the wheel is most often a green colour. Silicon carbide wheels are most often used as 60 grit for roughing and 80 grit for finishing. This is slightly finer than the 46 and 60 grit used for sharpening HSS but the silicon carbide wheels used are much softer than the aluminium oxide ones. Do not attempt to sharpen tungsten carbide with wheels meant for HSS or vice versa.

For fine finishing of tungsten carbide tips, you can use a diamond wheel (**photo 11**).

Fig. 1



11

A diamond wheel for lapping tools.

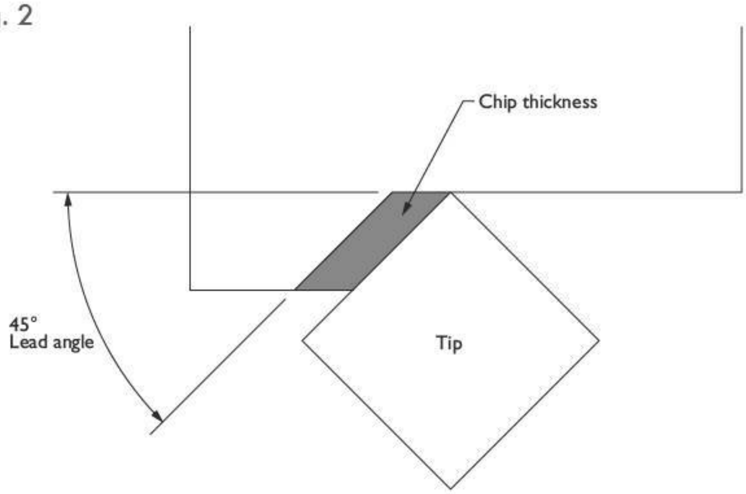
12

A double ended grinder with purpose made tool rests.

TABLE 1

Material, Cutter or Drill Diameter In millimetres	Carbon Steel Stainless Steel Alloy Steels	Cast Iron	Phosphor Bronze Gunmetal	Mild Steel	Copper Hard Brass	Aluminium Soft Brass Nickel Silver
	15 Metres Per Minute 50 Feet Per Minute	18 Metres Per Minute 60 Feet Per Minute	24 Metres Per Minute 80 Feet Per Minute	30 Metres Per Minute 100 Feet Per Minute	45 Metres Per Minute 150 Feet Per Minute	60 Metres Per Minute 200 Feet Per Minute
250	19	23	31	38	57	76
225	21	25	34	42	64	85
200	24	29	38	48	72	96
175	27	33	44	55	82	109
150	32	38	51	64	96	127
125	38	46	61	76	115	153
100	48	57	76	96	143	191
75	64	76	102	127	191	255
50	96	115	153	191	287	382
25	191	229	306	382	1461	764
19	251	302	402	503	754	1006
16	299	358	478	1902	896	1194
12	398	478	637	796	1194	1592
10	478	573	764	955	1433	1911
8	597	717	955	1194	1791	2389
6	796	955	1274	1592	2389	3185

Fig. 2



13

A hand held diamond lap.

These wheels are impregnated with diamond and will leave a smooth lapped finish but they are only suitable for removing very small amounts of metal. The double-ended grinder in **photo 12** was seen at a model engineering exhibition a few years ago (I think it was Harrogate). It is labelled HSS at one end and carbide at the other. The tool rests that are fitted are ideal for lapping carbide tooling as well as HSS tooling. The rests present the tool to the diamond wheel at the correct angle for lapping the cutting edge to a fine finish.

You can also use a hand-held diamond lap (**photo 13**) for finishing the cutting edge of both tungsten carbide and HSS cutting tools.

CUTTING TOOL PRINCIPLES

Feeds and speeds

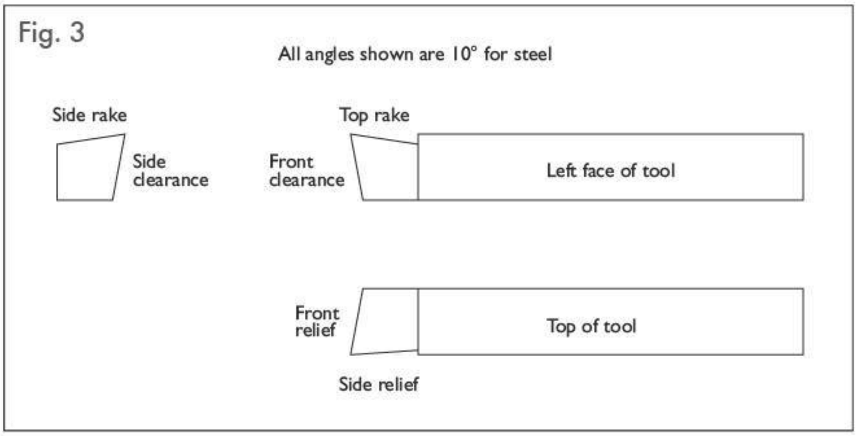
Feed is usually given as thous per rev. So, a feed of 5 thou per rev means that for every revolution of the material, the tool is feed 0.005 along or across the workpiece. A feed of 0.001 to 0.005 thou per inch (0.025 to 0.125mm) is suitable for use in the home workshop. Of course, if you have a larger lathe with more power, a heavier feed can be used.

Table 1 gives the speed for a HSS tool turning steel bar in a small lathe. I usually double these speeds for carbide although in industry they would normally be four or five times the HSS speed.

The lead angle

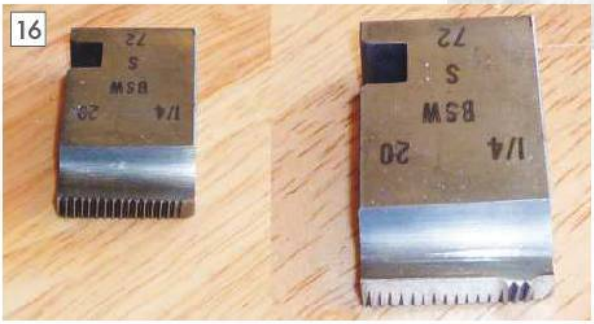
The lead angle of a turning tool is the angle at which the side of the tool approaches the work (**fig 2**). Given a constant feed, say 0.005 thou per rev, the thickness of the chip being removed will vary by approximately the cosine of the lead angle. So, a lead of 90 degrees (no angle) at a feed of 0.005 per revolution will give a chip thickness of 0.005 thou while a lead angle of 45 degrees will give a chip thickness of the cosine of 45 degrees or 0.707 of 0.005 thou = 0.0035. This

Fig. 3



A typical HSS turning tool for steel, note the top rake.

A tool for brass does not have top rake.



A die head chaser suitable or thread cutting.

increased lead angle means we can take a deeper cut for a given amount of power with less loading of the machine or the cutting tool.

Turning tool angles

A turning tool is basically a wedge that is forced into the material being turned (see the enlarged wooden tool shapes on page 31 in *MEW* 215, the May issue). The tool requires grinding to certain angles to make this wedging action easier to happen. For a normal right or left-hand HSS turning tool, angles of 10 degrees will suffice (**fig 3**). For steel the top of the tool should also be ground back on a 10 degree angle (**photo 14**) while on brass, the top of the tool should be left flat (**photo 15**).

Screwcutting

Another useful HSS tool is a screwcutting tool. For screwcutting I use a HSS chaser as sold for use in Coventry die heads (**photo 16**). These are available cheaply on eBay and Tracey Tools also sell them. Just carefully grind most of the teeth away leaving two or three teeth to chase the threads with. You will be surprised how simple screwcutting can be.

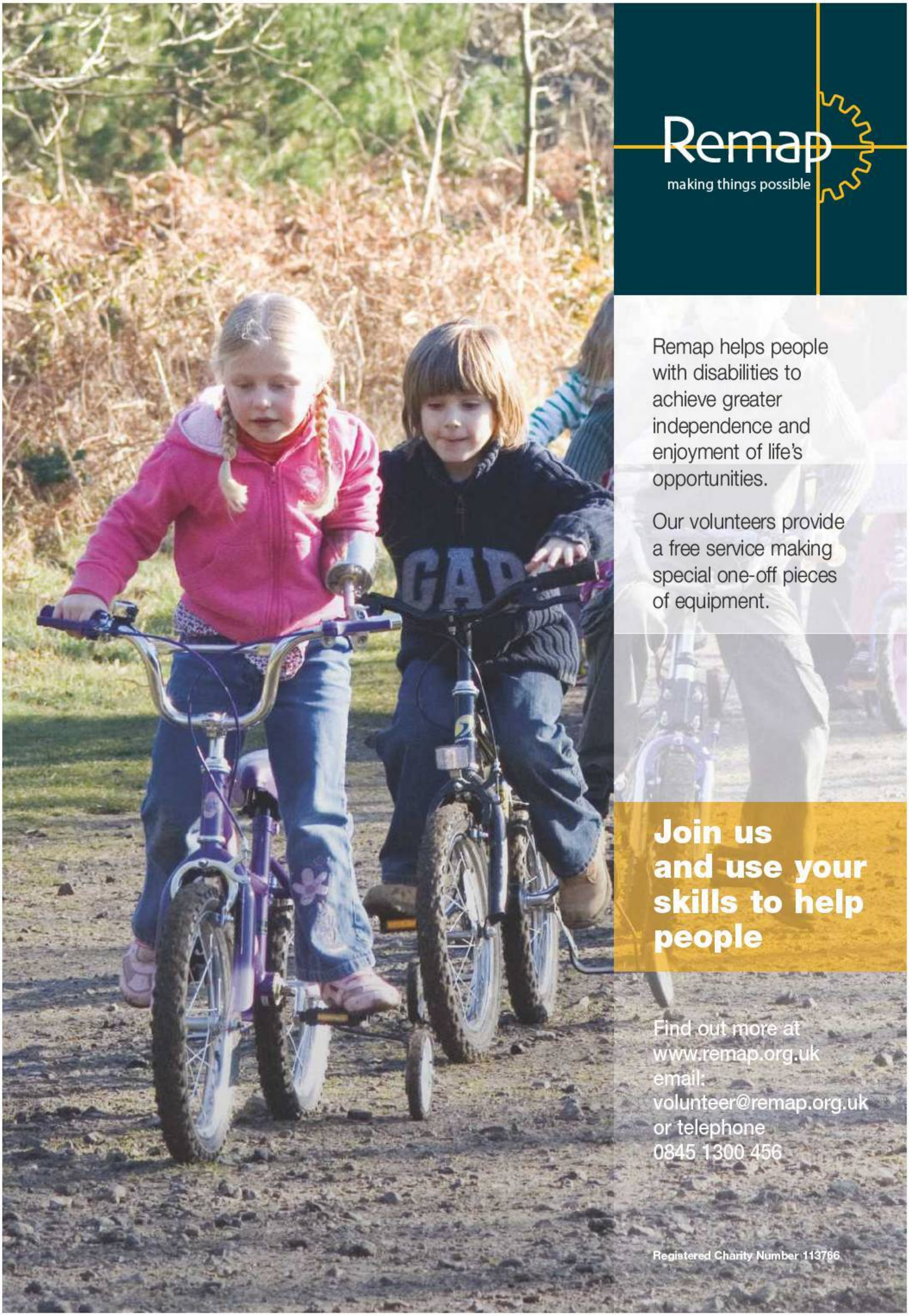
Setting the tool's centre height

It is important that the lathe tool is set to the correct centre height or it may dig in or chatter, Quick change tool holders allow the tool to be set quickly to the required height as well as allowing the tool to be changed quickly.

To be continued...

COMING UP...

Next time we will make a simple gauge for checking that the tool is set to the lathe centre height and take our first look at the milling machine.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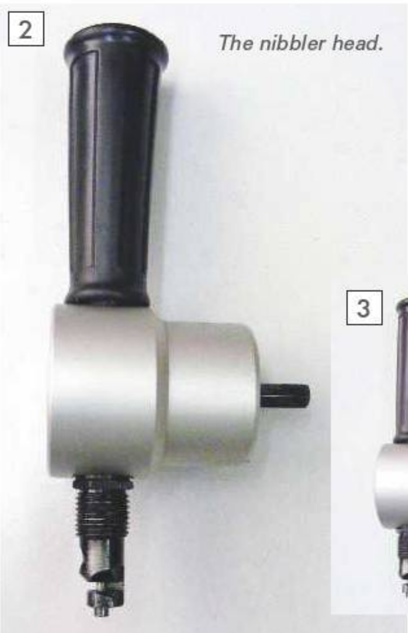
Improvements to a nibbler

Michael Cox discovers that these tools can have a useful role in the workshop.

I rarely have to buy sheet steel because I recover the steel panels from defunct domestic white goods (washing machines, dishwashers, dryers etc). Invariably these panels have turned up edges and removing the edges to provide a flat sheet can be a real pain. In the past I have tried using aviation snips but the problem with these is that the edge does not want to bend and this makes advancing the snips into the material difficult and furthermore since the edge is stiff the sheet is forced to bend and this tends to distort the sheet as it is cut. The snips tend to give a sharp, ragged edge to the cut out sheet. Another technique that I have used is to put a metal-cutting abrasive disc into a portable circular saw and use this to cut the edges of the panels. This works well but the discs do not last very long and the operation creates a lot of noise, abrasive dust and sparks. Both of these methods are quite slow and a progress rate of a few metres an hour would be typical.

One day when browsing the RDG Tools (**ref. 1**) site I spotted a nibbler attachment for an electric drill. This could cut sheet steel up to 1.8mm thickness and the speed of cut claimed was an impressive 2 metres per minute. Furthermore it was claimed that there was very little edge distortion. This sounded like the ideal solution for cutting the edge off of domestic appliance panels. The nibbler attachment was very reasonably priced at around £20 and I placed an order.

The nibbler kit.



The nibbler head.

The nibbler attachment

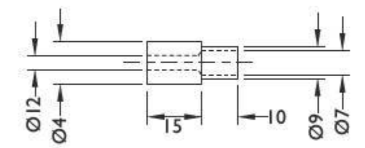
The nibbler was supplied in a good steel box, see **photo 1**. At the bottom of the photo is the nibbler head. This is double ended and both arms can be used for nibbling. In use one arm is normally covered by the handle shown on the right. Above the nibbler head is a spanner/hex key and above that is a replacement cutter rod. Between the nibbler head and the handle is a spare cutter arm. Also supplied is an attachment for cutting circles (not shown). The nibbler works by having a reciprocating cutter that nibbles out small crescents from the sheet leaving a 4mm wide kerf. The nibbler head is shown in **photo 2**. A portable electric drill provides power for the unit that simply attaches to 7mm hex drive shaft at the rear of the head using the drill chuck. Note that the metal being cut passes into the slot in the front of the nibbler arm and the reciprocating cutter cuts on the up stroke of the cutter rod against the solid support of the black threaded arm. The nibbles that are cut out exit via a small hole in the arm. The parts below the slot are just to provide support for the reciprocating cutter.

The first test was made on a rather thick panel (0.9mm) top off of an old dishwasher. I drilled a 12mm hole in the corner, inserted the tool and then started cutting using the turned up edge as a cutting guide. It sliced cleanly and quickly, with no distortion at the edge, through the sheet steel. It took less than two minutes to go right round the periphery of a 600mm square appliance panel. Needless to say I was impressed.

The tool as supplied has a few problems. The head is not fixed to the electric drill except by the drive shaft. This means that the head can swivel on the drive shaft and this is a little disconcerting in use. If the head were rigidly fixed to the drill it would be much easier to control. In addition the distance between the drill handle and the nibbler is quite large because of the length of the chuck. Because of the reciprocating action of the cutter there is some vibration in use. The cutter can also cut sideways a little, as well as straight ahead. Both of these factors make it difficult to make straight cuts freehand and some sort of guide is necessary for accurate cuts. A further problem, not related to the performance of the nibbler, is that it produces thousands of small crescent shaped pieces of metal during the nibbling process. These get everywhere and they embed in the floor and in your shoes.

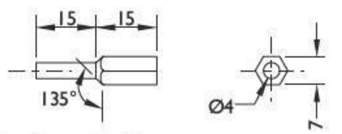
I decided to address some of the problems. The first modification was to fix the nibbler head rigidly to the electric drill, see **photo 3**. This makes it much easier to use as a hand held tool. The second modification was to design a clamp that

The hand held nibbler.



The Socket Blank

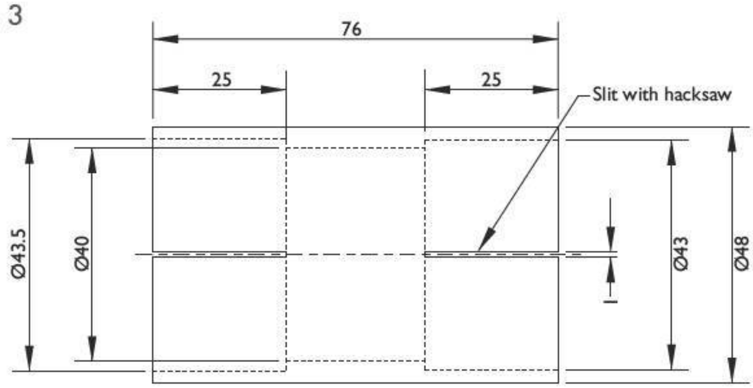
Fig. 1



The Form Tool

Fig. 2

Fig. 3



The Connecting Collar

would hold both the drill and nibbler firmly to a baseboard and then fix a table that would fit over the nibbler head. This modification is shown in **photo 4**. With this arrangement it is possible to fix a fence to the table and this then permits accurate cutting of sheet materials.

The hand held nibbler

In order to reduce the length of the unit I decided to eliminate the drill chuck and dedicate an electric drill to the nibbler. A basic variable speed, reversible drill is very cheap nowadays and I purchased one from Argos at a cost of £9.99 for use with the unit. The drill chuck was first removed from the drill. These electric drills are reversible so the chuck is screwed into the shaft of the electric drill with a right hand thread and it is then secured in place by a left hand screw through the drill chuck itself. This arrangement prevents the chuck unscrewing when it is running in reverse. The left hand screw was removed by opening up the chuck jaws to their maximum extent and then unscrewing it. Once this was removed the chuck can be unscrewed from the drill by inserting the chuck key and giving it a tap with a hammer in the required direction to unscrew it. Once loose the chuck was then unscrewed by hand. The chuck had a ⅜ inch 20 tpi male thread.

To replace the chuck I made an adaptor that screwed onto the shaft of the electric drill. One end was threaded ⅜ inch x 20 tpi to fit the drill and the other end had a 7mm female hex socket to fit the drive shaft of the nibbler head. It is important that the screwed end is coaxial with the socket since otherwise much vibration would ensue. At the time I did not have any broaches to make the 7mm hex socket and I pondered for some time on how to make this component. The solution that I developed was to form the socket.

First the socket blank (**fig 1**) was machined from 12mm round EN1A mild steel. The next step was to make the form tool (**fig 2**) from a length of 7mm mild steel hex bar. The socket blank was heated up to bright red heat and allowed to cool slowly to anneal it. When cold the socket blank was oiled internally and the form tool forced into the socket until it bottomed using the bench vice. The formed socket, with the form tool, was then chucked in the three jaw chuck of the lathe by the formed hexagon socket end ensuring that the chuck gripped across the flats. The protruding round end was then skimmed to clean it up and then turned down to ⅜ inch diameter for a length of 12mm. A run out groove was formed adjacent to the shoulder using a parting tool and the ⅜ inch section then single point threaded at 20 tpi until it was a good close fit in the electric drill shaft. Making the socket in this way ensures that the hex socket is concentric with the screw thread. The piece was removed from the lathe and the former pulled out. If this is difficult then place the socket end on a flat surface (i.e. the top of the bench vice) and tap the hex socket 'across the flats' with a light hammer in each of the three possible orientations and the form tool should just pull out. The socket should be tested at this stage to ensure it is a good sliding fit on the drive shaft of the nibbler head. **Photograph 5** shows the new hex adaptor screwed into the electric drill.

To fix the nibbler head rigidly to the electric drill I used a piece of thick walled 48mm diameter rigid plastic tube to make a connecting collar (**fig 3**). I am not sure where this came from but it had been floating around the workshop for years. A 76mm piece was chucked in the lathe and the interior bored out at one end to accept the shoulder of the electric drill and at the other end to accept the shoulder of the nibbler head. Note that the bored dimensions shown in fig 3. were correct for my nibbler head and drill but I would advise that these are only a guide. The bored out ends were slit using a hacksaw.

Assembly of the hand held nibbler

Next the unit was assembled. The hex socket was screwed into the electric drill shaft. Two 50mm diameter jubilee clips were slipped over the plastic connector collar and the nibbler head was inserted in one end and the electric drill in the other. The two jubilee clips were positioned and tightened to clamp the parts in place, as shown in photo 3.

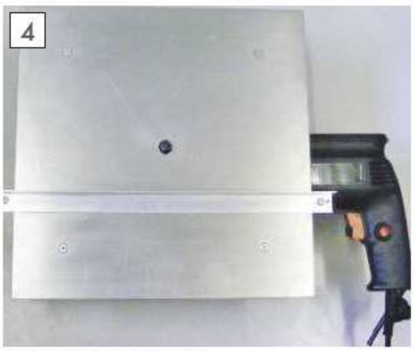
The nibbler table

The nibbler table was constructed from four main parts: a baseboard, a bracket to hold both the electric drill and the nibbler head, four pillars to support the table and the table.

The baseboard was a piece of solid oak 20 x 300 x 300mm cut from an old kitchen cabinet door. A piece of 18mm plywood or MDF would be a good alternative for this component.

The bracket (**fig 4**) was made from an aluminium casting although it could equally well be built up from pieces of flat stock. A pattern was built up from Styrofoam blocks and a sprue was attached. The pattern was buried in loose sand and molten aluminium poured into the sprue. (See *MEW* issue 181 for more details of this lost foam casting process). The finished casting, after removal of the sprues, is shown in **photo 6**.

The casting was then mounted in the mill vice ensuring that it was accurately vertical and the bottom surface machined flat with a fly cutter (**photo 7**). Using the



The nibbler with table.

The hex adaptor screwed into the electric drill.

The bracket casting.

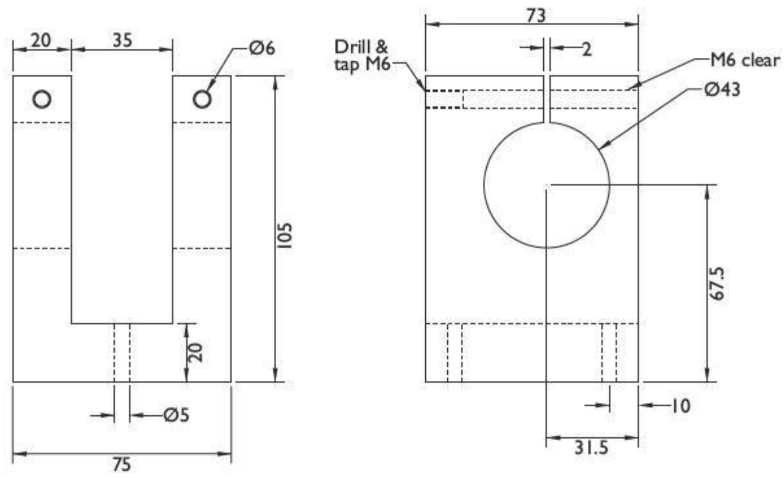
Flycutting the bracket base.

Boring the bracket.

flat bottom as a reference plane the casting was then marked up for the large holes. These holes were originally cut out with a 38mm bi-metal hole saw to remove most of the metal and then set up in the mill vice for boring with a piece of 3mm MDF underneath it. The holes were then bored out to the required diameter using a long boring bar mounted in a boring head, see **photo 8**. Note the size of the hole in fig 4 is only nominal and I advise that the actual dimensions of the shoulder on the drill and nibbler head should be measured and the hole sizes adjusted accordingly. The holes should be bored using a long boring bar that will enable both holes to be bored without removing the bracket from the vice. This will ensure that both holes are concentric. The holes for the clamp screw studs were then drilled out. Initially the bracket was drilled out all the way through with a 5mm long series drill. This was drilled out further with a 6.5mm drill leaving about 12mm of the 5mm hole for tapping. The 5mm section was tapped M6. The two 5mm holes in the base were marked up and drilled with a 5mm drill. The final machining operation on the bracket was to slit the casting using a 2mm slitting saw.

The clamping studs were just two 85mm lengths of M6 studding. These were screwed into the casting and locked in place on the threaded side of the casting with M6 washers and nuts. Two more washers and nuts were screwed onto the other side of the studs as clamping nuts. The bracket was tested to ensure that the drill fits on one side and the nibbler head the other and that tightening the clamp nuts locks both in place. The assembly was then dismantled and the bracket cleaned, degreased and painted. The finished bracket is shown in **photo 9**.

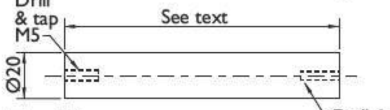
The nibbler head was clamped vertically in the bracket and this assembly was placed on the baseboard. The height of the



The Bracket

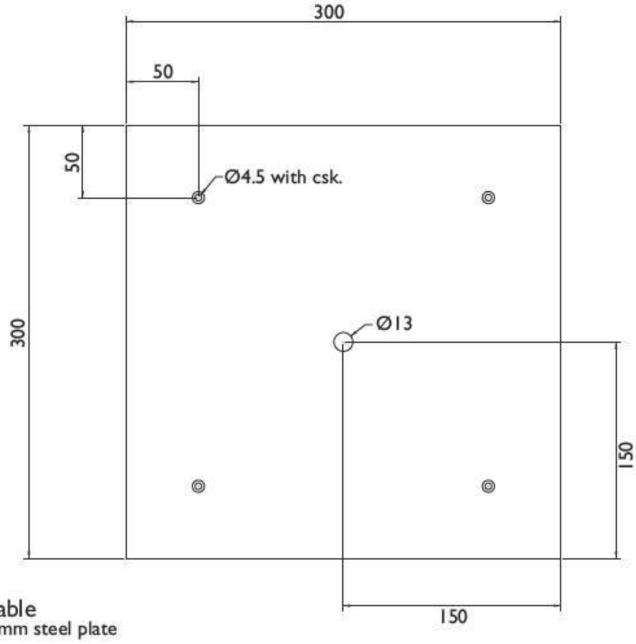
Fig. 4

Fig. 5



The Pillars
Mat'l: Ø20mm mild steel, 4 off

Fig. 6



The Table
Mat'l: 3mm steel plate

The finished bracket.

The finished nibbler table.

The underside of the nibbler table.

bottom of the cutter slot was measured with a height gauge. This height minus 3mm, the thickness of the table, is then the length that the support pillars must be cut. It is important that the height of the bottom of the slot is at or very slightly above the height of the table. If it is below the table then the reciprocating cutter will cause the table to vibrate excessively.

The pillars (**fig 5**) were made from 20mm round steel bar. The end was faced off and drilled out 4.3mm for a length of 15mm and tapped M5. It was next parted off 0.5mm longer than required. The pillar was then re-chucked and the parted off end faced to the required length. This end was drilled out 3.3mm for a distance of 17mm and then tapped M4. Four such pillars were made.

The table (**fig 6**) was made from a 3 x 300 x 300mm piece of steel plate. This was purchased cut to size. On receipt it was found to be flat and square and no further preparation other than to file and smooth the edges and corners was required. Four 4.5mm holes were drilled 50mm from each two adjacent edges at each corner. These were then countersunk to accept M4 countersunk socket head screws. In the centre of the plate a 13mm hole was drilled. This was not easy because the sheet would not fit in the throat of my bench drill and I had to drill this hole in stages freehand with the plate clamped in the bench vice. The hole had to be cleaned up a bit with a round file and burrs were removed with a counter sink drill bit.

Assembly of the nibbler table

The table was placed on the on the baseboard and clamped in place using toolmakers clamps. Using a portable drill with a 4.5mm drill the positions of the support pillars were spotted through onto the baseboard. Before unclamping the plate the front of both plate and baseboard were marked using a marker pen. This is to ensure that the two parts are always assembled in the correct orientation. Once separated the spot marks on the baseboard were drilled through 5.5mm on the pillar drill. The pillars were then attached to the baseboard using M5 x 30mm screws with a penny washer under the head. The nibbler head was clamped vertically in the bracket and this assembly was placed on the baseboard with the nibbler towards the front of the baseboard. The table was lowered so that the nibbler head protruded through the table and the small holes in the table were located over the pillars. The table was secured with four M4 x 16mm socket-head countersunk screws. The bracket was swivelled to line up the edges with the edges of the baseboard. The position of the bracket was marked onto the baseboard by drawing around it with a scriber. The table was removed and the bracket carefully positioned inside the scribed lines on the baseboard and the bracket securing holes spotted through onto the baseboard using a transfer punch. The punched positions were then drilled through with a 3mm drill and the bracket secured into position using 4 x 30mm wood screws. The table can then be replaced and secured into position with the screws.

The completed assembly is shown in **photo 10**. As a finishing touch four rubber buffer feet were added to the underside of the table, see **photo 11**.

The table fence

The table fence (**photo 12**) is designed to provide a straight edge that can be clamped to the table as a guide when cutting.

The straight edge was made from a 343mm length of 1.5 x 18 x18 aluminium angle.

The two clamps were made from two pieces of steel 6 x 16 x 25mm. The edge was milled down as shown in **fig 7**. and the 3.3mm tapping hole and the 2.5mm pin hole were drilled. The clamp was then clamped to the end of the aluminium straight edge and the holes spotted through. The 3.3mm hole in the aluminium was enlarged to 4.5mm and the 2.5mm hole to 2.6mm. The clamp was then tapped M4. A piece of thin steel rod (actually a wire nail) was machined down on the lathe to be a force fit in the 2.5mm hole and this was pressed into the clamp.

These operations were then repeated for the other clamp at the other end of the aluminium straight edge. The clamps are held to the straight edge by two socket head M4 screws with a washer and a spring washer under the head. The pin prevents the clamp from swivelling.

Conclusions and use

The hand-held nibbler is much more convenient than the standard arrangement in use and it is very easy to use for cutting large sheets.

The table and fence arrangement permits accurate cutting of intricate shapes from sheet materials. Where accurate, distortion free cuts are required it provides a viable alternative to a much larger and more expensive shear.

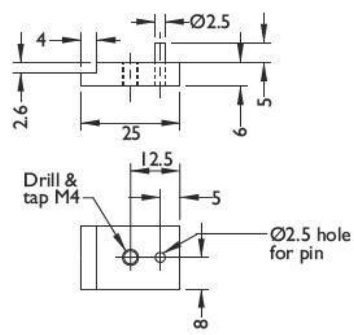
It is important to ensure that the nibbler is well lubricated during use. I usually oil the reciprocating cutter before use and also use a smear of oil along the cutting line.

I have had the nibbler head for about three years and it has proved totally reliable. It must have cut more than a hundred metres of sheet steel in this time and it is still cutting well using the one end of the original cutter rod. I still have the other end of the cutter rod to use as well as the replacement cutter rod. ■

REFERENCE

1. RDG Tools, 01442 885 069
www.rdgtools.co.uk

The table fence.



The Fence Clamp
4 off

Fig. 7

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■ Harrison L5 9 inch, travelling steady, fixed steady, 11 inch faceplate, 15 inch faceplate, 8 inch Pratt ind. 4-jaw, 7½ inch Pratt 3 Jaw steel body, new boring table with nut. Chucks are 1½ inch x 6TPI, fixed 4 way toolpost. **T. 01237 441765. Bideford.**

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SWARF STOPPERS

Looking at photo 57 in Pt 4 of David Piddington's Instrument Vice article (*MEW* 212), and reading about the problems of swarf getting into the 3-jaw chuck, this solution occurred to me:

1) Go to a tyre repair place and ask if you can have a couple of ruined inner tubes.

2) Cut a circle out that will cover the chuck in question, plus a bit, and an undersized hole in the middle.

3) Stretch the inner hole down over the workpiece and, presto, an apron to protect the chuck without getting in the way (see below). Make sure the cutter won't come into contact with the rubber during the course of the work.

Once the job is finished, brush the apron off into a scoop, then remove from the workpiece.

The rubber is very stretchy and half a dozen or so of these with different sized holes in the centre (even square or rectangular holes) should cover most work.

I always have some inner tube lying around as I find it useful for all sorts of jobs. I even used strips as a makeshift drive belt for my miniature Flexispeed lathe's foot treadle drive until I was able to get a leather belt. I got mine from a truck tyre repair place. They pointed me out the back where they were scattered among a mountain of dead tyres.

Hope this is helpful, and is something I'll have to bear in mind if I ever set up a vertical chuck. Ah, it could also be put over stock in vices to keep swarf off your parallels etc.

Duncan McHarg

David Piddington, replies: *I would like to thank Duncan McHarg's excellent idea of using old motor inner tube rubber. I admit my use of kitchen roll was a quick fix stop gap solution (puns intended) but from my motorcycling days when bikes didn't have tubeless tyres I had such an old tube and arranged a swarf catcher as in the attached image. It's not perfect but it helps in keeping tiny particles from the slideways.*

PAINTING PATTERNS

I refer to the Everyday Engineering for Absolute Beginners article in *MEW* 208. Generally, I pretty much agree with what Mr. King has to say about patterns and foundry work, particularly the bit about asking advice from the foundry before setting out to make a tricky pattern with maybe 5 or 6 cores

Later, however he says that patterns are traditionally painted red where the core prints are, but black for the main body of the pattern. This hasn't been my experience at any of the several UK commercial foundries I have used over the last 40 years, where normal practice is red for the main body of the casting, which is going to be used 'as cast', black for core prints, and yellow on faces which are going to be machined.

I did some checking on line, and this seems to be the norm, although I do have a book from the 1940s which uses the same colour code as Mr King. Probably the best thing is to check with the foundry which you are going to use, and use the same coding system as they do. I admit I don't use the yellow at all, just the red and black. I paint the core boxes black as well so it's clear what they are. Believe me, it is important to the moulder to have the core prints clearly identified, he may be used to trying to work out what people want, but it doesn't mean that he likes doing it, and you are paying for his time. If he gets it wrong because you haven't identified the core prints, then it's not his fault and you will be paying for a new casting. I've got about 30 or 40 patterns now, from various projects, each pattern has a number, recorded in a notebook, and written on the pattern with a Tippex pen.

If it's a two part pattern, then it says 'Pattern No. xxx Part 1 of 2 etc. The core boxes are labelled 'Pattern xxx Core box 1 etc. and I also put the core number on the corresponding core prints on the pattern. Tippex is pretty tough stuff and doesn't seem to rub off during moulding, although I admit most have only been used once or twice.

If you are only doing one or two patterns, then yes, polyurethane paint will be OK, but if you are doing a number, it's worth getting some of the proper pattern makers paint; it seems to strip better from the mould. I use John Burns Patterncoat, the downside being that it's only available in 2½ litre tins, and is pretty expensive stuff. It's available (or was a couple of years ago) in traditional form containing lead, or in a lead free version. I have to say the leaded version covers much better; you only need two coats at most, but probably three or four for the lead free paint.

Richard Wilson
Birmingham

PI AND SCREW THREADS

I have read with interest the recent excellent articles by Brian Wood on the subject of gearing ratios for thread pitches and cutting D.P. worms – among other 'threading' possibilities. Of possible interest for this series of articles is a personal 'hobbyhorse' of mine; that is also using some of the possibilities of a built in screw-cutting gearbox, viz:-

As in the articles the basic requirement for cutting Imperial DP worms and also Hobs is a lathe with a (4, 6, or) 8 TPI leadscrew and a screw-cutting gearbox with a reasonable selection of normal pitches. I added a set of four gears that initially will probably have to be bought. These are 25t, 50t, 51t, 77t (fitted as 77 x 50 / 51 x 25 = 1:3.1416). These gears replace the usual 1 : 1 ratio between the mandrel and reverse gears and the gearbox input when using the gearbox for its designed purpose. Incidentally in reverse that ratio gives 1/3.1416 or 'one pie–th', this also has uses.

The method is to use a mindset that recognizes the gearbox/leadscrew combination for what it in effect is - a variable pitch leadscrew. If this is then combined with a gear drive from the Mandrel to the Gearbox that provides a ratio of 1 : 3.1416 (and in most cases I use power input to the leadscrew not the Mandrel), then what we have achieved is any pitch of 'threads per inch' set on the gearbox is spread out to become a 'DP' pitch on the work.

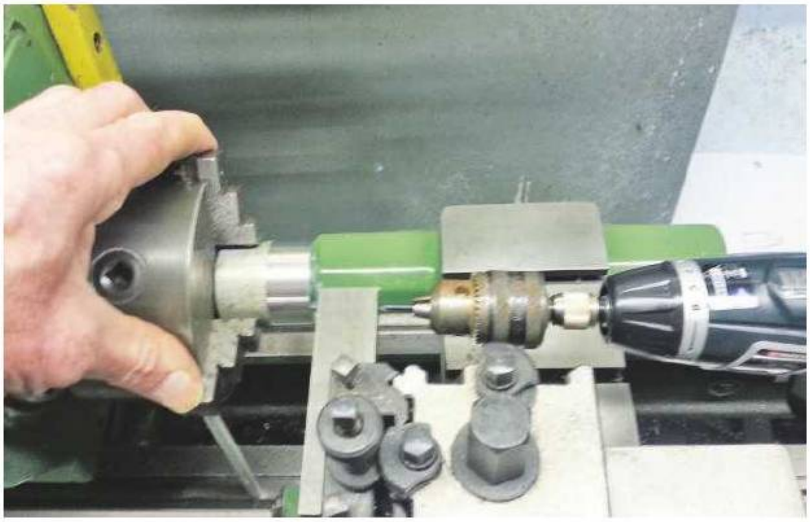
So if we take for example: set 16 Threads per inch on the gearbox and multiply the input drive by 3.1416. The leadscrew now moves the cutter by 16 tpi x 3.1416, which is the same pitch as '16 per inch of diameter'; the thread of 'rack form' cut will be 16 DP. 16TPI = 0.0625 inch pitch, multiplied by 3.1416 = 0.19635 inch – right on to 5 decimal places. BUT DO NOT DISENGAGE THE LEADSCREW HALF NUTS DURING THE OPERATION!

Some of the larger (and more expensive) Chinese and Taiwanese 'geared head' lathes sold here in New Zealand have this 'pi' factor for cutting DP worms built in as basic by means of some sort of differential or epicyclical mechanism, which is what gave me the idea in the first place. I have saved others doing the weeks of conjugate fractions with 'Brocot's' tables to get those four gears!, six gears will give you if you must, an accurate 'pi' to about 12 places – but you can work it out!.

I started on the above many years ago because my lathe did not have the standard fixed set of gears, but instead like many modern lathes has a semi-fixed ratio between mandrel and 'Norton type' gearbox. This meant that some of the pitches available meant a change in that ratio for which gears were supplied. The combination with the gearbox making the tables of gears for cutting DP worms useless as I did not have the gears.

I do not know if any of the above will work on metric gears as I have not given it any thought, perhaps one of the 'Ancient Wise Ones' of the hobby would care to comment.

Peter J King.
Christchurch, New Zealand



SIMPLE INDEXING

It was a nice article by Richard Rex; he required three holes on a 0.92 inch PCD

Another method I have successfully used that could be a useful tip for anyone with limited equipment is to:

1) Face and turn the component in the lathe using the 3 jaw chuck.
2) Then isolate the lathe for safety.
3) A length of mild steel, 6 x1 x ½ inch is mounted on its side in the tool post and protruding forward to clear a small battery drill, having pre drilled a hole though one end for a pilot hole. (So the hole is in line with lathe axis).
4) Align the hole on the centre height and on the centre line, using a centre in the tailstock.
5) Taking up any backlash, wind the cross slide back half the required diameter.
6) The chuck jaw can now be used to index 3 holes on the PCD using a suitable length of stock as a stop, from the lathe bed or setting up a magnetic base in the swarf tray.
7) Drill each hole using the pre-drilled hole as a guide/drill bush with the battery drill.
8) The holes can then be opened up to the required diameter using a pillar drill.

A 4 jaw chuck would enable four holes to be equally spaced on a component. Many thanks for a well-produced magazine.

David Shore

LINSEED OIL

In his very interesting and useful article in issue 210,Fred Maddalena discusses the Chemical Colouring of steel and mentions the use of linseed oil and boiled oil.

Linseed oil is to all intents and purposes an innocuous material to have around, but it does have one bad property. If a cotton rag is used to mop up a spill, crumpled up and thrown in a bin, there is danger of a fire. How long this takes depends on ambient temperature, access to air etc but overnight to several days is about right. This behaviour is more of concern to woodworkers than metal workers because woodworkers tend to use more linseed oil and readily combustible wood shavings are also likely to be present. A friend of mine lost his garage in this way.

Boiled linseed oil was widely-used in the old-time varnishes but its only current use as far as I know is in artists paints. It consists of linseed oil which has been heated with driers e.g. lead, cobalt to increase its viscosity and hence drying rate. It is a far greater fire risk than linseed oil and its use is best avoided completely.

The vegetable oil mentioned by Mr Maddelena is less of a fire risk and as he says, less likely to release toxic fumes than hot, old motor oil.

Charles Lipscombe
Australia

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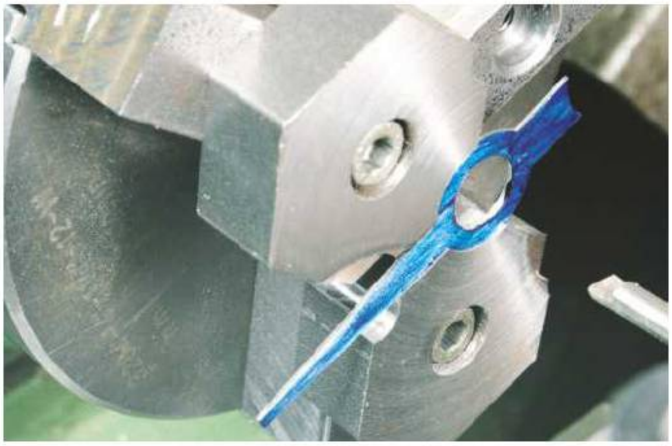
Using Two Soft Jaws

Harold Hall's **HINTS**

Harold Hall tries an unconventional approach and encourages us to consider setups that are beyond the normal, not only with soft jaws.



Harold's two-jaw technique gives just enough support for the light cuts needed to finish this tricky task.

I had made a clock hand and had to produce a hole in the centre which was then to be a very firm push fit on the boss on which it was to be fitted. Whilst the boss would of course be turned to fit the hole, the hole had to be truly round else the fit would not be secure enough.

A drilled hole in material that thin was of course not on, especially at that stage, other than maybe sandwiching it between two thicker pieces, then reaming it whilst still in the sandwich. The problem then being getting the hole central in the hand, even so, this looked liked the method I would have to use. Of course, I should have produced the hole before cutting the hand's shape, even then drilling would not be on, but the sheet could have been held on the lathe's faceplate for boring.

I did also consider using double adhesive tape to hold it to a solid faceplate with some supporting pieces added around it, but thought that in removing it, it would be easily bent. If that happened, flattening it would be next to impossible.

I also, foolishly, considered using soft jaws but obviously the two projections could not be accommodated. I noticed, however, that two jaws would wrap around the central hub by more than 180 degrees and so an idea was born. I think the photograph I have included shows the setup adequately and little more needs saying, other than that I produced the recess with the three jaws fitted, then removing one.

The situation reminded me where a group of technicians are discussing a problem, they are encouraged to say just what comes to mind, no matter how foolish, as this may spark an idea by another that solves the problem. Brainstorming I think it is called. ■

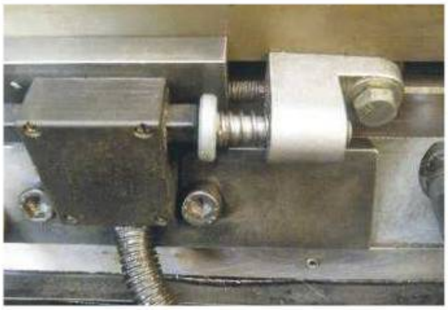
In our Next Issue

Coming up in issue 217

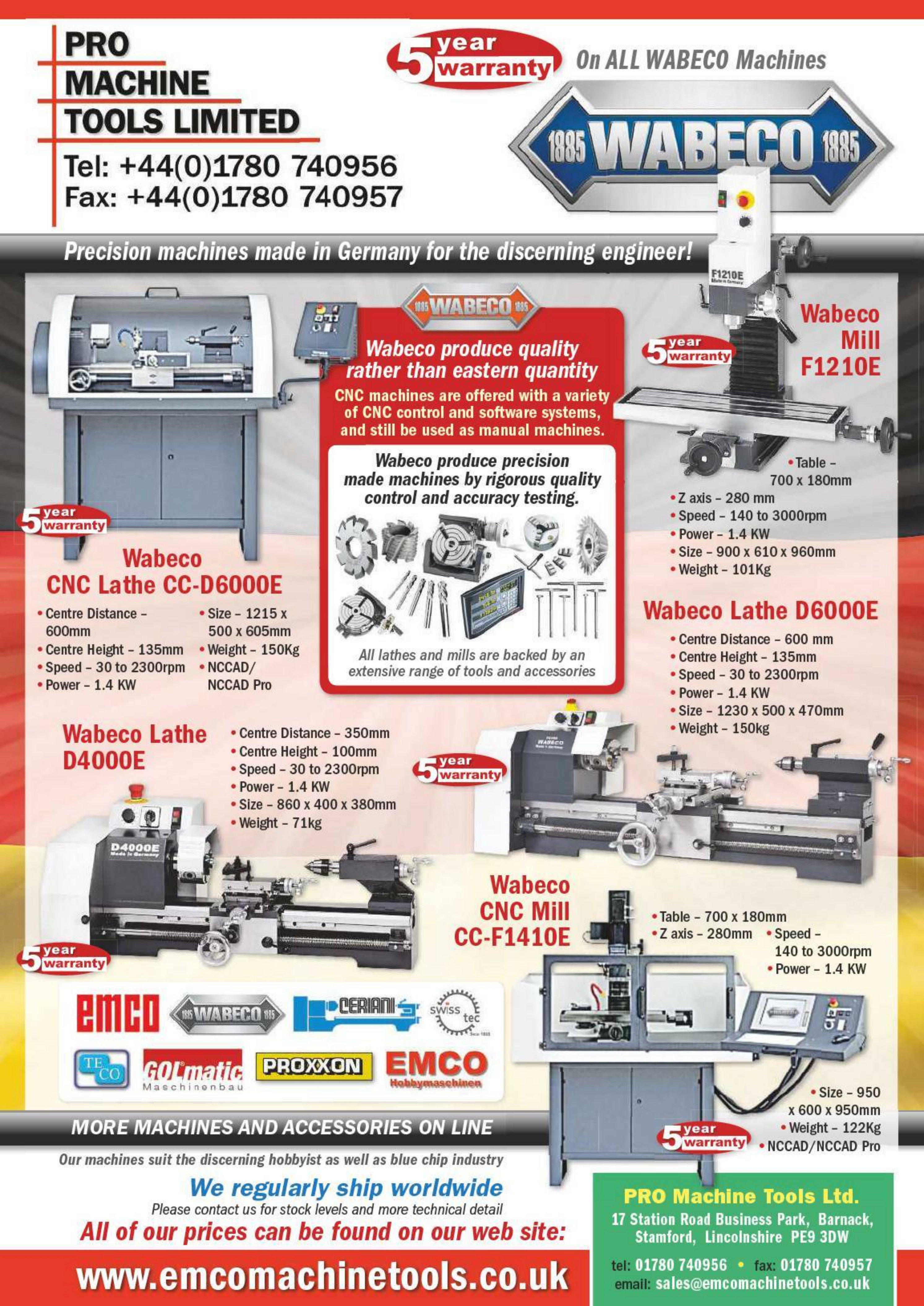
On Sale 6th June 2014

Alastair Sinclair describes how he pressed his mill to serve as a vertical lathe.

John Smith loses sleep over workholding mandrels.



Howard Jennings shows how to combine power and hard stops for a mill.



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• Centre Height – 135mm
• Speed – 30 to 2300rpm
• Power – 1.4 KW
• Size – 1215 x 500 x 605mm
• Weight – 150Kg
• NCCAD/ NCCAD Pro
Wabeco Lathe D6000E
• Centre Distance – 600 mm
• Centre Height – 135mm
• Speed – 30 to 2300rpm
• Power – 1.4 KW
• Size – 1230 x 500 x 470mm
• Weight – 150kg
Wabeco Lathe D4000E
• Centre Distance – 350mm
• Centre Height – 100mm
• Speed – 30 to 2300rpm
• Power – 1.4 KW
• Size – 860 x 400 x 380mm
• Weight – 71kg
Wabeco CNC Mill CC-F1410E
• Table – 700 x 180mm
• Z axis – 280mm
• Speed – 140 to 3000rpm
• Power – 1.4 KW
• Size – 950 x 600 x 950mm
• Weight – 122Kg
• NCCAD/NCCAD Pro
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Grinding Endmills with Radiused Edges Part 2

John Pace concludes his article for users of the Quorn T&C grinder.

The *Quorn* Tool and Cutter grinder may not be familiar to some of our readers. It was designed many years ago, by Professor Dennis Chaddock, as a versatile industrial machine that was also suited to home construction. It never went into production but very many have been made. The undeniable versatility of the Quorn comes at the cost of some complexity. In this article John Pace describes some aids and techniques that he uses to undertake some of the more challenging tasks.

A smaller grinding allowance is set as the cutter size is reduced, this obviously becomes a matter of judgement and experience. The work head is locked in position. The tilting bracket is set at 6 degrees so the cutter is tilted up toward the grinding wheel. The micrometer is removed, the workhead rotated 90 degrees clockwise, the edge of the flute lined up with the grinding wheel (stationary) and the clearance angle observed. I use a simple accessory which replaces the grinding wheel for setting up and fits in the grinding spindle as shown in **drawing 3** that resembles a faceplate, this makes this observation much easier. Ideally the face of this plate should touch along the land of the ground flute so the clearance angle will match. This can be difficult to see so I usually allow the heel to touch showing some clearance at the cutting edge. In **photo 6** the arrow indicates the leading edge of the cutter is just clear of the faceplate. This will mean that there will be a greater angle on the radiused part of the edge than the flute but the cutter will be free cutting.

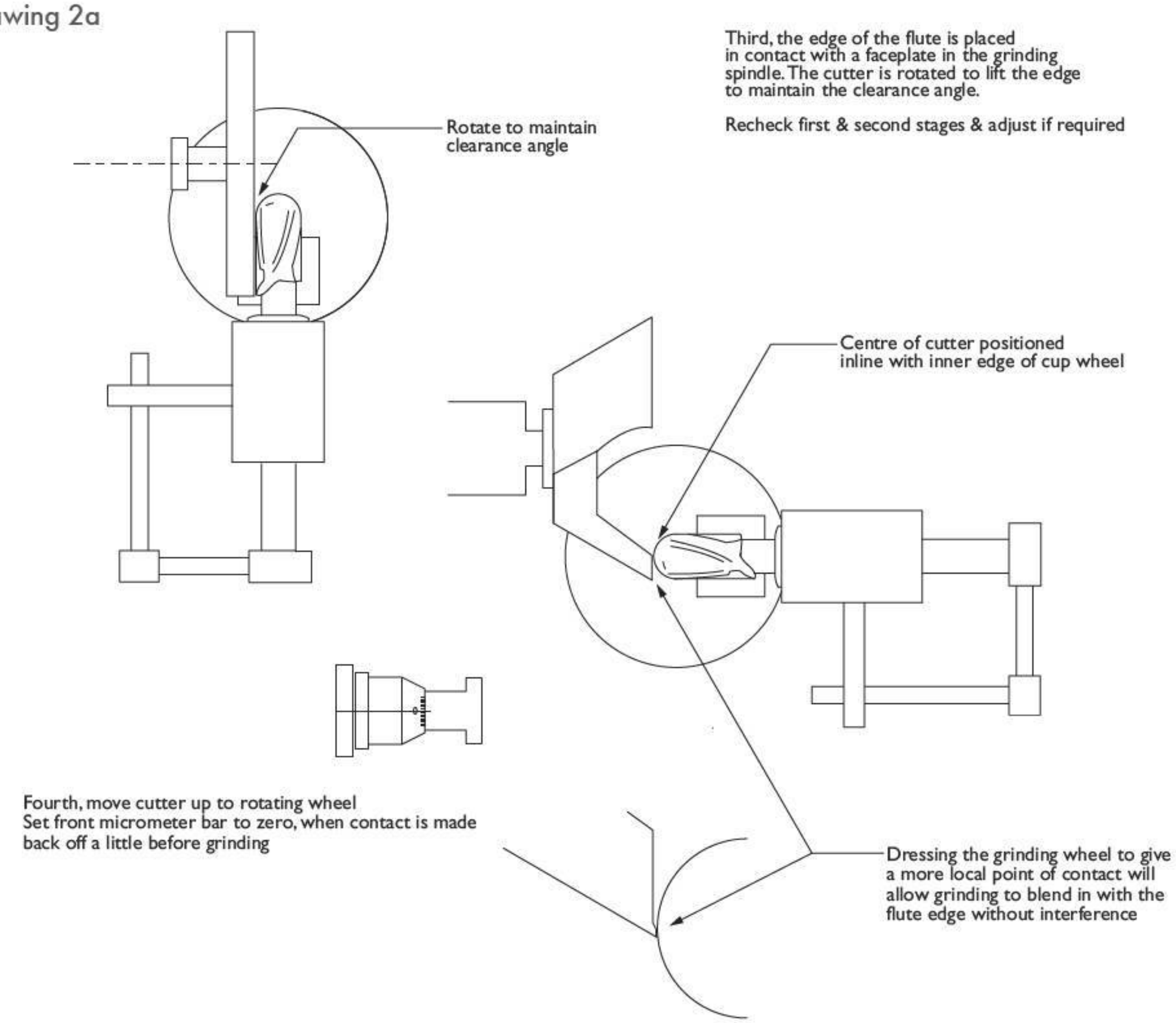
It should be noted that in the Quorn book instructions the cutting edge is set up 90 deg from the setting pin and setting the tilting bracket should give the correct clearance to the radiused part of tooth. However this is done the important thing is to have a positive clearance at these edges. Most ballnose cutters made have the radiused portion ground off parallel to the axis, if the ball nose or radiused corner follows the helical path of the flute, some variation of the finished profile can result. Providing the requirement for the finished cut is only cosmetic the only real importance is that the cutting edge has enough clearance. If there is any doubt about this a quick check can be easily made using a dti. Resting the stylus on the land, if the cutter is slowly rotated, the dti will indicate the rise of the cutting edge, which must obviously be positive all the way to the cutting edge.

If the cutter has been rotated to adjust the clearance angle as in **drawing 2a** position 3, recheck the settings again with the micrometer. The grinding wheel is fitted with its axis square to the bed bars, I set the rotating stops to grind to the centre of the cutter but leave the edge setting to 80 degrees. The cutter is carefully adjusted up to the rotating wheel as in position 4, as soon as contact is heard the front bar micrometer is adjusted to zero and grinding commences. Once the 0.005 inch grinding allowance is used up the machine is stopped and the cutter inspected. If more grinding is needed the work head and cutter will need re-setting to give more grinding allowance. Continuing to grind without doing this will run the grinding wheel into the diameter of the cutter and remove the previously sharpened flute edge. When eventually the radius is ground, the tilting bracket is adjusted to grind a secondary clearance angle, I find about 20 degrees is enough. The diameter of reground 3 flute cutters can be measured simply by using a vee block and clock gauge as seen in **photo 7.** The cutter is mounted in the vee radius and the clock gauge set zero on the shank. The vee block is re-positioned and the cutter rotated under the gauge to get the highest reading. In this case, 0.043 inch doubled to 0.086 and added to the 0.625 inch shank = 0.711 inch. This ¾ inch cutter has been ground several times on the cnc machine and still cuts as new. Shown here in **photo 8** this three-flute ¾ inch endmill was the other one of two that I bought at the same time, this one has also been re-sharpened several times. The ends of the teeth have been chipped, to save grinding the end away and making the cutter shorter it has been used to make a radiused tip cutter, the resharpened cutter is seen in **photo 9.**

Facing plate fitted to grinding head used to check the clearance angle.

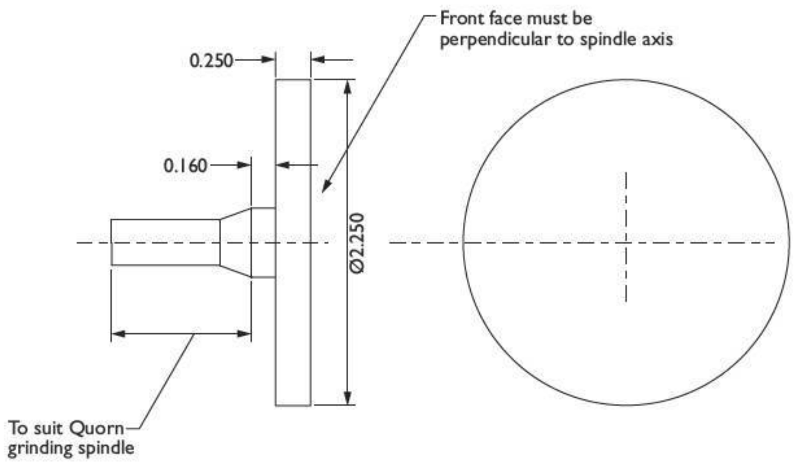
Measuring the diameter of a ground 3 flute cutter.

Drawing 2a



Setting For Grinding Ball Nose Cutters

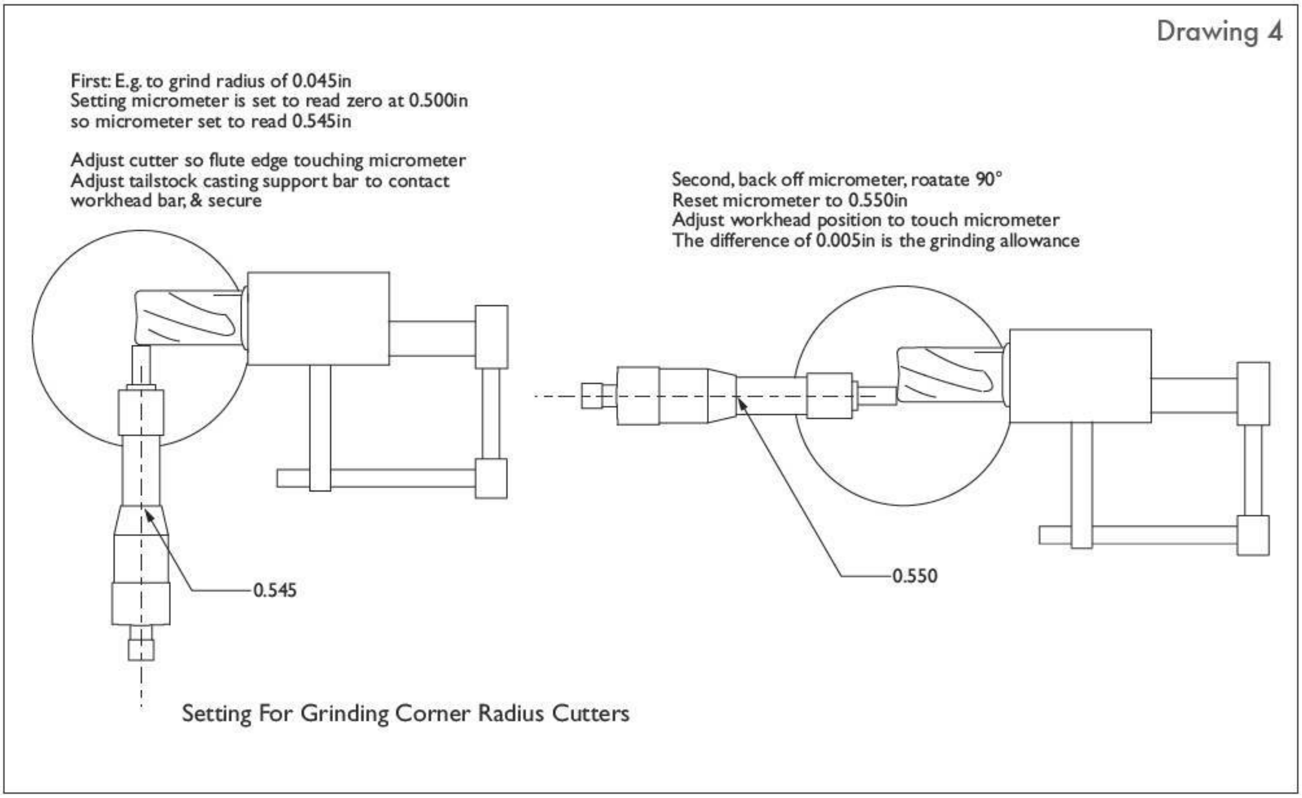
Drawing 3



Setting Faceplate Steel

The damaged edge of this cutter re-ground and used for a radiused edge.

Cutter restored and ready for use.



10

Setting cutter first position for corner radius.

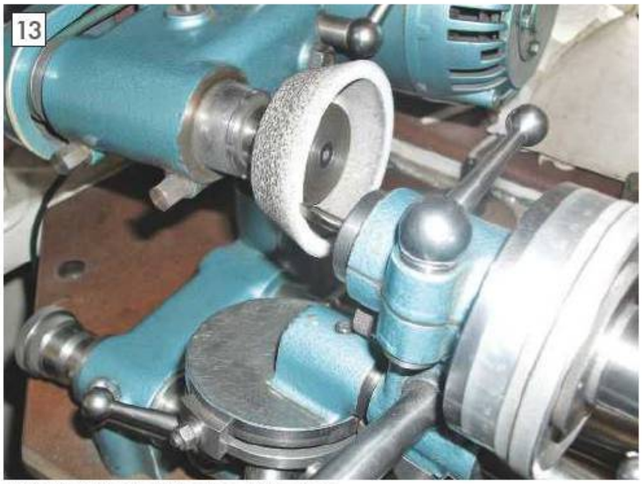
11

Setting the position of the cutter grinding allowance.

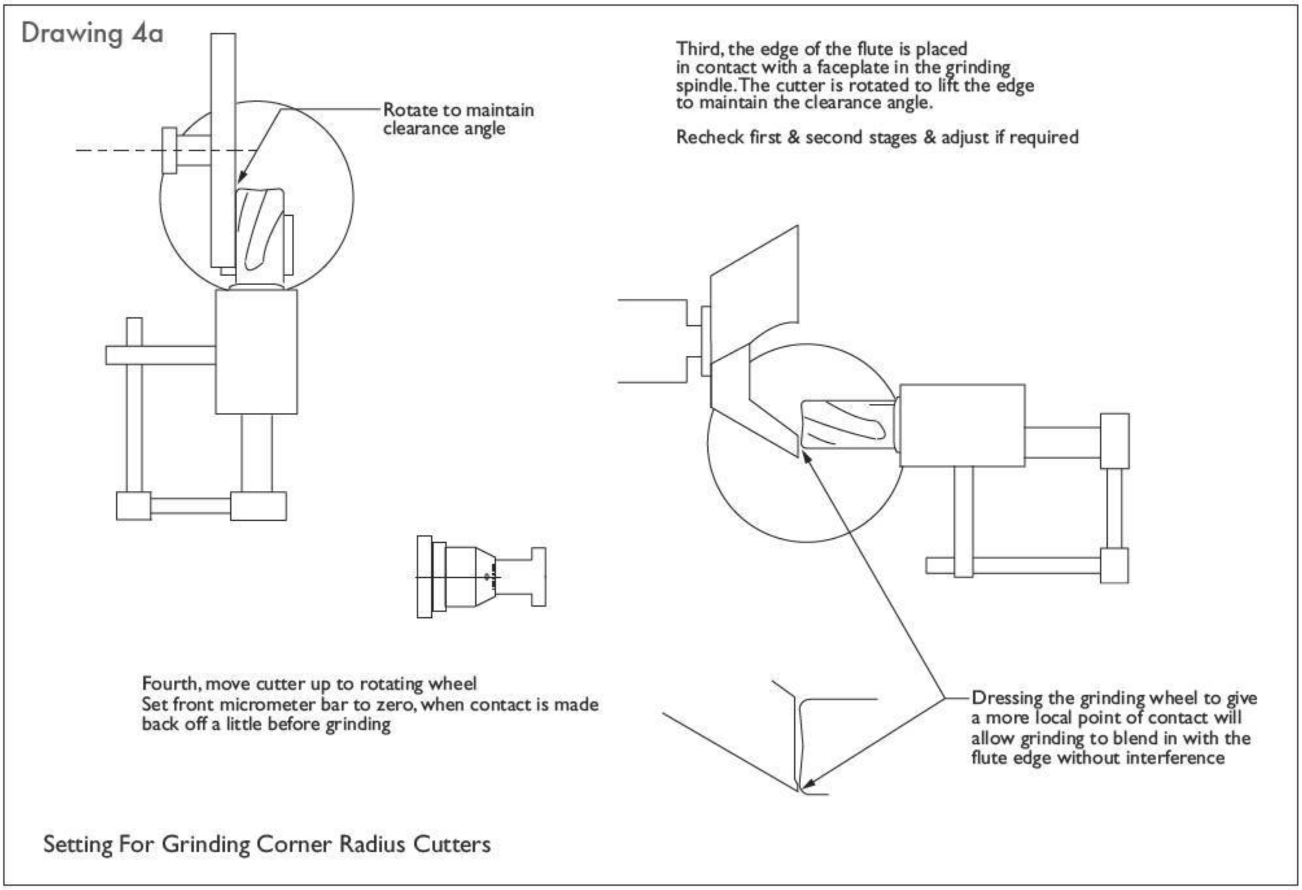
12

Radius edge cutter used in leadscrew clearance slot.

13



Grinding the radius on a lathe tool.



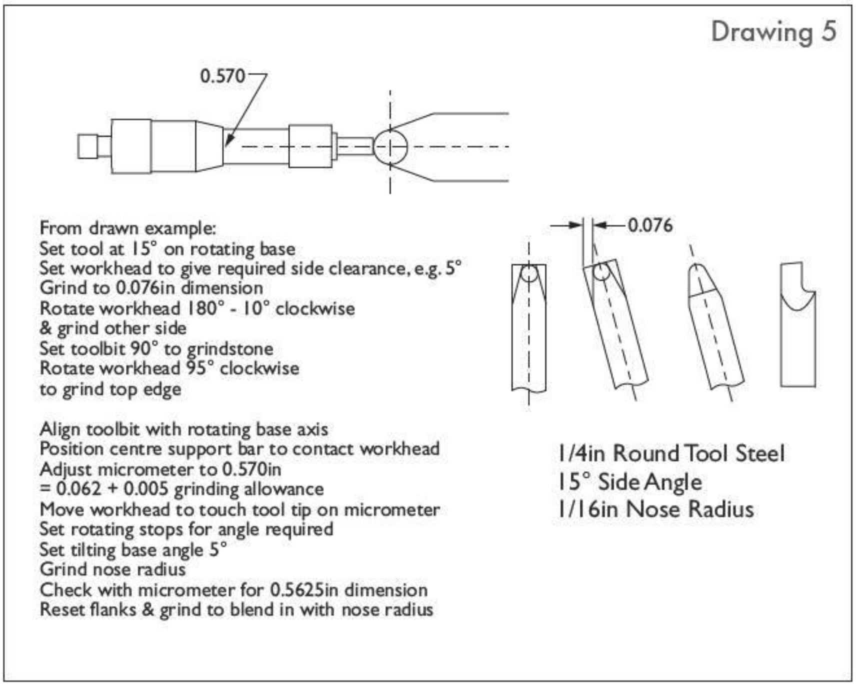
Setting For Grinding Corner Radius Cutters

Setting up to grind cutters with a corner radius

A similar sequence of events is required to set up and grind cutters with a corner radius. For this it is not necessary to know the diameter of the cutter or to use the setting pins. The sequence is shown in **drawing 4.** The example shows a cutter with a corner radius of 0.045 inch, the micrometer is set at 0. 545 in position 1 and rests against the flute (**photo 10**). The centre casting is adjusted to bring the two bars in contact as in the earlier example. The micrometer is repositioned as shown in position 2. The setting has a few thou added for the grinding allowance and the edge brought into contact with the micrometer (**photo 11**). Again for best results the cutter should have been sharpened along the flutes and also the end teeth, these will be ground again when the corner is ground but this makes it easier to setup.

With the cutter set in position, as with the previous example, the workhead is rotated bringing the flute edge in contact with the setting faceplate (position 3 **drawing 4a**). As this type of cutter will likely follow a helical path all the way up to the radius, when setting this clearance the cutter may need to be rotated slightly. If this is the case the positions 1 and 2 will need to be checked and reset. When the cutter is set and ready to grind the cutter is set in position 4 and carefully brought into contact with the grinding wheel. The front bar micrometer is set to zero and grinding can commence. The cut should be backed off a little, as if the corner is not already ground a rather heavy cut will occur as the corner stands out proud. When the grinding allowance is used up the end teeth should have been ground again as a few thou had been added at the start. Stopping the grinding wheel and inspecting the cutter should reveal if any further grinding is necessary, a useful tip is to run a black felt tip pen on the edges before grinding - this will show up clearly which parts have been ground. As in the previous example the rotating stop is set at 80 degrees. The rotating stop for the end teeth is set 2 degrees past zero, so the heel of the tooth is undercut. The rotating stop can be adjusted closer to 90 degrees providing the grinding wheel is not cutting into the flute, a narrow flat section on the grinding wheel makes a more local contact and makes this easier to do.

I choose cutters that have damaged end teeth, or would need excessive grinding



along the tip of the flute edges to bring them back into use, for corner radiusing. I feel that this is a better use for old cutters than chopping off the end of the cutter to get back to an unworn section of flute, as has been suggested previously in *MEW*. A radiused cutter was used to cut the leadscrew clearance slot in this machine slideway (**photo 12**). In some cases there is a good reason to have a radius instead of a sharp corner, particularly in items made from cast iron. In this instance the radiused edge will also prevent the build up of swarf lodging in a sharp corner in the shaper slide.

Lathe and shaper tooling

Grinding lathe or shaper tooling with a nose radius is also much easier to do, using the same alignment pieces for setting up. The setup is much the same as with the milling cutters. The tool shown in **photo 13** has an equal angle from its axis and the nose radius ground to blend in both sides. If the tool is an important one, a few moments spent drawing in a cad program can be useful to get the measurements for setting the micrometer. This need not be a full drawing, just enough to work out how much to remove from each side. **Figure 5** shows an example of this basic idea. Perhaps this seems a lot of work to do to grind a toolbit but when using larger size tool bits it will save more time than it takes to do the drawing.

Photograph 14 shows a collection of reground radiused edge milling cutters. The secret to be able to grind these cutters either ball nose or corner radius is, like everything else, lots of practice but having this simple little addition makes the initial setting up a lot easier.

14

A selection of finished milling cutters.

Some thoughts on the CNC grinder and the Quorn

I had an invitation from the SMEE to take part in the 2012 MEX show at Sandown park as they were featuring a section on CNC machines. I was happy to be able to take part and the CNC cutter grinder shown in photo 2 was displayed and running a simulated cutter grinding sequence. It was an interesting experience, many of the people who stopped and looked at the machine asked if it was worth doing. I posed this simple question "so you have just bought this nice lathe tool from X, cost about £2.00, taken it home, used it a few times and its gone a bit dull. What do you do?" On every occasion the response was "well I will grind it!" The second part of the question was "you also bought a milling cutter from the same stand, cost about £15.00 also used it a few times, not cutting as well as when it was new. What will you do with it?" The reply was more often than not "chuck it in the ice cream box with all the rest!" In view of the difference in price from the former to the latter there does not seem to be much logic with this response. I know it takes quite a bit of effort to set up for cutter grinding but it can be a rewarding activity in its own right.

Refering back to the book By Professor Chaddock, in the introduction to Building the Quorn he states that: "The answer is of course, that end mills, circular saws and milling cutters of all sorts require re-sharpening just as much as lathe or any other cutting tools, if they are to be kept in good condition and to do good work". The Quorn grinder is an excellent project to undertake and would be a good second project for a beginner. How do I know? – I was a beginner when I built mine. I know it looks a complicated machine but when it is broken down and viewed as separate parts it becomes less daunting. The Quorn book breaks down the construction in this way and the build instructions are clear and concise. Not much workshop equipment is needed - according to the introduction the machine was designed to be made using only a 3½ lathe and small milling machine. That is what I used, a Myford lathe and a Dore Westbury milling machine. Should you be thinking about building a Quorn grinder don't be put off by some of the negative things that have been said by people who have not built one. Try if possible to ask the opinion of someone who has built one. There are nearly always several on display at the Model Engineer Exhibition. Try and engage in conversation with the owner or builder - most will only be too happy to talk about their machine. I have not regretted a single moment spent building my Quorn grinder, it has been one of the best pieces of equipment that I have ever made. Used in conjunction with the cnc cutter grinder they are an unbeatable combination. ■

CNC in the (Model Engineers') Workshop

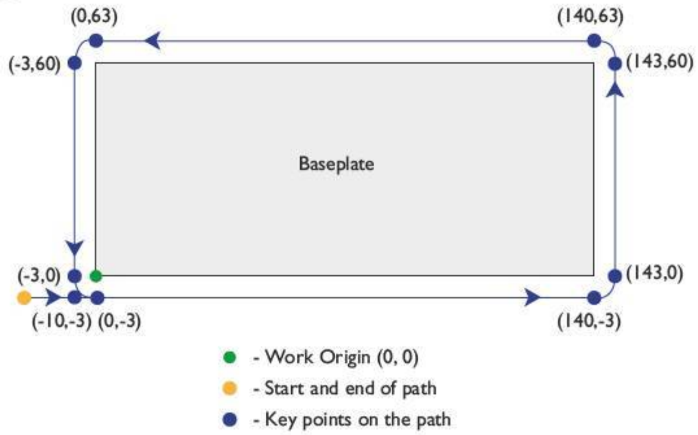
Part 14

Subroutines

This series of articles starts with the fundamentals and covers many aspects of CNC programming and machining. The series is not specific to one make or model of machine tool, but it does feature Mach3 software throughout. There is a support website for the series at: **www.cncintheworkshop.com**

This month, Marcus Bowman makes repetition easy.

Fig. 66



Note: this diagram was referenced in MEW *issue 215.*

Make a subroutine

Let's take each cut around the path by lowering the CP (Z) then using the code shown last issue to go around the path. If that action of lowering and cutting is repeated enough times, that sequence will do the job. That's the technique we used in our last project, so there's nothing new in the concept. For the moment, just to make life easy, we will forget about ramping into the work; let's take one step at a time.

Instead of having to type the code for the path each time, it can go into a subroutine. A subroutine is simply a section of code we can use as many times as we like. We only need to type the code once, but can use it at any time, and use it repeatedly if need be.

To identify the section of code, it has an identifying number at the beginning, and a specific command at the end. Here's what it might look like:

```
O100 (The start of the subroutine with
reference number 100)
[put the code to machine the
periphery here]
M99 (signals the end of the subroutine)
```

In O100, the O is a capital letter and the 100 is a number. M99 is always the command used at the end of a subroutine; the number doesn't change.

Although we gaily talk about the G-code language, and although the majority of commands do begin with G, the O code denotes a flow control command related to the logic of the sequence of commands in a program. There are M codes, F, S and T codes too. Why we favour G would be a mystery unless we knew that it is entirely a co-incidence and has nothing to do with the fact that some commands begin with the letter G (see the notes on the support website at **www.cncintheworkshop.com**).

Reference numbers can be anything in the range 1 to 9999.

To avoid confusion, subroutines go after the M30 statement at the end of a program so they do not appear in the normal flow of commands in the main program.

To use a subroutine, use the command M98 P~ substituting the reference number of the subroutine in place of the ~ character. So M98 P100 would call up the code from subroutine O100 and carry it out. When it has finished (i.e. when the subroutine reaches the M99 command) the program interpreter returns to where it was in the main program and carries on from there.

This program will repeatedly lower Z and cut the periphery:

```
G0 Z20 (Safe Z)
G0 X-10 Y-3
G1 Z-1
M98 P100
G1 Z-2
M98 P100
G1 Z-3
M98 P100
... and so on
M30
O100
---- put the code to machine the
periphery here ----
M99
```

That has the same sequence as the programs we have used before, but the structure is neater and, as we will see, it allows us to use other powerful techniques.

Clean code

Using the subroutine is termed 'calling' the subroutine; so M98 P100 calls subroutine 100. It's a computer programmer's term, really, but useful nevertheless, because it is generally understood, at least in the word of code.

One of the important things about subroutines is:
clean entry/clean exit

That means the subroutine should begin its movements from a predictable start point which must be the same each time. It should finish at a predictable end point, which must be the same each time.

The only exception to this rule is when we have deliberately created just that: an exception. Even then, there must be a reason for that, and the start and end points each time the subroutine is called must be predictable.

The subroutine should leave no loose ends, and should cause no unexpected effects for the rest of the program.

In practice, this means we need to consider where the CP is before we call a subroutine, and think about how to get to a suitable position before the subroutine does its work. Similarly, at the end we need to think about where the CP will be and whether we need to do some additional moves before continuing with the other parts of the program. The more of this that can be done inside the subroutine, the better.

Improving the final finish

The program should do its job quite nicely, but we can easily improve the surface finish by taking a fine finishing cut in the opposite direction, using climb milling.

To do that, move the CP outwards a little for the initial roughing cuts (perhaps 0.1 or 0.2mm), use the subroutine technique as before, then take a final cut at full depth moving the CP clockwise and cutting to final size.

```
(Machine the work 0.1mm oversize)
G0 Z20 (Safe Z)
G0 X-10.1 Y-3.1
G1 Z-1
M98 P100
G1 Z-2
M98 P100
G1 Z-3
M98 P100
... and so on, finishing with a cut at Z-10
(Machine the work to final size by climb
milling)
G0 X-3 Y-3
G0 Z-10
G1 X-3 Y60
G2 X0 Y63 I3 J0
G1 X140 Y63
G2 X143 Y60 I0 J-3
G1 X143 Y0
G2 X140 Y-3 I-3 J0
G1 X-3 Y-3
G0 X-10 Y-3
G0 Z20 (Safe Z)
M30
O100(Machine the work oversize,
cutting anti- clockwise)
(Entry assumes X-10.1 Y-3.1)
(Exits with X-10.1 Y-3.1)
G1 X140 Y-3.1
G3 X143.1 Y0 I0 J3.1
G1 X143.1 Y60
G3 X140 Y63.1 I-3.1 J0
G1 X0 Y63.1
G3 X-3.1 Y60 I0 J-3.1
G1 X-3.1 Y0
G3 X0 Y-3.1 I3.1 J0
G0 X-10.1 Y-3.1
M99
```

Complete the program using the basic structure outlined in *MEW* 209, with Comments, an Initialisation Sequence, a Main Program and an End command, following that with any subroutine definitions.

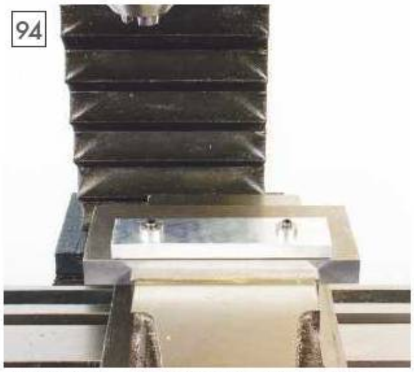
Note that if your workpiece is sitting on a sacrificial sheet at least 0.6mm thick it won't matter whether you are using 10mm or imperial thickness ⅜ inch (9.525mm) material. The additional descent will simply be into the sacrificial sheet.

Mount the workpiece in the fixture, set the Work Origin with Z0 at the top surface of the material, jog the cutter above the work, and run the program to machine the periphery of the base of the folder.

Machining the reinforcing bar

Like the base plate, the best way to deal with the reinforcing bar (**fig 67**) is to bolt the material to the fixture as shown in **photo 94** (not forgetting the sacrificial material) then machine around the periphery. The bar is a little shorter and less broad than the base plate or the clamp plate, and it is symmetrical about its centre point which lies on the line between the two locating pins, so it is convenient to move the Work Origin to the centre of the bar. This is not essential, but it makes life easier when we have to identify the co-ordinates of the corners and the path of the cutter. There are some sophisticated ways of moving the WO when we are working with several workpieces, but, for now, it is enough to use MDI mode to move the CP to X70 Y12.5 and set X0 Y0 at that point.

94



Workpiece screwed to a sacrificial base.

Fig. 67

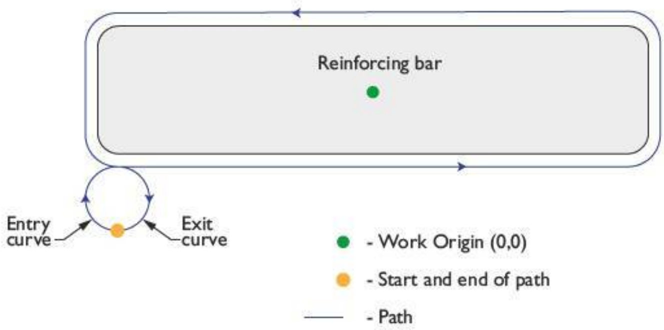
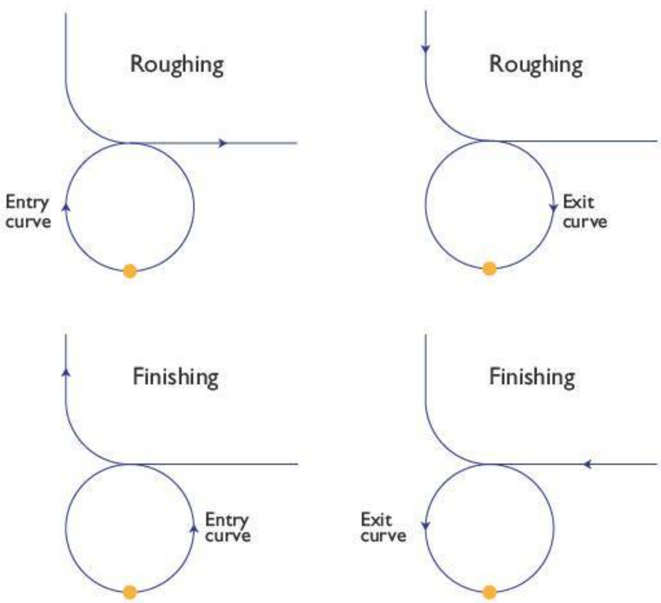


Fig. 68



We can easily return to our original WO position for the clamp plate, later.

We can take a similar approach to machining the periphery as for the base plate but improve the way we handle the Z values. With the Work Origin set to the centre of the bar a suitable path around the periphery for a roughing cut 0.1mm oversize all around might be as shown in **fig 68**, created using the following commands:

```
G0 X-54.5 Y-19.1 (Set initial position
clear of the work)
G2 X-54.5 Y-13.1 I0 J3 (Entry curve to
reach the work)
G1 X54.5 Y-13.1
G3 X60.6 Y-7 I0 J6.1
G1 X60.6 Y7
G3 X54.5 Y13.1 I-6.1 J0
G1 X-54.5 Y13.1
G3 X-60.6 Y7 I0 J-6.1
G1 X-60.6 Y-7
G3 X-54.5 Y-13.1 I6.1 J0 (Turn to complete
the periphery)
G2 X-54.5 Y-19.1 I0 J-3 (Exit curve to take
cutter clear)
```

The first G3 command is used to provide a smooth entry curve into the cut, avoiding any noticeable marks caused by an abrupt change of direction and the consequent decelerate – stop – accelerate sequence.

The final G2 command provides an exit curve, taking the cutter smoothly clear of the work.

Figure 68 shows how these entry and exit curves work.

Arithmetic

Mach3 can do arithmetic, and that's useful here because we can make it add a number to the existing value of Z each time we use the subroutine. Repeatedly using the subroutine will then make it take successively lower cuts, dealing effectively with the need to lower Z each time. All calculations must be enclosed in square brackets.

Mach3 can cope with statements like [4 + 5] or [6 - 2]. It can also deal with two signs together, so sums like [4 -2] or [6 - -2] are fine. If you recall the rules we used in a previous instalment for dealing with two signs together, Mach3 knows and uses those same rules. Do use square brackets, though. Extra pairs of brackets are no problem; but too few brackets will cause errors.

If the answer to a sum is to be used right away, that's fine, so statements like:

G1 X[3 + 4] will be carried out without difficulty.

However, we often need to do a calculation which won't be used straightaway, so the other thing we need is somewhere to store the answer to a sum, and we do that by using the equivalent of a storage box. To be compliant with the language of computer programming, the storage box is called a parameter (although there is some variation across computer languages, and you may find other terms used in software other than Mach3).

So that we can refer to a parameter later (to retrieve the answer to the sum) each parameter is given a number, in much the same way that each subroutine is given a number. Use the hash sign # to denote a parameter, and an integer (a positive whole number) to identify which parameter. So #252 means 'parameter 252'. Avoid parameter numbers less than 40 or greater than 4999, for the moment, as those behave in a slightly different (but sometimes very useful) way.

If we use a parameter to store the current Z height, we can change the value stored there each time the subroutine is called.

Here's an example:

```
#41=0 (Parameter 41 stores the current Z
value)
G0 Z20 (Safe Z)
G0 X-54.5 Y-19.1
M98 P115
M98 P115
M98 P115
... and so on, until the subroutine
has been called 10 times
M30
O115 (Subroutine to machine
periphery 0.1mm oversize)
#41 = [#41 – 1] (Make the contents
of parameter 41 one less)
G1 Z#41 (Set Z to the number s
tored in parameter 41)
---- Put the commands to machine the
periphery 0.1mm oversize here ----
M99
```

Every time the subroutine is called, the value stored in #41 is reduced by 1. The effect of successive calls to the subroutine is to machine repeatedly around the periphery, 1mm lower each time.

We can go further, though, by using an extended form of the M98 subroutine call command, using the letter L followed by the number of times the subroutine is to be used. Think of L as meaning 'Loop' in the sense of 'repeat'.

M98 P115 L10 calls the subroutine 10 times in quick succession, so it is exactly the same as typing M98 P115 ten times. The main program code now becomes:

```
G0 Z20 (Safe Z)
G0 X-54.5 Y-19.1
M98 P115 L10
M30
```

95

The surface finish we are aiming for.

Add additional program code to machine the periphery to finished size by climb milling (as we did for the base plate). You only need to travel around the periphery once, at full depth, for that final cut.

There is a finished program on the support website, if your brain cells are as tired as your typing fingers.

Secure the material to the fixture, then run the program. **Photograph 95** shows the quality of finish you might expect to achieve from the roughing cut (on the right face) and the finishing cut (on the left face).

Adding a rounded edge

The reinforcing bar will work perfectly well with sharply defined edges, but in an attempt to visually soften the outline, and to reduce the opportunity for cut fingers, it might be an idea to round or bevel the edge around the top of the bar. That can be done now, or the bar can be returned to the fixture later. I suggest doing it now.

To round edges, you can use a corner-rounding end mill (**photo 96**) which forms a neat radius around the edge as it cuts.

The geometry of this kind of cutter is interesting, as the angle between its 'wings' is slightly greater than 90 degrees, making it a little easier to blend the radius into the vertical and horizontal faces of the work (**fig 69**). Four effects are possible:

A smoothly blended corner (**fig 70a**), a corner with one quirk (a step or ledge

96

A rounded edge achieved using a form cutter.

Fig. 69

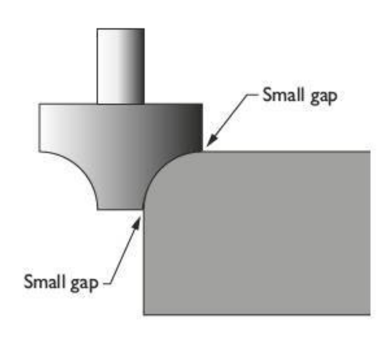
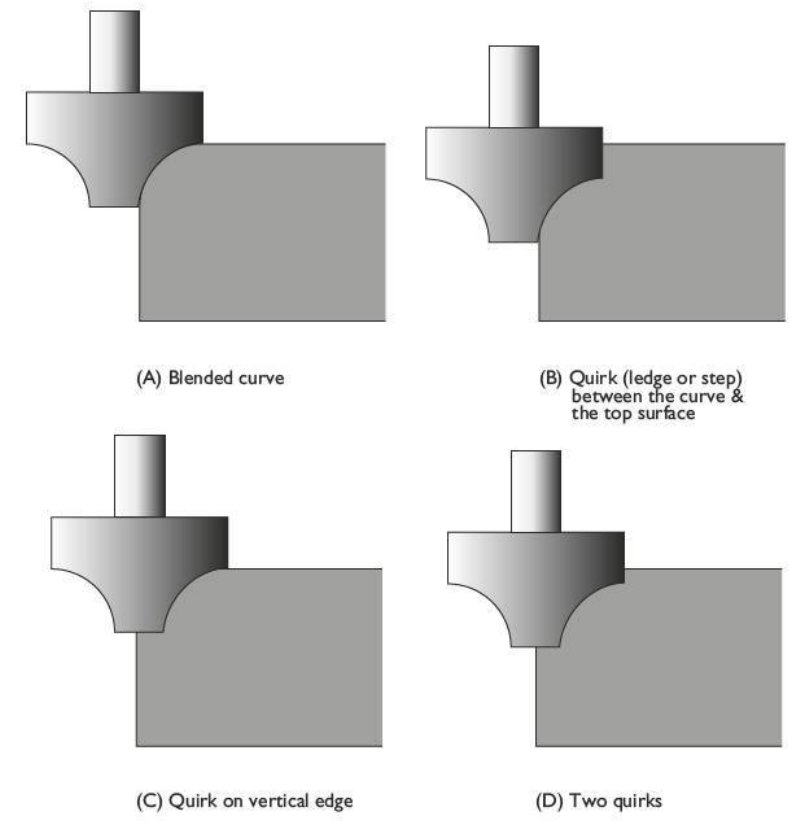


Fig. 70



between the curve and an adjacent face) on the horizontal face (**fig 70b**) or the vertical face (**fig 70c**) or a corner with two quirks (**fig 70d**). The effect you use is purely an artistic choice.

What's important is that we know how the radius is positioned in relation to the end and side of the cutter (**fig 71**). I used a 2mm radius cutter. That means the radius of the internal curve on the cutting edge is 2mm. Assuming the radius of the cutting face is centred on a point co-incident with the bottom face and the outer diameter of the cutter, you can do a visual check of the curve by holding a 4mm diameter twist drill against the cutting edge. You can also do a calculation as shown in **fig 72**. Some suppliers list not only the radius of the curve, but the tool diameter and the tip diameter, so if their tools have been ground accurately, your measurements should merely confirm the supplier's figures.

Now that we know the position of the offset of the curve in relation to the vertical axis of the tool, we can use that information to work out the path of the CP. **Figure 73** shows that for the cutter I used, the CP should run 6mm outside the periphery of the clamp bar, and the maximum Z distance should be 2mm.

Modify the program you used to machine the periphery, to take perhaps 4 cuts downwards to form the periphery 0.1mm oversize, then take a final climb cut to finish to size. The surface finish will not be as good as with the single flute straight cutter, but it should be pretty good. I found my cutter left an almost imperceptible witness around the vertical side of the bar, so I will take account of that next time I use that tool.

We will return to the important business of tool dimensions shortly.

As with the other programs, there is a completed example on the support website.

Reset the Work Origin

Before moving on to machine the clamp plate next time, take the CP to X-70 Y-12.5 and set the Work Origin there, corresponding to the left front corner of the finished clamp plate. That undoes the move we carried out to shift the WO for the reinforcing bar.

To be continued...

Fig. 71

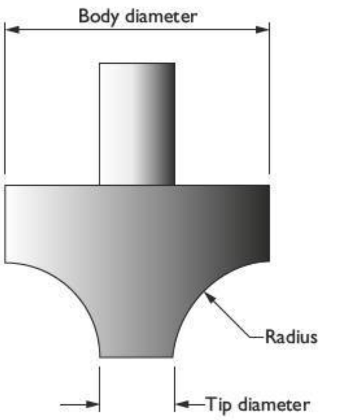


Fig. 72

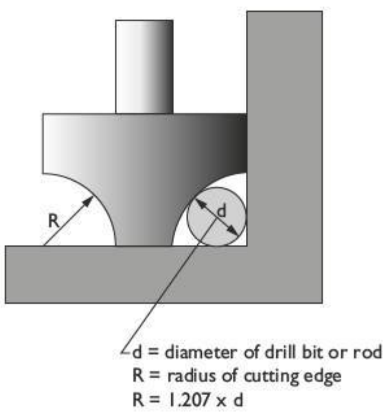
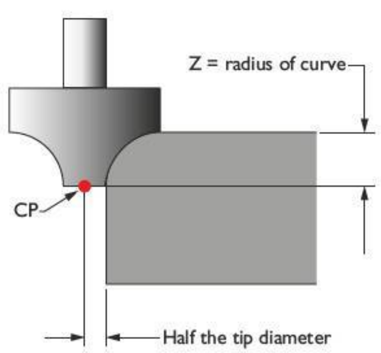


Fig. 73



A Raising Block for the Warco VMC Part 2

Roger Vane's sturdy design could easily be modified to suit some other larger milling machines.

When I bought my Warco VMC milling machine my main concern was the lack of distance between the spindle nose and the table. On my particular machine this is just 12.5 inch, so when a tall vice and keyless chuck are in use with a large workpiece, things can become rather tedious. After 4 years of frustration the time had come to do something about the problem - hence the raising block.

The Raising Block fitted to the VMC Mill.

Back to the main block

Before carrying on, it is worth mentioning that I have seen a photograph on the Model Engineer website of a Warco VMC where the spigot appears to be much longer than on my machine. In this case the bored recess in the top of the main block would need to be correspondingly deeper (**ref 2**). My guess is that this spigot could be around 1 inch long, maybe a bit more. I understand that this is an earlier, Taiwanese built, machine.

I refitted the drawbar to the opposite face of the main block, but without the nut this time around, as the drawbar would have to be removed prior to the final through boring operation. The main block was then set to run true in the 4-jaw, with a dial gauge used on the existing turned diameter as shown in **photo 11**.

Before facing and turning the diameter, I used a large centre drill to make a centre cone to replace the M10 thread so that tailstock support could still be achieved. The end of the block was then faced to a clean-up and again it was not necessary to face exactly to the centre as this would become the recess and the through bore.

I undertook turning the diameter in two stages. The first stage, as shown in **photo 12**, was to reduce the diameter sufficiently to clear the front of the saddle. Following this the left-handed tool was repositioned conventionally, **photo 13**, turning from left to right to blend into the already completed section.

The time had now come to remove the tailstock support and bore the recess and through hole. The drawbar was left in place at this stage.

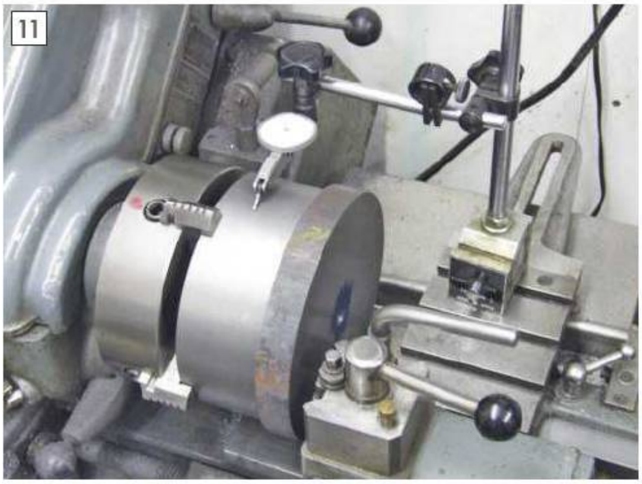
I started with the recess which was bored out to suit the spigot on the machine turret - in my case this was 3.306 inch diameter, which allowed for a very small clearance on the spigot as I aimed for a close running fit. This is where the 'plug gauge' on the end of the new spigot came in useful. The wisdom of trying for this close fit would be tested at the final assembly stage of the project as I might have to rework the bore. I decided to make the bore for the spigot somewhat deeper than really necessary and finished it at approximately 0.7 inch deep although the spigot on the machine was only 0.55 inch high - I really didn't want to revisit this part of the process. Machining the bore for the spigot is shown as **photo 14** - the blue line was marked around the periphery of the spigot and was purely a guide to let me know when I was approaching size and that I should start measuring the bore on a regular basis.

I would advise anyone following this process to allow adequate depth for this bore, particularly if your machine dimensions are unknown at the time of making the raising block. Should anyone have a problem with this bore not being deep enough I have included some thoughts on how to rectify the situation at the end of this article (see **'Fine tuning'** in the next issue).

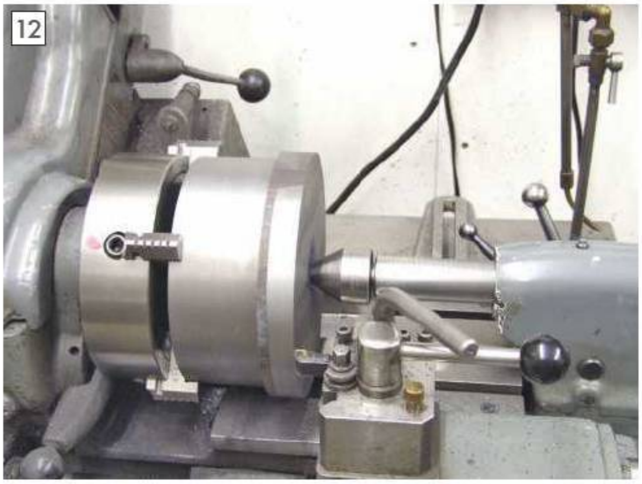
With the boring tool still set-up in lathe I then chamfered the entry to the bore which would assist when fitting the milling head to the block at the final assembly stage, **photo 15**. You may ask why chamfer angle on the spigot is 30 degrees, whilst the chamfer angle in the bore is 45 degrees - I have no idea and simply copied the angles on the machine.

Prior to removing the drawbar I worked on the through bore as deeply as I possibly could. In drilling I went deep enough to run into the small void behind the drawbar and then went on to touch it, progressively opening the hole up with ever larger drills This was followed up by boring out to within about ten thou of the finished dimension of 1 inch (in my particular case).

Finally, I could not put off removing the drawbar any longer. With the drawbar removed, it was possible to drill and bore the remaining section to match the existing bore, following which was the rather tedious job of increasing the bore

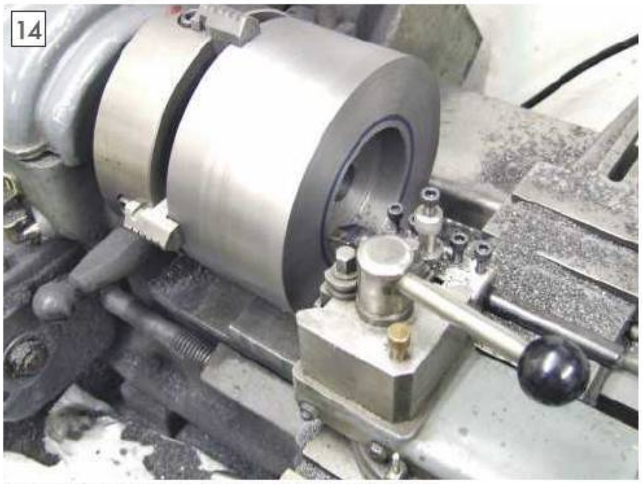


Clocking the main block to run true before machining the second end.

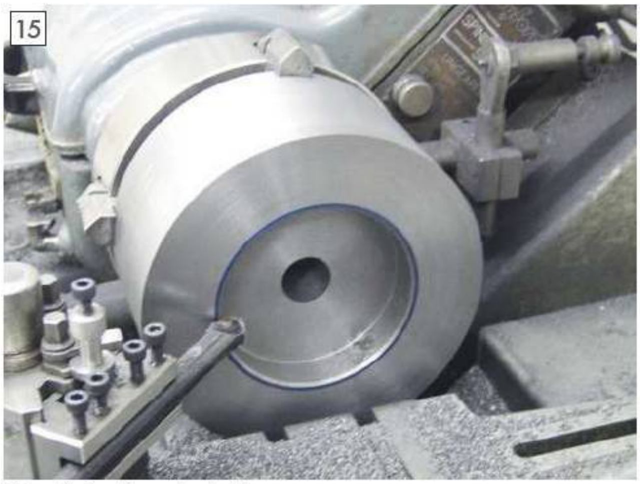


Initial stage of turning back the outside diameter on the second end.

Now that the blank can clear the front of the saddle the LH tool can be used in the conventional position, turning from left to right.



Boring the recess in the top of the main block.



Chamfering the entry to the recess.

Boring the 1 inch diameter through hole in the main body.

to a good slide fit on the plug gauge and hence my mandrel. I say tedious, because this proved to be a long, boring exercise (excuse the pun) due to the amount of spring in the tool, extended as it was to just over 3 inch from its holder, **photo 16**. Making a good job of this bore paid dividends later on when the main block would sit accurately on the mandrel, aiding my quest to ensure that both top and bottom faces of the finished raising block would be parallel to each other. I was pleased when eventually a good, rattle-free fit was achieved.

That's it! The worst turning jobs had now been completed and with it all of the major turning operations on the raising block components were now complete and so it was then on to drilling and milling.

Preparing the blanks for the rotary table

Whilst the spigot could easily be clamped onto my 6 inch rotary table, the baseplate and main block were too large for the use of clamps. Holes were drilled in these so that clamping studs could be fitted directly into the tee-nuts. In drawing up the raising block, I determined that the best position

Drilling the holes for the studs which will hold the baseplate onto the rotary table.

The three finish-turned blanks ready for the rotary table.

The spigot was the first part on the rotary table to drill and counterbore the holes for the M6 capscrews. The operation shown here is pilot drilling the spigot for roll pins. Note the centring plug and the packing underneath the spigot.

The protective packer used when drilling the stud holes in the baseplate was used to locate the holding down studs.

for these holes was on a PCD of 2.75 inch, bearing in mind that the holes would fall within the spigot bore on the main block and would need to be clamped using spacers as shown in a later photograph.

The packing piece under the baseplate had a ¼ inch hole drilled in the centre, into which was fitted a length of ¼ inch diameter rod with the centring plug. This assembly of parts was then clamped to the milling machine table.

As I was using ⅜ inch studs made from stock material which was slightly down on nominal size, I decided to drill ⅜ holes in the baseplate and the main block. With the aid of a DRO the positioning was straightforward once the material had been centred under the machine spindle. **Photograph 17** shows the last hole being drilled in the baseplate. The ⅜ inch diameter holes had passed into the packer when they cleared the baseplate and these were then drilled through on the bench drill, allowing me to use the packer as a positioning guide for the studs.

The main block was treated in a similar manner, using a new packing piece to preserve the first for later use as a guide. A close fit for the studs would provide extra security against any movement of the main block during the milling operations.

Please note that the position of the four stud holes shown on the drawings apply to my own particular rotary table, where the table is set at the zero position. Other rotary tables will almost certainly place these holes in a different angular position, but the only feature which may be affected would be the position of the M6 tapped holes for attaching the spigot - the angular position of these is not critical. Due to this potential variation, no angular dimensions are given on the drawings.

All three blanks were now ready for the rotary table operations, as shown in **photo 18**.

Rotary table operations

The rotary table operations were sequenced to avoid changing the PCD until the holes in mating pairs of components had been drilled. Before starting to machine each part, the rotary table was set to the zero position and all angles quoted below are taken from that zero position.

The depth of tapped holes and counterbores are given, assuming that anyone making this raising block uses blanks for the spigot and baseplate with a finished thickness as stated on the drawings. Allowances would need to be made if the blanks were any thinner.

Spigot

The spigot was the first part to be drilled on the rotary table. It was placed on a packer so that the rotary table would not be damaged as the drill broke through and centred under the machine spindle with the ½ inch diameter centring-pin (shown on the tooling drawing). Luckily, there was just sufficient space for conventional clamps to be used.

The machine table was then moved 1.3 inch, allowing the generation of the 2.6 inch PCD as the rotary table was turned through the full 360 degrees. Four holes were drilled through and counterbored to suit M6 capscrews at positions 0, 90, 180 and 270 degrees.

I also drilled two ⅛ inch diameter pilot holes for rollpins. These holes would eventually be used to spot through into the baseplate and then be opened up to suit larger rollpins - I used $^3/_{16}$ inch diameter pins, as that was the size I had in stock. In placing the holes for the rollpins care was needed to avoid the holes used for bolting the baseplate onto the rotary table. The near-complete spigot is shown on the rotary table **photo 19**, with the pilot holes for the rollpins being drilled through ⅛ inch diameter.

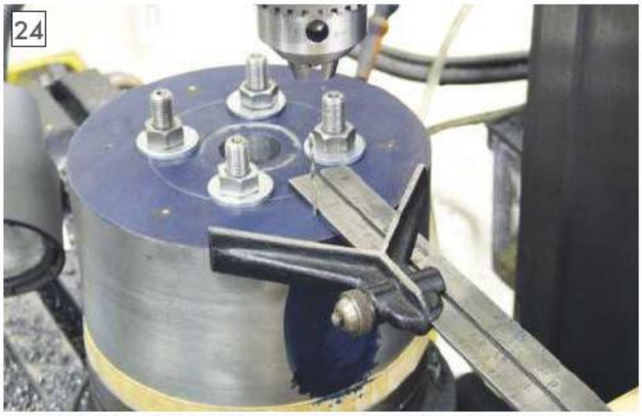
Baseplate

The protective packer used when drilling the four securing holes in the baseplate was then placed onto the rotary table, positioning the studs as shown in **photo 20**, which made it easy to fit the baseplate. The centring plug can also be seen - it was located by a ¼ inch diameter pin passing through into the centre of the rotary table.

Drilling the 10.5mm hole reminded me exactly why I was doing this job - the drill point only just cleared the baseplate, so drilling the much thicker main block should prove interesting.

Opening up the counterbores to 16mm diameter.

This face will be skimmed at the final assembly stage, so a countersink cutter is being used to avoid any sharp edges later on.



Using the rule and vee from the combination set to mark a centre line which will be transferred to the opposite face of the main block to position the studs which hold the turret in place. Note that the inner extent of the pocket has been scribed onto the face of the main block.

The baseplate was then securely bolted down and the rotary table set to zero.

Without changing the PCD, the first operation was to drill and tap the holes for the M6 screws which would hold the spigot to the baseplate. These holes were made a shade over ½ inch deep to suit the 30mm long capscrews that I was using.

The PCD could now be changed to 4.562 inch (the PCD of the tee-slot) to enable all of the other holes to be drilled. As a precaution and not wishing to scrap expensive material, I spotted two opposite hole positions and then checked that the PCD was correct.

Satisfied with the PCD, I could now get down to drilling the ring of holes. Firstly, the three holes for the studs which would attach the raising block to the column were drilled at 0, 120 and 240 degrees. On the turret these had been drilled to 12mm, but I felt that this was a bit excessive although I presume that this was done to cover any inaccuracy in their radial positioning. I decided to drill mine 10.5mm diameter. When drilling these holes the drill point only just cleared the baseplate as seen in **photo 21**, which served to remind me why I was doing this job.

Next to be produced were the holes for the M10 capscrews which would secure the baseplate to the main block. Holes were drilled at 30, 60, 90, 150, 180, 210, 270, 300 and 330 degrees. These holes were drilled M10 clearance and then counterbored out to 16mm diameter. The counterbore was formed in two stages, firstly using a 13mm slot drill and then following this up with a 16mm slot drill. I counterbored these holes sufficiently deep to hide the head and allow for this face of the baseplate to be skimmed on final assembly to achieve a parallel dimension with the top of the main block. The head on an M10 capscrew should be 16mm (0.630 inch) deep, so I made my counterbores around 0.7 inch deep, **photo 22**. Before moving on I also countersunk the counterbored holes to avoid any sharp edges or burrs as a result of skimming the face on final assembly, as can be seen in **photo 23**.

The last job on the baseplate was to drill pilot holes for rollpins at 45, 165 and 285 degrees. Again, I drilled ⅛ inch diameter holes at this stage - they would be opened-up to 3/16 inch diameter when the baseplate was finally fitted to the main block.

Main block

The final part to be processed on the rotary table was the main block. Here, both faces would be worked upon as pockets and tapped holes were required on the plain face, whilst tapped holes were required on the recessed face. Before mounting the main block on the rotary table I applied marking blue to the non-recessed face and then scribed a circle at 3.4 inch diameter to mark the inner extent of the pockets.

Firstly, the main block was mounted 'recess down' for drilling and tapping the M10 holes which were to connect it to the baseplate. The PCD remained set at 4 9/16 inch. The pockets would also be machined in this face at a later stage.

Before doing anything else, I needed to identify the position of the studs on the recessed side of the block. These are directly above the centreline of the pockets on the finished raising block. To find this centreline I drilled a ⅛ inch diameter hole at the zero position and then placed a 1/16 inch drill in it. The vee and rule from a large combination set allowed me to mark a radial line through the centre of the ⅛ inch diameter hole by pinching the 1/16 inch drill against its wall. **Photograph 24** shows the general idea. This line was then transferred down the side of the block for eventual transfer onto the recessed face. Obviously this task had to be performed before the pockets were milled out, otherwise the opportunity would have been lost. Just as a precaution, I decided to mark out all three centrelines just in case anything went wrong and I lost the alignment of the only hole to be marked out.

REFERENCE

2. Photograph of spigot www.model-engineer.co.uk/albums/member_photo.asp?a=13378&p=229886

To be continued...

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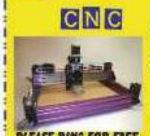

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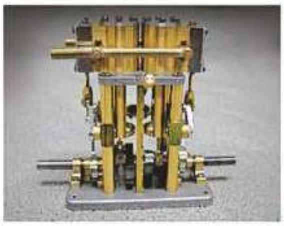

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