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On the Editor's Bench

On the move

Please note that there is a new editorial email address for Free Adverts and articles. Please use the address on the Free Adverts page for all correspondence direct to David Clark.

Letters will be forwarded by the Post Office for a few months. I will update the Contributor's Agreements soon.

Teach-In 2014

This new series starts in this issue. I have started with a look at planning permission and sheds and will continue with sheds and prefabricated garages next time. The series will be very comprehensive and will probably last into 2015.

The first machine purchased will be a lathe, I have chosen a Myford ML10 as they are well made and are readily available for about £500 with some equipment. You can of course buy whatever lathe you wish, it will make no difference to the series.

I originally purchased an 8 foot x 6 foot garden shed but I found out two weeks later that we were moving so I sold it on eBay. I would have taken the shed with me but the new property has a substantial clean and dry brick outhouse so I will use this as a workshop instead.

I am looking forward to the Model Engineer Exhibition, I am going for a few hours on Sunday, hopefully getting there for about 10am. The maker part of the show will be first on my agenda as this sounds interesting especially as you can buy a RepRap 3D printer for about £600 from the RadioSpares website:

<http://uk.rs-online.com/web/>

ARTICLES WANTED

I would like to see some more interesting and unusual articles for Model Engineers' Workshop. I still have quite a few articles in the bank but this will soon deplete if I don't get some more. All articles are being moved on to a central server so if you think I have one of your outstanding articles, please let me know so I can ensure it is included in the article bank.

I have an account with RadioSpares so I am seriously considering buying one and doing a short series on it. The printer sounds very useful for making patterns and things as well as printing out complete components. Also on the list of things to look at is a laser cutter, a small A4 one would be fine.

Scribe a Line

Scribe a Line is not dead, it is just having a rest. It should be back in MEW 212. Keep those letters coming, I will need more shortly. Please supply a head and shoulders photograph of yourself to accompany your letter. I also need to know where in the country (or the World) you live. We will only print the nearest large town or the country if you prefer. Other readers like to know where you live.

David A. Clark

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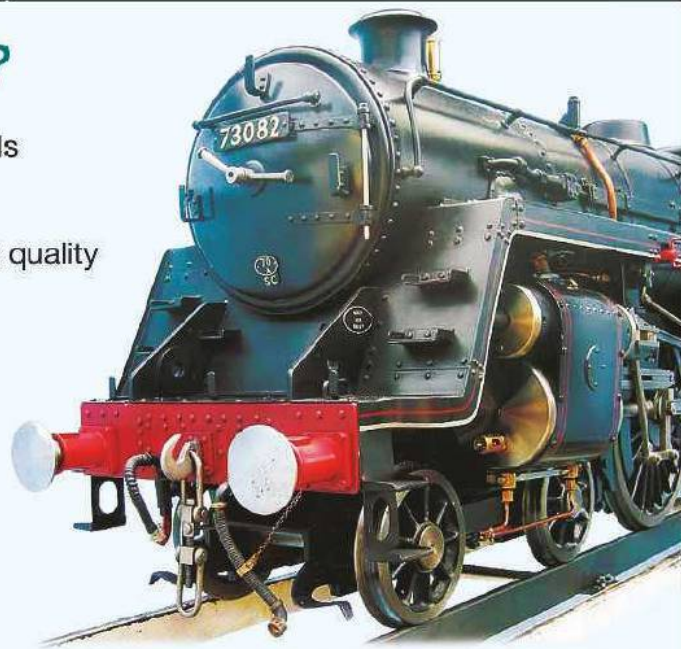
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CARDIFF 44-46 City Rd, CF24 30N	029 2046 5424	LINCOLN Unit 5, The Pelham Centre, LN5 8HG	01522 543 036	SOUTHERN 516-518 Portsmouth Rd, Sea	023 8055 7788
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COLCHESTER 4 North Station Rd, CO1 1RE	01206 762831	LONDON 503-507 Lea Bridge Rd, Leyton, E10	020 7489 2129	SWINDON 21 Victoria Rd, SN1 3AW	01793 491717
COVENTRY Bishop St, CV1 1HT	024 7622 4227	LONDON 100 The Highway, Docklands	01850 228 063	TWICKENHAM 83-85 Heath Rd, TW1 4AW	020 8992 9171
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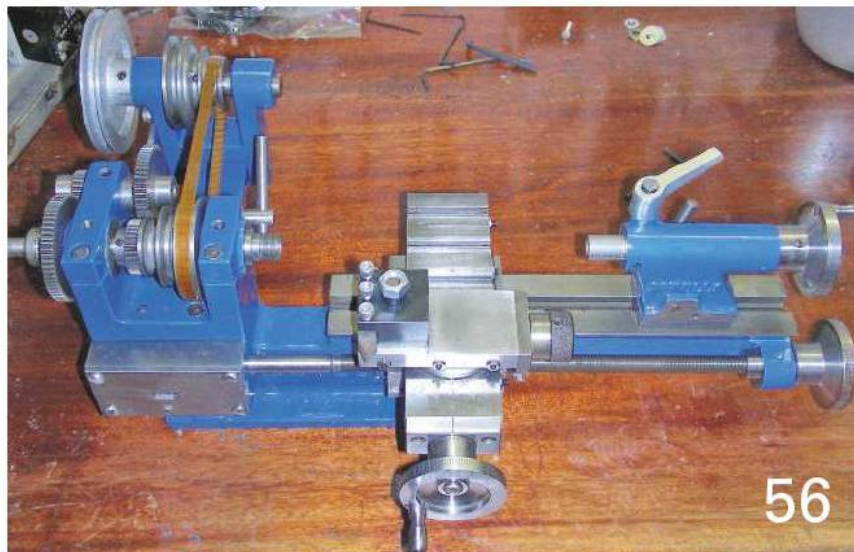
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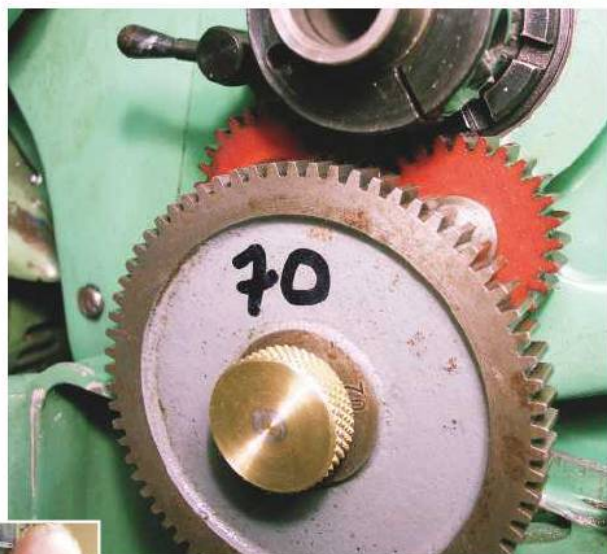
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See page 34 for details.

Coming up...

in the February issue



Brian Wood looks at simple gearing for metric threads on Myford ML7 lathes with gearboxes.



Mark Noel uses a computer mouse as a Digital Readout Device.



David Clark continues his new beginners series with advice on sheds and garages.

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This Unimat Conversion is described in this issue, see page 25. Photo by Terry Gorin.



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CNC in the (Model Engineers') Workshop



Part 9
Driving round
the bend

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 and Vectric software throughout. There is a support website for the series at:
www.cncintheworkshop.com

Marcus Bowman looks at CNC for the beginner.

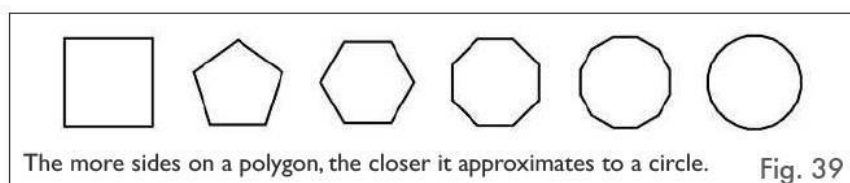


Figure 39 shows that if we start with a square and increase the number of sides, we soon get to the stage where the shape looks awfully like a circle. You might think a circle has a curved periphery, but unless we use a rotary table, a CNC circle is a polygon with a lot of small straight lines. The more lines there are, the shorter they will be, so the better the polygon will resemble a circle, and because we can easily cut lots of sides we can usually get a pretty good result. The result will certainly be good enough for everyday use and we are limited only by the effects of backlash and rigidity.

The trouble is, working out where the vertices (corners) are for a square is usually not too difficult, and doing the same for a polygon with a few more sides is do-able, even if it requires more troublesome calculations, but calculating the co-ordinates for lots and lots of sides leads to what the Victorians often called *brain fog*.

Fortunately, there are G code commands which can do that for us. In fact, we can use two simple commands designed specifically to move around a circular path, and all the relevant calculations are done while the machine moves the CP.

G1 moves the CP in a straight line. G2 moves the CP in what appears to be a circular path, clockwise (as viewed looking down through the Z axis and the mill spindle).

G3 moves in a 'circular' path, anticlockwise.

Editors note: The direction of G2 and G3 are easy to remember. G2 is clockwise (two characters = CW) while G3 is counter clockwise (three characters = CCW).

We will refer to these G2 and G3 paths as being circular, from now on, but they are not; they just use small straight lines to approximate a circular path. That should be good enough, under most circumstances. When we run into unexpected problems, we can return to the fundamental truth that the CP follows a polygonal path.

A circular path can be a part-circle (i.e. an arc) or a full circle, or more than a full circle. The path can be 'flat', parallel to the mill table and in the X-Y plane (fig 40), or it can be a spiral, moving the Z axis up or down as the CP moves in an XY circle. That creates a spiral path which looks a lot like a helical spring (fig 41).

To be able to work out the path, Mach3 needs to know some basic information. If you were going to draw a circle on paper, you would want to know the position of the centre of the circle, and the radius of the circle (the distance from the centre of the circle to any point on the circumference of the circle) as shown in fig 42. Using G code, there are two basic ways to specify the size and position of the circle. For the moment, we will use just one of those methods, because it's more versatile. It's the 'Centre Format Arc'.

All we have

If all we had were straight line moves, we would still be able to do some good work with our CNC machines. That's just as well, because the straight line move is all we have. But it's surprising where straight lines can take you. Remember that the control software, and the NIST core within that, can make the Controlled Point (CP) travel in a straight line between any two points.

A line is fine, and if we combine a sequence of moves we can travel around a square path. If we do a bit of trigonometry, we can use straight lines to travel around the periphery of any polygon. A polygon simply means a shape with many corners, and in a *regular* polygon the sides are all the same length and the angles are all the same.

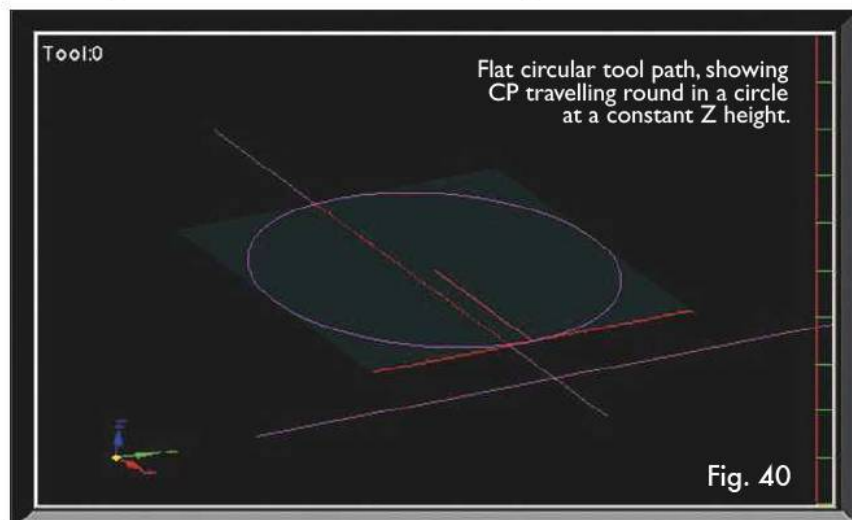


Fig. 40

First, the CP must be on the circumference of the circle (fig 43) so this is a circular move from where the CP is right now. If you want to machine a circle or an arc somewhere else, you will have to go there first. We will refer to this starting position as the current location, or the 'current point'.

Next, we need to know where the end of the path will be. If we move a full circle that would be a move back to the point where we are now but if the CP is to move in an arc and not a full circle, Mach3 needs to know where to stop. Sometimes it is easy to identify that point, and at other times we may need to do a bit of careful reasoning from a drawing, but we do need to know that point. We will call that the 'end point'.

Finally, we need to know where the centre of the circle is, in relation to the current point. The G code interpreter can then work out the radius of the circle, which will be the distance from the current point to the centre of the circle. It is aware of the starting point because that's where the CP is right now, and it can simply travel around the circle until it gets to the end point.

There are two ways to specify the centre of the circle. One is to specify the actual co-ordinates of the centre, and it is called 'Absolute IJ mode'. This is not too handy, because it nails down the centre of that circle quite firmly, and we will see later that it is useful to have a bit of flexibility so that we can cut the same circular path in a different place. If we specify the actual co-ordinates (i.e. the 'absolute' co-ordinates) we will find it difficult to do that, because we have said where the centre of the circle is always to be.

The second way is to specify the X and Y distances from the current point to the centre of the circle. That means the centre is always placed in relation to where the CP is currently located. If we move the CP to another place, we can cut a similar circle there because the centre is located in relation to the current point. There is a wrinkle or two, but that's a big advantage. This second way is our recommended method, for now, and it's called 'Incremental IJ mode', such handy names?

We can specify which mode we want by using the command G91.1 to set Incremental IJ mode, or by using G92.1 to set Absolute IJ mode.

In a program, our recommended initialisation block already contains G91.1, so that takes care of that, while that program is running.

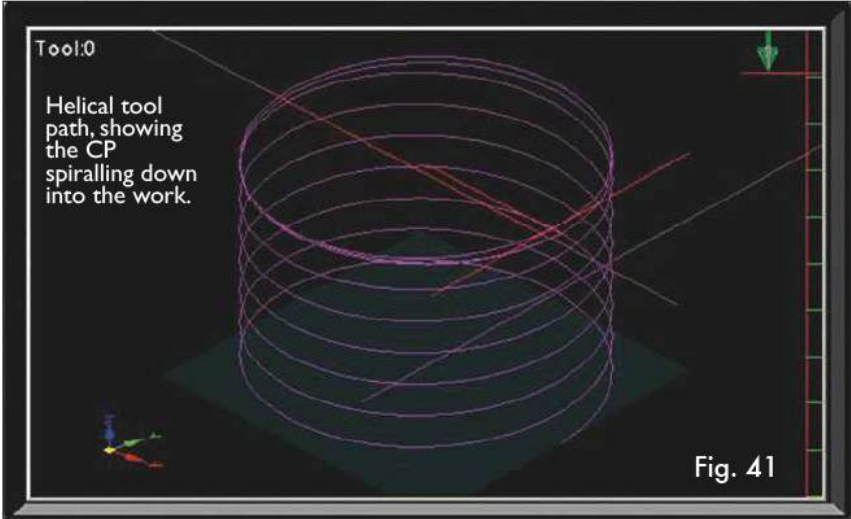


Fig. 41

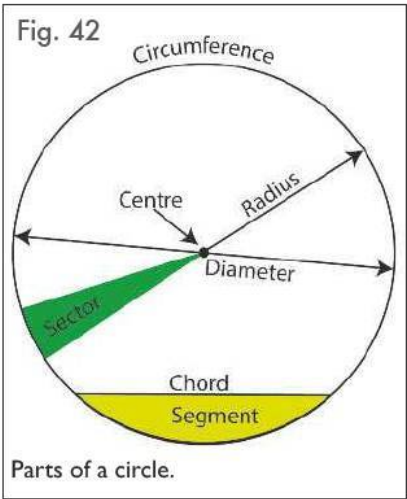


Fig. 42

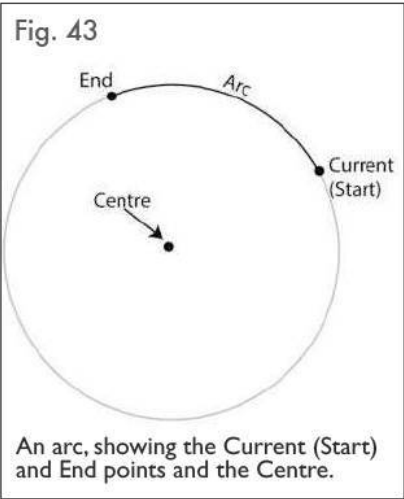
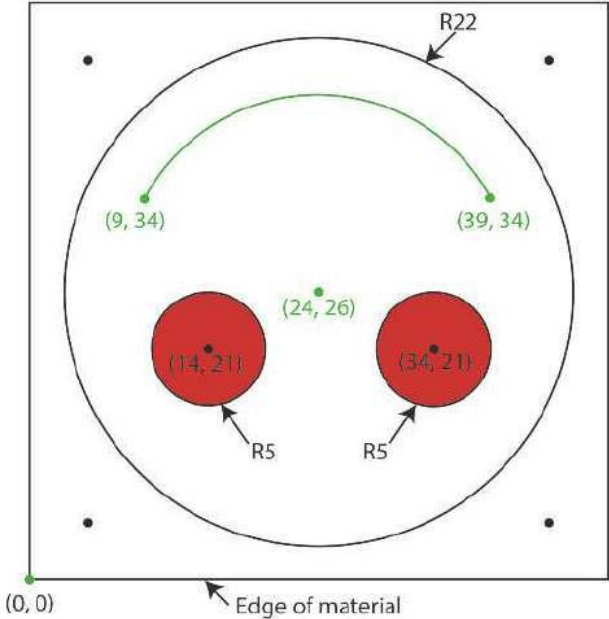
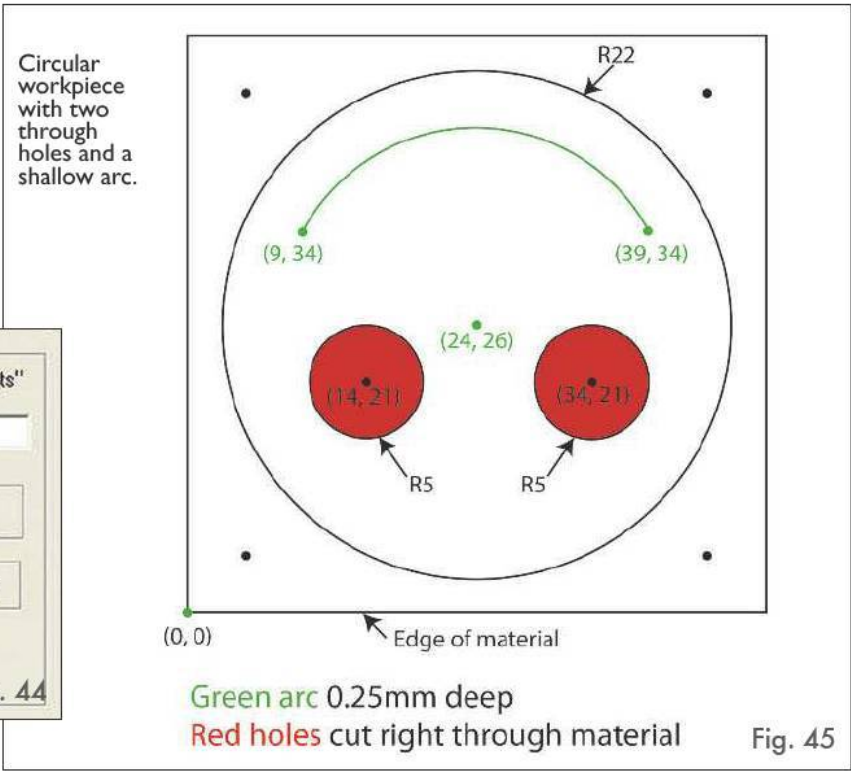


Fig. 43



Green arc 0.25mm deep
Red holes cut right through material

Fig. 45

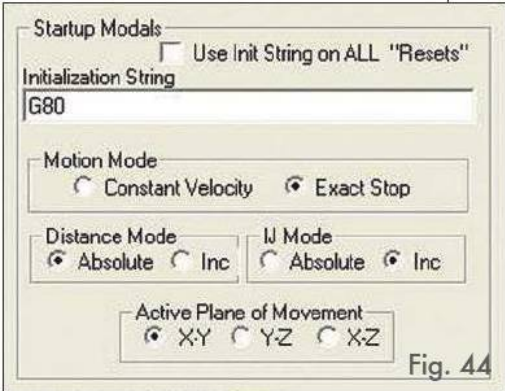
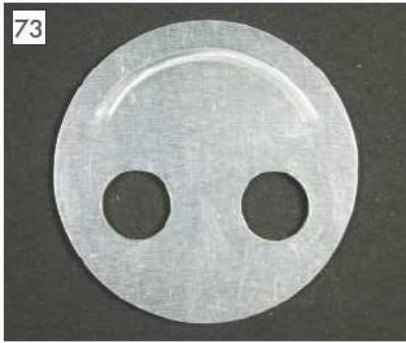


Fig. 44

Set the IJ Mode from the Config > General Config menu.



The finished work.

You can also type G91.1 in MDI mode. But to simplify things, in case you forget, Mach3 can be set up to use G91.1 by default. From the menus, choose Config > General Config; look in the second column from the right, about half way down, in Startup Modals, and set IJ Mode to Incremental (fig 44). When Mach3 starts up, it issues some commands to set itself up, and this is where it gets some of its settings.

Good practice means we should specify the IJ Mode within a program, for example, but having this set as the default condition means if we are working in MDI mode and not running a program, we can still use Incremental IJ mode without having to issue a G91.1 command every time.

For now, you should also check the box marked 'Exact Path'.

An example

After all that preamble, let's take an actual example.

Figure 45 and photo 73 show a circular plate with a pair of circular holes and an arc. Let's assume a workpiece which is a 1.5mm thick piece of aluminium or brass sheet, 50 x 50mm, with the work origin (0, 0) at the front left corner.

The programs which follow assume the use of a 2mm diameter end mill or slot drill, but you could use a 3mm or 3.16mm diameter cutter if you adjust some of the sizes given in the example programs.

The largest arc is a shallow groove, 0.25mm deep. The two smaller circles are cut out of the workpiece and then the circumference of the outer circle is cut to full depth to release it from the sheet.

The centre of the large circle is at (24, 26). You may wonder why it's not dead centre, at (25, 25). That's because you will not learn as much if X and Y have the same value. Think of it as an excuse for more advanced mental gymnastics.

Taking the green arc first:

If the CP is at the left-hand end of the arc, at (9, 34) and the arc ends at (39, 34) then the CP will need to move clockwise, so we need to use a G2 command.

The format of a circular move is:

G2 X~Y~Z~A~B~C~I~J~

where the ~character (the tilde character) stands for a number.

We will not be using the A, B or C axes for a while, so we can simplify that to:

G2 X~Y~Z~I~J~

The X, Y and Z values are the co-ordinates of the end point of the arc.

I is the distance along X from the current point to the X co-ordinate of the centre of the arc. Calculate it using the formula $I = X_{\text{centre}} - X_{\text{current}}$.

In this case, $I = 24 - 9 = 15$

J is the distance along Y from the current point to the Y co-ordinate of the centre of the arc. Calculate it using the formula $J = Y_{\text{centre}} - Y_{\text{current}}$.

In this case, $J = 26 - 34 = -8$

So our command becomes:

G2 X39 Y34 Z-0.2 I15 J-8

To try that out, set Z0 with the tool at the top surface of a convenient piece of material. Then, *altering the following code to take account of any obstructions*, cutting in air 10mm above the work:

G0 Z10

G0 X9 Y34

G2 X39 Y34 Z10 I15 J-8

How could we take that cut, for real? If you use a centre cutting end mill or slot drill, you could use

G0 Z10 (take the cutter above the work)

G0 X9 Y34 (position the CP above the start of the arc)

G0 Z0.01 (lower the CP to just above the work)

G1 Z-0.2 (take a plunge cut to depth)

G2 X39 Y34 Z-0.2 I15 J-8 (cut at constant depth)

Or you could position the CP on the top surface, at the start of the arc; cut around the arc, descending as you go, reaching full depth at the end. Then cut back at constant depth to the start of the arc. That way, the cutter will gradually ramp into the work as it cuts, then remove the tapering bottom of the arc on the way back.

If the return cut starts at the right hand end of the arc,

Xcurrent = 39, Ycurrent = 34

$I = X_{\text{centre}} - X_{\text{current}} = 24 - 39 = -15$

$J = Y_{\text{centre}} - Y_{\text{current}} = 26 - 34 = -8$

The cutter travels anticlockwise this time, so the return cut for the arc is:

G3 X9 Y34 Z-0.2 I-15 J-8

and the code becomes:

G0 Z10 (take the cutter above the work)

G0 X9 Y34 (position the CP above the start of the arc)

G0 Z0.01 (lower the CP to just above the work)

G2 X39 Y34 Z-0.2 I15 J-8 (cut clockwise, ramping into the work)

G3 X9 Y34 Z-0.2 I-15 J-8 (cut anticlockwise, at constant depth)

G0 Z10 (lift the CP clear)

Look at where you are going

If we were orienteering, I imagine it would be useful to look up from the map, from time to time, and use common sense to decide in which direction we should travel. Oh look; it's over there, to the left... 500 metres away.

I and J state how much the CP needs to travel from the current point to get to the centre of the arc. Imagine standing at (9, 34). How would you move the CP to get to (24, 26)? For X, you would move it 15 to the right, so I15. For Y, you would move it 8 towards the front of the table. That's travelling in the negative Y direction, and that's -8 units, so J-8.

This amounts almost to counting on one's fingers, but it gives a useful check on our calculations.

Arithmetic interlude

The arithmetic of all of this is quite simple, except that it is sometimes not. Negative numbers can cause local overheating of long dormant brain circuits, especially when there are multiple negatives in a subtraction. Forgive me for teaching my grandpa to suck eggs, but here's how I see it:

A sum like $39 - 24$ should cause no trouble, because we are subtracting two positive numbers. But look at this arc (fig 46):

If the CP is at X-21 Y34

$I = X_{\text{centre}} - X_{\text{current}} = -6 - -21 = 15$

If you are comfortable with that calculation, just skip the rest of this arithmetic explanation. If not, please continue.

Just to be pedantic, every number has a sign. Where it is a positive number, we usually omit the sign, but it is useful to leave it in, sometimes. In that case, our sum becomes:

$(-6) - (-21)$

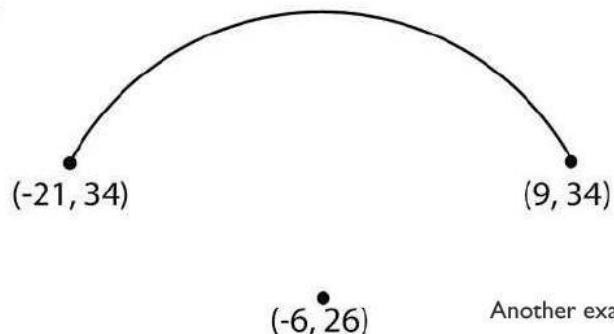
There are a couple of simple rules as to how to handle multiple signs which occur together:

+ next to + is the same as one + sign

+ next to - is the same as one - sign

- next to - is the same as one + sign

Fig. 46



Another example arc.

So our sum becomes:

$$-6 + 21$$

Now look at the size of the numbers. 21 is bigger than 6. How much bigger? 15. But the biggest number is positive, so the result will be +15 (written simply as 15, omitting the positive sign).

Check using the Look Where You Are Going method. Standing at the current point (-21, 34), is the centre of the arc 15 units to the right (or 15 units towards the back of the table, for Y movements)?

If the CP is at the right-hand end of the arc, at (9, 34),

$$X_{\text{centre}} - X_{\text{current}} = -6 - +9 = -6 - 9 = -15$$

Check: Is the X co-ordinate of the centre 15 units to the left of the current point?

Cutting out a circular hole

Now look at the left-hand circle in fig 45. Its centre is at (14, 21) and its radius is 5,

We could position the cutter over the circumference of the circle, and cut an arc all the way round, finishing where we started. The trouble is that wouldn't give us what we want. Unlike the previous arc, where we simply cut along the path of the arc, this time we must take into account the radius of the cutter. Figure 47 shows that when we cut inside a circle, to leave the circumference at the final finished size, the path of the CP is inside the circumference, and its radius is the radius of the circle minus the radius of the cutter. That's because the cutter cuts on its outer edge, which is further away from the centre of the circle than the CP.

Assuming a 1mm radius (2mm diameter) cutter and a 5mm radius (10mm diameter) circle, the CP needs to follow a path with 4mm radius (i.e. $5 - 1\text{mm}$).

Where to start? It doesn't matter much for this circle. Move the CP to (18, 21) which is as good as any other point. From the centre, moving to left or right, up or down takes us to a point whose co-ordinates are easy to calculate. It is unnecessarily difficult to calculate the co-ordinates of any other point on the circumference of the circle, unless you fancy a bit of recreational mathematics.

The cutter moves around the inside of the circle, and the spindle turns clockwise, so conventional milling means the teeth of the cutter should bite into the material as it moves forward. That means the cutter should move clockwise.

The End of the path will be the same as the Start: X18 Y21

The Centre is at X14 Y21 so $I = 14 - 18 = -4$ and $J = 21 - 21 = 0$

That makes sense, because standing at the current point (18, 21) which will be the Start, moving 4 units in the -X direction (to the left) takes the CP to the centre of the circle.

G0 Z10 (Safe Z)

G0 X18 Y21

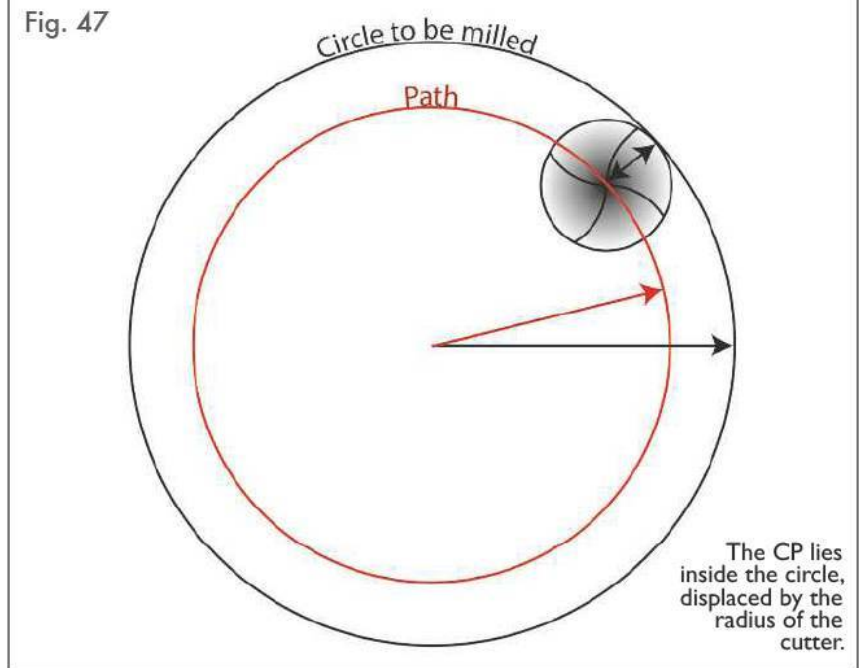
G0 Z0.01

G2 X18 Y21 Z-0.25 I-4 J0

will spiral around the circle, descending as it goes, until Z is -0.25

Add some G2 commands with the same values except that Z should increase each time, perhaps in increments of -0.25, until Z is -1.50

Fig. 47



That reaches full depth but leaves the ramped part created at the beginning of the last pass. There's a choice here:

Continue with the G2 commands, making the last two Z values -1.75 and -2.00, or take the cutter down just below the bottom surface of the work, then do a final pass at that Z height, to leave a flat bottom on the groove, removing the remaining tapered section left from the previous cut. The pass with Z-2.00 is simply to ensure that the cutter does cut all the remaining material and is right through the sheet, because the previous cut started at Z-1.50 and there may be small errors in the sheet thickness or our Z positioning.

G2 X18 Y21 Z-1.60 I-4 J0 (ramps down from the last height)

G2 X18 Y21 Z-1.60 I-4 J0 (flat bottom)

That frees the centre from the rest of the disc, but the cutter will cut into the surface

under the workpiece, so that should be the same material, or softer, than the workpiece itself. It also means that we need to get into the habit of regarding the supporting material as sacrificial, because it is going to get cut every time the CP descends below the bottom of the work; and that will be often.

The waste should break free, so be ready to step out of the way. I recommend blowing the waste away as it breaks free, using an airline or a puffer of some sort. The waste itself won't do much harm, but with a small cutter working in a small hole like this there is always the danger of damage if the waste jams between the circumference of the circle and the cutter.

The other circle, with centre at X34 Y21 can be cut in just the same way. In fact the commands will be the same except for the values of Xcurrent and Ycurrent.

To be continued...

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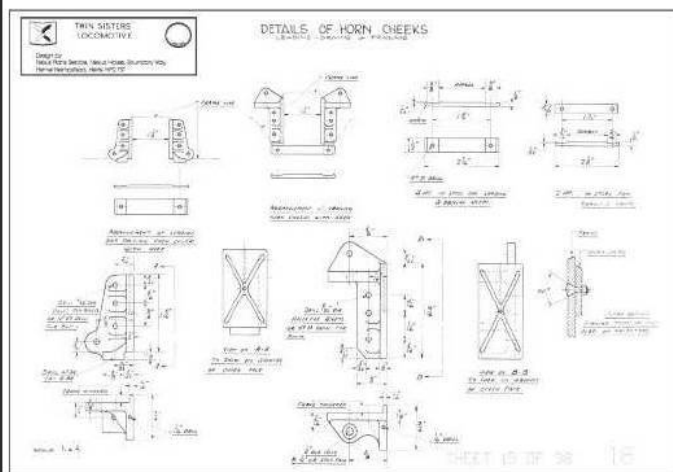
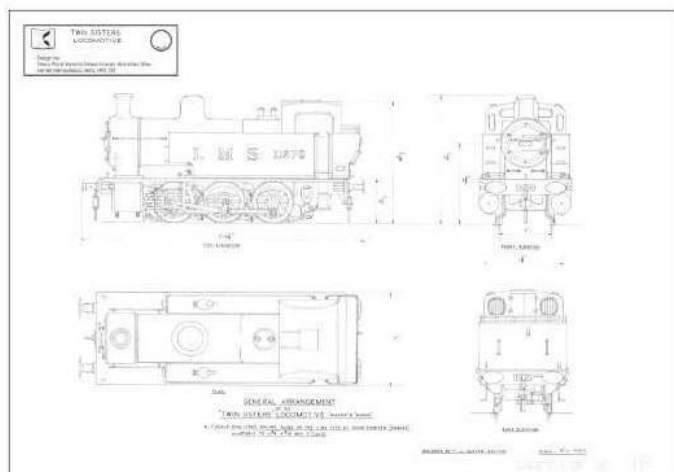
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**BETTER
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Making an Instrument Maker's Vice ^{Part 3}



David Piddington machines a Hemingway kit of casting and materials.

I was asked by one of our regular advertisers 'Hemingway Kits' if I would make two of these vice assemblies to check the drawings for accuracy, and to compose an outline of how the project might be worked.

Next, slacken off the cross slide locking screw and wind the slide towards you. We now need to take a minimal cleaning-up cut across the box face which is easily done by improvising a flycutter (**photo 36**) where it can be seen that I used a right-hand HSS turning tool set across the jaws of my self-centering chuck. This is not the correct use of a chuck, but a light loading such as this should not damage your equipment and it works well for me.

It is necessary for both ends of the boss to be true to the bore for if not, both the head end, and particularly the clamp nut will tend to sit at an angle and easy rotation will suffer.

Facing off the opposite end was then a problem that I puzzled over for several days. Obviously it had to be at exactly 90 degrees to the bore. The ideal would be a face mill of ½ inch bore and of a greater diameter than the boss. I used a cutter like this when an apprentice on the fitting benches where two internal bosses had to be 'trued' up prior to hand-scraping while fitting an oscillating component between them. However, I don't have a face mill and suspect few readers will have either and, having had a brief look on the Internet, I'm not certain what these are



The two finished vices.

catalogued as anyway, so the option of cutting this face while still in situ for boring had to be abandoned except for the possibility of making a special cutter and a bore-sized mandrel for same and back facing; experts only.

Using my equipment including the rotary table with both a horizontal and vertical mounting, I made a split expanding mandrel from silver steel and with a Number 3 taper tap size ¼ inch BSF did a trial assembly as shown in **photo 37** and **photo 38**.

Oh! And, yes, I know it's a crude slit made with a saw in a vice, but if readers really want to set up with a slitting saw and make a precision slot just for one job, please go ahead. **Photograph 39** shows the initial test cut being completed using the side of an end mill, and with an additional rotation prevention device, a small Myford angle plate, at the front to 'push' against the cutting force.

Editor's safety note. Please add a clamp to the casting and the angle plate.

I was surprised at having removed only a minimal amount of metal from the first face to find that my castings must have been close to final size as received. However, measure your casting before machining remembering that the overall dimension is not critical, in fact the design of screw and clamp knob allows for a shorter upper boss. Warning, take light, smooth cuts, limiting the onward cutter feed to no more than ¼ inch for each pass, as this is not a robust method of securing the casting.

Remove the sharp bore edges and do any additional surface trimming that you desire and then we can continue with machining the steel components. There is a cutting list on Hemingway Sheet 1 of 3 and I suggest that you identify each piece with a felt tip pen mark on the item number. Please note that there is no



Facing the boss.



Expanding mandrel to take the casting.



The casting on the mandrel.



Machining the boss.

number 10 on the list, though as I was supplied with two off x 4BA socket head cap screws, I assumed these were for that item. There is sufficient metal on item 4 to make this and item 12.

To establish a route towards completion of this project, the numbers of the cutting list seemed a good way to proceed.

Photograph 40 is of my unmachined parts numbered for identification. I used white, as this shows better on a photo.

The clamp spindle (**drawing 2**) is $\frac{7}{8}$ inches diameter mild steel and is provided with a $\frac{7}{8}$ inches chucking and machining allowance. Face both ends of both lengths of bar and put a BS2 centre drill at both ends having checked that the end is running truly. If it is not, then use your fixed point steady to keep it true. A Griptru chuck is ideal as it can be reset when required for accuracy. Alternatively, particularly for the centering, use the four-jaw chuck setting the bar using a DTI (Dial Test Indicator).

Photograph 41 shows the centering and facing set-up. Incidentally, to set the steady first loosen the three steady bars with the main unit close up to the chuck jaws. In press them in turn finger-tight on to the component bar and tighten the clamp nut. This operation should be done with the over arm clamp nut also finger tight only. Tighten the steady bar nuts



The raw materials.

fully. Now move the unit outward to the end of the bar, as in the picture, and put a few drops of lubricating oil on the bar and tighten the over arm clamp nut. Now carefully face off the component bar to $3\frac{3}{16}$ inches long and centre drill. Repeat for the other ends and parts.

Next, between centres, 'rough out' the bar as seen in **photo 42** but starting from the larger end would be better. Imagine that the smaller diameter length has yet to be machined, thus the large end is first 'roughed' to $\frac{5}{8}$ inch diameter and $\frac{5}{8}$ inch along and then the bar is reversed and the smaller diameter taken to $\frac{5}{8}$ inch diameter and $2\frac{1}{8}$ inches long. This part will remain a chucking spigot and will ultimately be



Centering and facing the bars.

removed. The remaining diameter may be machined to $\frac{15}{16}$ inches diameter

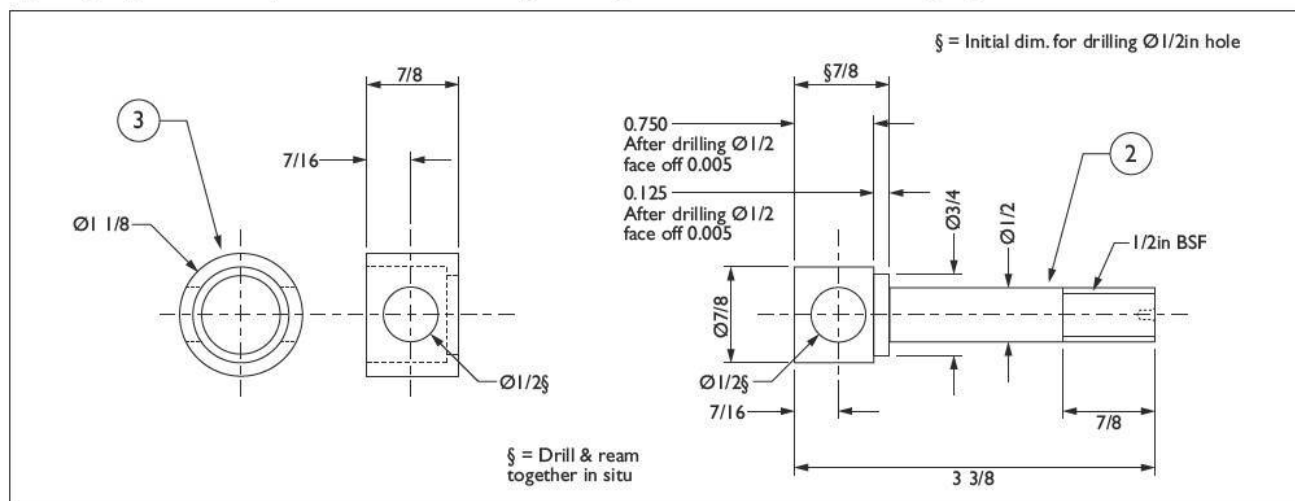
Note also the crude swarf deflector made from an offcut of 0.010 inch brass shim, vital for me as my workshop is an indoor ground floor spare bedroom, or at least that's what the building was designed for. Also note the extended 'Piddington' tool holder which I described in *Model Engineer* volume 162 of 1989, issue 3844, which enables the top slide to remain parallel to the lathe's axis and still clear the tailstock.

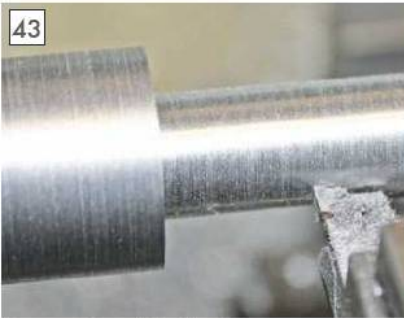
Remember that removing metal also creates a lot of heat, which in turn creates expansion of the workpiece so after every long cut, and after 2 or 3 of the shorter ones, readjust the tailstock centre to be firm with no slack. In 'the good old days' before live centres were readily available, hardened plain centres were used and with these it was essential to frequently re-adjust the centres for, if you didn't, you incurred the foreman's wrath when the centre point welded itself to the component and scrapped both that and itself. We frequently used to lubricate with tallow in attempts to avoid these disasters, but I believe we all learned the hard way, possibly more than once.

I am assuming that you will already have a driving plate and carrier. My home-made unit is shown here. The plate is made from $\frac{3}{8}$ inch x 2 inch MS plate as is the carrier. The driving plate is centrally secured to a Myford (reference 1935) chuck back plate with 4 inch x $\frac{1}{4}$ inch BSF Countersunk socket screws. The contact arm of the carrier is shaped to a width of $\frac{5}{8}$ inch to fit closely in a slot machined centrally on both halves of the driving plate. Cutting slots both sides make for equal balancing.

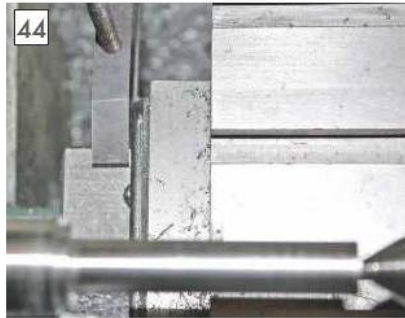


Roughing out the bar.





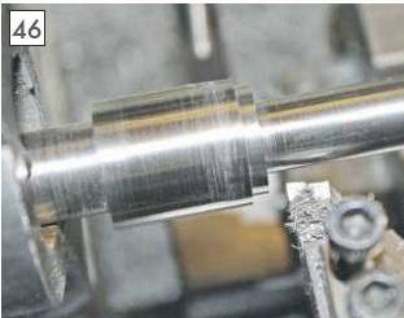
43 Tangential tool finish right; Carbide tool finish left.



44 Improved length stop.



45 Improved depth stop.



46 The completed shoulder.



47 Ready for threading.



48 The finished thread.

The contour of the plate has proved satisfactory in its rotational balance. However, the drive part was bent at its upper end with the aid of an oxy-acetylene torch to get it red hot. Anyone copying this idea without the necessary heat could substitute a 90 degree piece to fit between the forks double-screwed to the main dog body. It will also be noted that the Vee where the workpiece is clamped has two brass contact inserts to reduce clamping damage to components; these were brazed in position, but again could be screwed on.

Returning to the clamp spindle, finish machine between centres being very careful to adhere to strict dimensions. No manufacturing tolerances are given but the $\frac{1}{8}$ inch length should become a close running fit inside the upper boss of the casting and the other end and the clamp ring should be machined similarly. So, if the drawing says $2\frac{1}{2}$ inches, then work as close as possible to the decimal conversion, i.e. 2.500 inches. The $\frac{3}{4}$ inch diameter shown $\frac{1}{8}$ inch long which has to be a close sliding fit inside the clamp ring should be made exactly 0.750 inches diameter so that it can be used as a gauge when finish boring the ring. For the actual finishing it is perhaps best to revert to HSS tools rather than carbide tipped. The best I have found is a tangential tool described and advertised in recent years though I made my own. Carefully ground, this tool can produce an excellent surface. **Photograph 43** shows the difference; that on the right is the tangential tool result and that on the left was done with an almost new carbide tip, only used for these two shafts, both using the same spindle speed of 600rpm and the same feed of 0.002 inches per spindle revolution.

I took additional photos to show how, should readers have a batch of identical parts to make, I machined the angle to accept the clamp ring. **Photographs 44** and

45 are of some length and depth stops improvised with toolmakers clamps and **photo 46** is of the completed shoulder to accept the clamp ring.

Reverse the clamp spindle between centres and set a length stop so that the major diameter is exactly 0.875 inches long and reduce the smaller diameter to about $\frac{1}{8}$ inch. This is now only a chucking spigot for the threading operation and will eventually be removed altogether. Pick up a very fine file with a handle and remove the burrs from the three machined corners giving these a tiny radius. It is best to use the file left-handed to keep your hands as

tightened, tighten the chuck also. The thread length is given as $\frac{7}{8}$ inches. Make a felt tip pen mark around the bar at this distance to work to with the front face of the die. Use a lubricant such as RTD. And the highest spindle speed in back gear. **Photograph 48** shows the result, though the tool post had to be removed to allow support for the die handle as it would be unwise to attempt this using your hand for this operation. After the threading there will be some burrs left so remove these carefully with the fine file used recently. A rub with some well-worn emery cloth might not be amiss either.

Remember that removing metal creates a lot of heat, which in turn creates expansion of the workpiece so after every long cut, and after 2 or 3 of the shorter ones, readjust the tailstock centre to be firm with no slack.

far away as possible from the revolving driving plate and carrier.

As already mentioned, we can now thread the clamp spindle end. For those intending to screwcut this will be done with it already between centres. As I already had a pre-set die in its holder which will cut an exact size thread I chose that option. If you are like me put the clamp bar back between centres but without the carrier and then position your fixed steady and adjust the bearing blocks on the 'to be threaded shank' as in **photo 47**. Now remove the steady, driving plate and headstock centre, re-fit your three-jaw chuck putting in the clamp spindle spigot end with the chuck jaws finger tight. Reposition the steady leaving sufficient protrusion for the die to cut the thread and with the over clamp fully

The part list for the clamp ring (**drawing 3**) lists it with diameter of $1\frac{1}{8}$ inches and it is supplied as bright drawn stock at this nominal size, which, when measured, is one thou' undersize and not necessarily a precision diameter along its length. With the possibility that your chuck is well used and not accurate, the use of machine-able soft chuck jaws is recommended. Readers who have not used this process before should note that after buying a set, these must be carefully fitted to your chuck using a fine file along the inner slot sides of the jaws, but not the chuck slides, until the new jaws will slide smoothly into their appropriately numbered slot. It would be best to dismantle the chuck and clean out any swarf and grease internally, then grease-lubricate and reassemble.



A 'spider'.

Before boring the jaws to accept your workpiece, a block of metal, or a special device called a 'spider' must be positioned at the back of the jaws so that they may be tightened on to it. The spider must be sufficiently large to enable the minimum amount of metal to be bored from the jaws to a diameter of about 0.000 to 0.002 inches less than the diameter you wish to hold ensuring a firm grip. If larger, then the workpiece can 'wobble' and accuracy will be lost. These spiders are badly named as they usually have three adjustable bolts in it at 120 degrees. A spider is shown in **photo 49**; you might make several of these in different sizes. The boring process is shown in **photo 50** where the 'spider' is just visible. When you have more than one component it is best to set a depth of cut stop for the tool. If possible the $\frac{3}{4}$ inch hole should be reamed, but lacking one of those, bore to a gauge made from $\frac{3}{4}$ inch diameter precision ground mild steel or silver steel. Aim for a close sliding fit on the gauge.



Boring the jaws.

Finish boring for the body of the clamp screw at $\frac{7}{8}$ inch, setting a depth stop for the tool as described before using the body of the component as the gauge. Make sure that the bore depth is exactly the same as the length of the clamp bar where this will fit. Then carefully part off leaving an amount for cleaning up to length later. I recommend using a live tailstock centre to support the work, though you might wish to make an oversize slip-over centre for larger bore diameters. **Photographs 51** and **52** show this operation and the home-made accessory unit.

Re-chuck the clamp ring and face off both ends as required making certain that the end with the internal collar is exactly in line with the mating face on the clamp spindle. Then, noting that the length of the turned boss on the spindle is exactly 0.875 inches long, make sure that the outer end of the clamp collar is exactly in line with its mating face. Carefully remove all sharp



Parting off...



...using a false centre.



The tooling bush.

edges just enough so that you cannot cut your fingers on. This was called 'breaking the edge/corner' in my younger days.

We now need to hold these two components securely together while the cross hole for the vice strut is drilled and reamed. The way that suggested itself to me was to have a special long bush that could be clamped to the threaded end of the clamp spindle and pressing firmly onto the clamp collar using a nut on the threaded end. This would be reamed through $\frac{1}{2}$ inch diameter having a shallow recess in one end to clear the $\frac{3}{4}$ inch diameter of the clamp spindle's central boss. A piece of $\frac{1}{8}$ inch diameter by $1\frac{1}{4}$ inch long mild steel with a shallow recess on one end face, machined out to just larger than $\frac{3}{4}$ inches, will serve for this and I will recommend a drawing to be included, as well as a piece of bar in the kit (photo 53).

In order to use this we now need a locking nut and it is unlikely that most readers will have a standard hexagon nut for this. However, the vice needs a clamp knob (**drawing 4**) and a vice knob (**drawing 11**) of which the former has the thread needed. The 1¼ inch diameter bar supplied is long enough for both components. Face the minimum of metal from both ends ensuring that the faces are at ninety degrees to the axis.

My method now uses my rotary table together with a chuck with a dedicated back

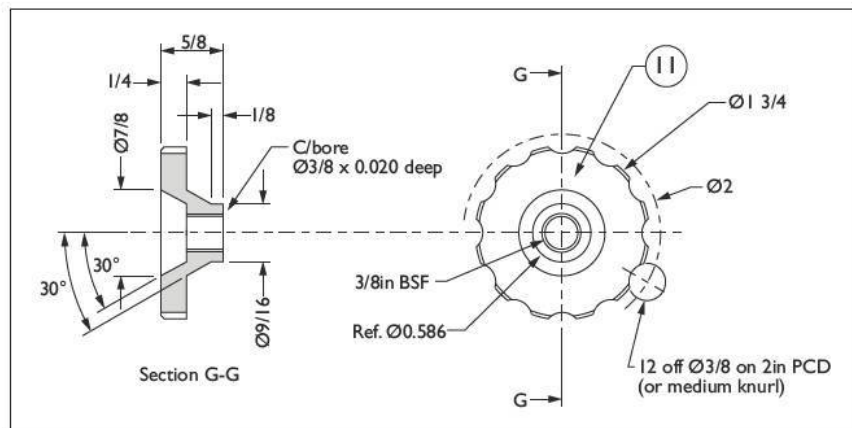
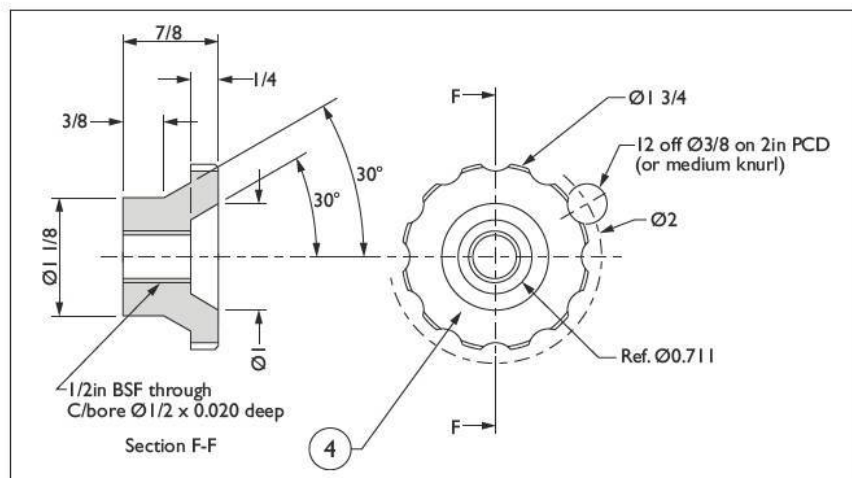


plate solely for use on this equipment. First align the table with the axis of the milling head spindle and, as an optional extra, also align the unit square to the mill table (photo 54). Make sure you take up the entire leadscrew backlash, and note in which direction, so that when you set the radius for the grip indents, 1 inch for a 2 inch PCD (Pitch Circle Diameter, you wind the table in that same direction and then lock firmly both the X and Y table axes. Note also that there is a location bar from the Clarkson chuck to the three-jaw chuck with which the bar is gripped (photo 55). This is before the backlash setting is done and the chuck locked to the table (photo 56).

After fitting and clamping a $\frac{3}{8}$ inch end mill into the quill chuck, set a depth stop to, say, $\frac{1}{2}$ inch from the top of the clamp knob steel and plunge the cutter carefully down. Repeat this for the other eleven grips making sure that you index accurately at 30 degrees each which on a 60:1 ratio worm wheel is five turns of the setting handle for each division. If you have an industrial dividing head, this may have a different worm and wheel combination in which case you will have to work out the correct number of turns or just use the degree scale on the rotary table. Photograph 57 shows the work in progress. It is inevitable that swarf will enter the body of the chuck, but this can be considerably reduced by forcing in small wedges of 'kitchen roll' paper as can be seen in this image. Then invert in the vice and repeat for the other end, though make sure the chuck jaws grip between the machined indents.

With two knobs of unequal dimensions I spent a long time deciding on whether to leave the bar in one piece and turn end on for common dimensions, or to part off into two separate pieces. Parting off in a smaller lathe has its difficulties, particularly for larger diameters such as for this project but I felt this was the way to go remembering that soft chuck jaws would enable the inner tapers to be standardised even though their diameters differed. Put some marking pen around the circumference at about half way between where the small ends of the two nuts reach and then scribe a line to the approximate centre. Then with the bar in a standard chuck, supported with a tailstock live centre, plunge your parting tool in as



Aligning the rotary table.



Clamp the chuck to the rotary table.



Cutting the scallops.



Aligning the chuck on the rotary table.



Home-made top slide stop.



Using the three-way carriage stop.

Having sawn through almost to the middle, remove to the bench vice and finish sawing there. Should your piece have taken you right through, that piece of wood will save the embarrassment of cutting into the lathe bed where anyone who sees it will know you are a clumsy *****!

As I mentioned at the start, I am making two of these vices to check the drawings, and this being so I desired to make them as identical as possible. So for the clamp knobs I imagined I was making a larger batch and adopted suitable processes. My Super 7 has had a number of changes over the years to facilitate such manoeuvres and to this end I made up a simple adjustable length stop for the top slide (photo 58) and also a three-position rotating saddle stop as in photo 59.

To be continued...

Parting off in a smaller lathe has its difficulties, particularly for larger diameters such as for this project but I felt this was the way to go remembering that soft chuck jaws would enable the inner tapers to be standardised even though their diameters differed.

far as you can, say $\frac{1}{2}$ to $\frac{3}{4}$ inch using cutting oil. The remainder is best hand sawn through. There is a great temptation to do this in the lathe instead of in the bench vice, so if you do then (a) set the lathe spindle to the slowest direct drive speed, say 200rpm and (b) secure a piece of wood to the lathe bed beneath the line

of cut. With a new 18tpi saw blade using straight, purposeful, forward strokes, cut through the bar keeping your leading hand and overall sleeve well clear of the revolving lathe chuck. This procedure may prove impossible if you have a chuck safety guard fitted so recourse to the bench vice may well be the safest anyway.



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Building a Miniature Drilling Machine

Part 3

Stephen Bondfield uses an outrunner motor to power a drill.



Very little has been published outside of the realms of radio controlled models, on the subject of outrunner power units which are used to drive model aeroplanes, boats and trains. The brushless outrunner motor has not yet found its way into mainstream mechanical and precision engineering applications. The design of this bench drill produces an efficient, functioning item that is simple to make and simple to use.

A similar bush is in the lower arm to allow free rotation of the drilling table to ease the positioning of the workpiece on the table. All of the aluminium inserts for each arm's clamp ends were also fitted with bronze bushes, which greatly enhance smooth movement and adjustment and prevent wear when moved on the column of the drill.

The bronze material used for the bushes was found to be quite compatible with both the stainless steel column and the barrel which contains the bearings and drive shaft for the drilling assembly. There hasn't been any evidence of 'spalling' between the surfaces of the two different metals that might otherwise occur when two metal surfaces are moved against each other under pressure and force.

Photograph 17 shows a collar that can be clamped onto the column to allow the drilling head to swing without falling down. There is no need for a column under the drilling table as the arm rests on the lower column mounting.



The column collar.

The brushless motor is attached to the drill/barrel assembly by a flange fitting to one end of the motor (photos 18, 19, 20 and 21). The extended section of the flange mount is fitted into the barrel section and secured by three equally spaced 3mm screws. A simple linkage is secured on to the shaft of the motor, by three equally spaced grub screws around its circumference.

A horizontal slot machined through the other end of the linkage forms the secure location for the Tee formed at the end of the drill shaft which is also slotted, drilled and tapped 3mm to accept the 4.5mm diameter rod fitted across its slotted upper end (photo 22).



The drive dog on the motor.



The finished drill.

The drilling assembly is fed by a pinion driving a 32 Diametral Pitch rack which has a sprung return as in a conventional bench drill.

The barrel was made from a piece of 32mm diameter 304 grade stainless steel round bar, drilled 16mm through its entire length. One end was bored out to accept the motor flange and linkage to the drill shaft and bearing. The other end was bored out to accept the thrust and ball bearings for the drill chuck.



The motor fits onto the flange.



The motor flange and drive dog.



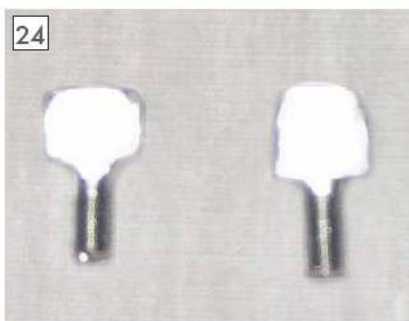
The barrel and motor flange.



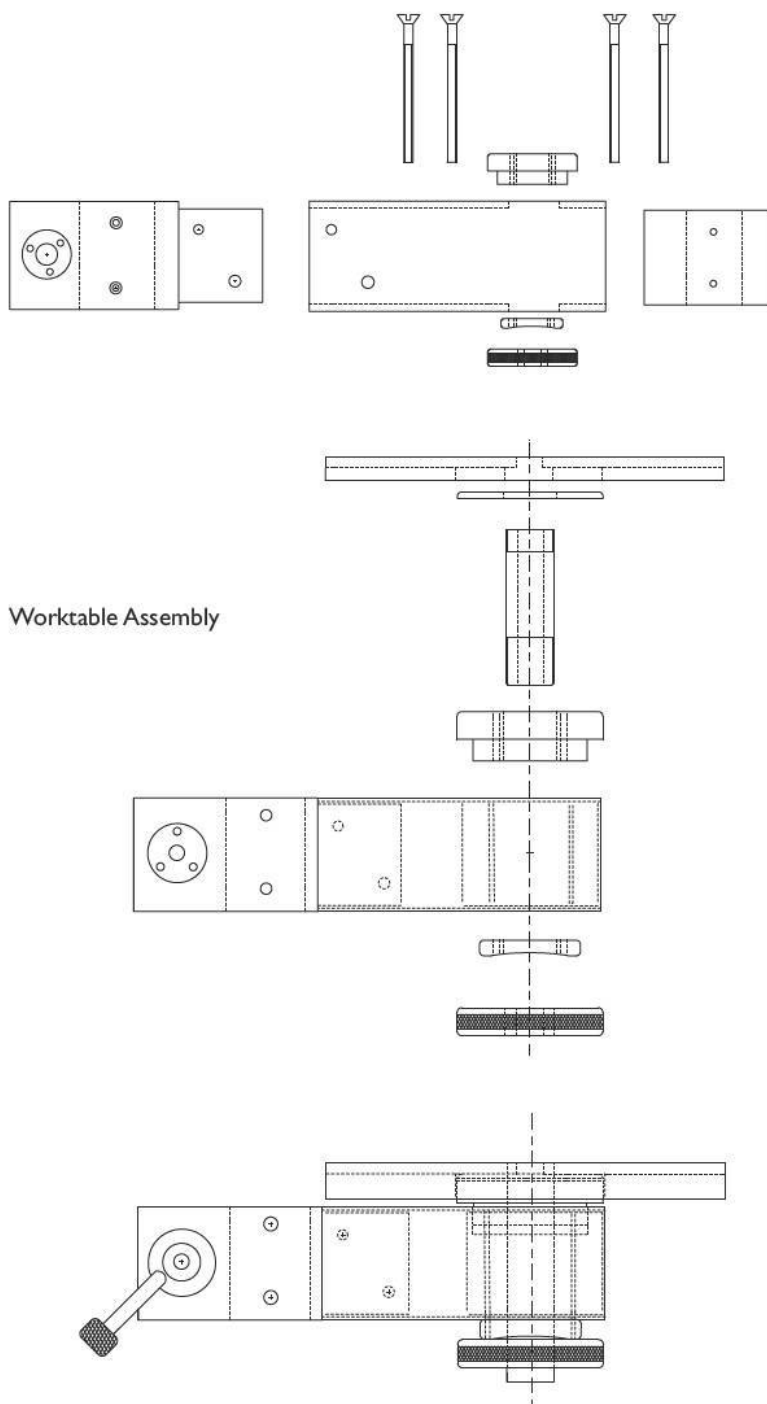
The keyed drive shaft.



The rack slot milled and drilled.



The threaded tabs.



Worktable Assembly



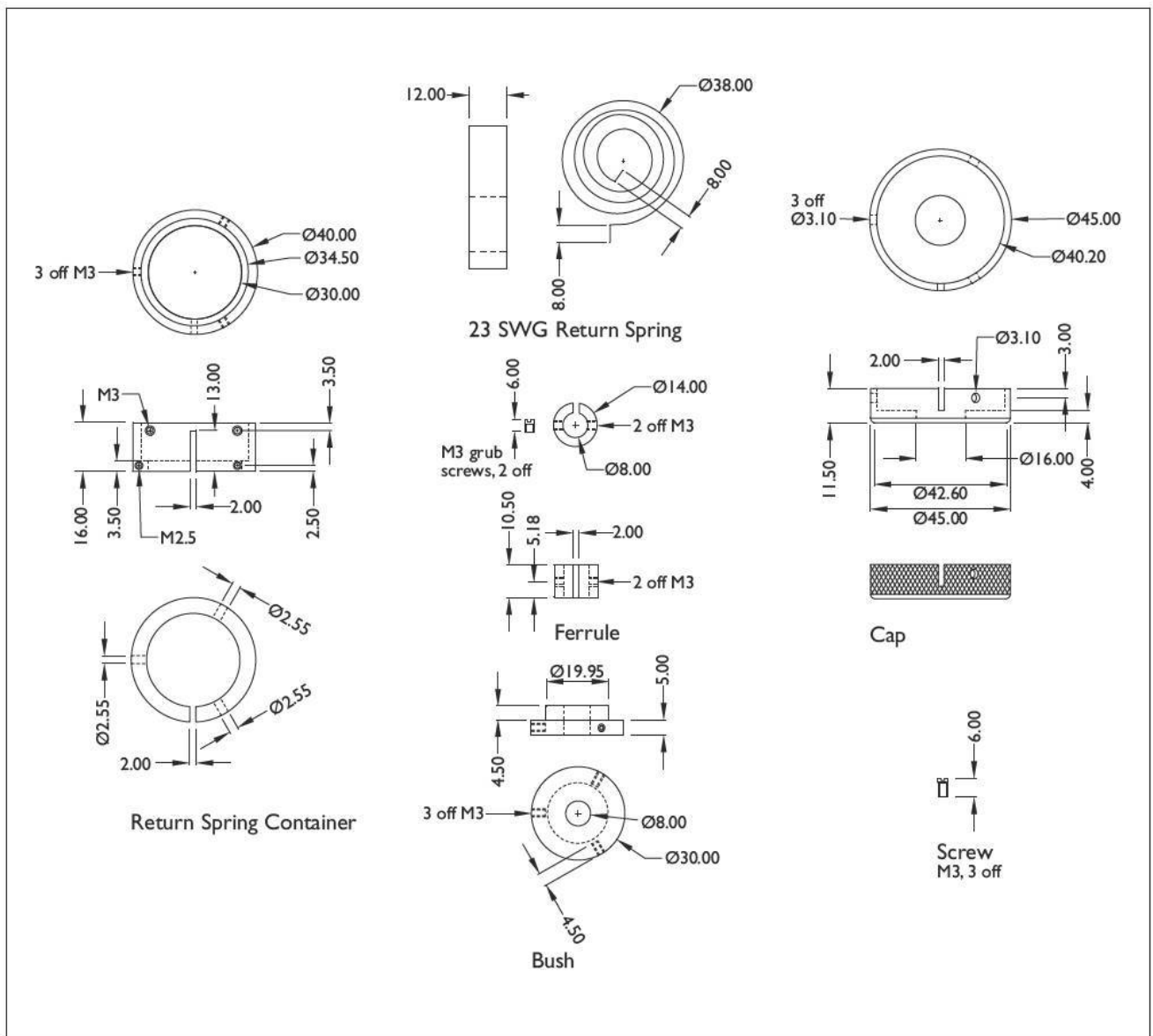
Side view of the tabs.



The tabs in the barrel.

Machining the rack slot

After these actions had been completed the barrel was held within the parallel clocked jaws of the milling machine vice and the 10mm wide slot for the rack was then machined 3mm deep and 63mm long. Two holes were then drilled and tapped 3mm, at 41mm between centres, in the centre of the slot, the first being 15mm from the drive motor end (**photo 23**). These tapped holes accept the two tabs (**photo 24**) that fit inside the slots that will be machined into the underside of the rack. **Photographs 25 and 26** show the tabs fitted to the barrel.



When in place, the rack is drilled across its width and the two holes are positioned to intersect the two tabs at their centre height within the rack. The holes are then reamed out with a taper pin reamer to accept the taper pins that hold the rack securely within the recess of the machined slot on the outer surface of the barrel. When fitted, each side of the rack is filed to remove any projection of the taper pins.

The barrel is the most important member of the drilling assembly and its vertical movement is provided by a capstan/quill action integrated with the rack and pinion (photo 27).

Accuracy in the construction and mating of the moving parts is necessary if precision is to be achieved. Firstly, the close fitting of the barrel within the bronze bearing and the subsequent vertical movement is prerequisite to accuracy when drilling and must be at exactly 90 degrees to the work table of the lower radial extension below.

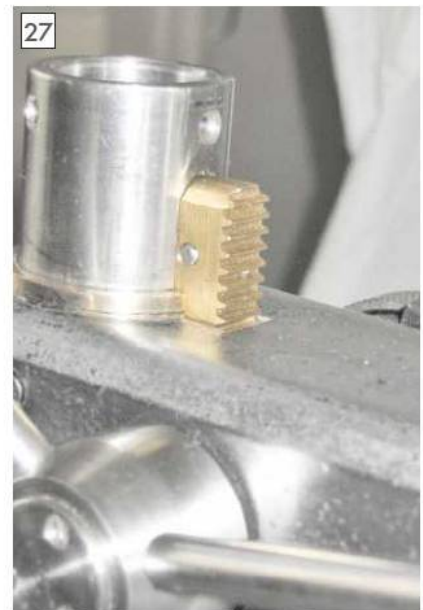
The enclosing tension of the plain bearing can be varied by tightening the four 3mm grub screws which locate and secure the bearing within the aluminium

insert within the steel box section. These four screws are fitted from the outer surface of the box section and are then tapped to extend all the way through the aluminium insert to the bearing shell itself upon which they exert pressure. This action has a direct effect on the feed of the barrel, creating more resistance as the screws are tightened.

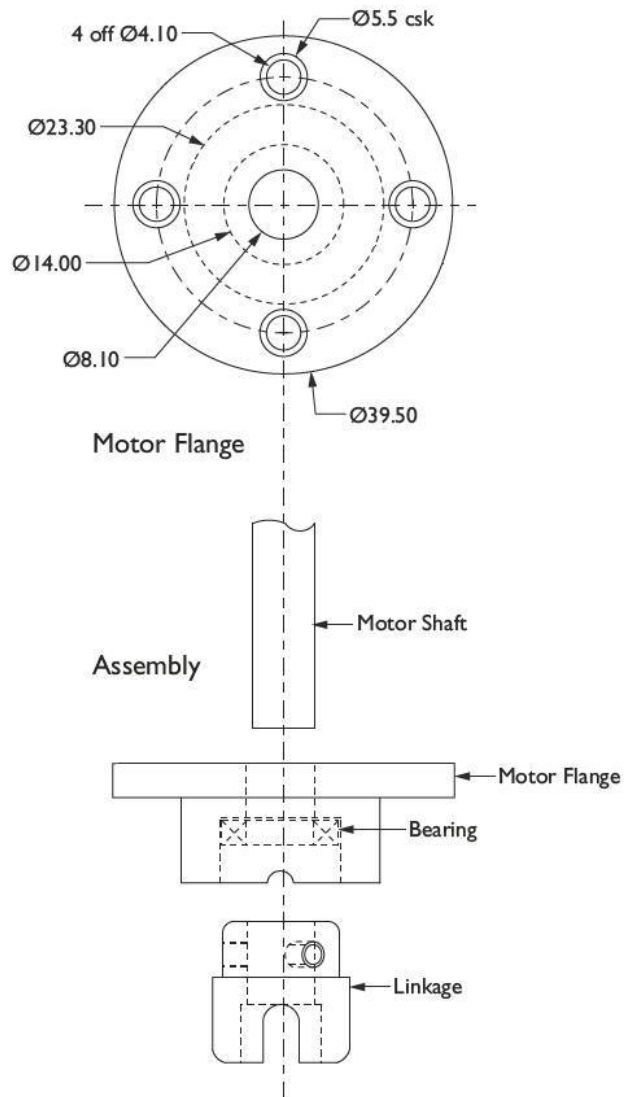
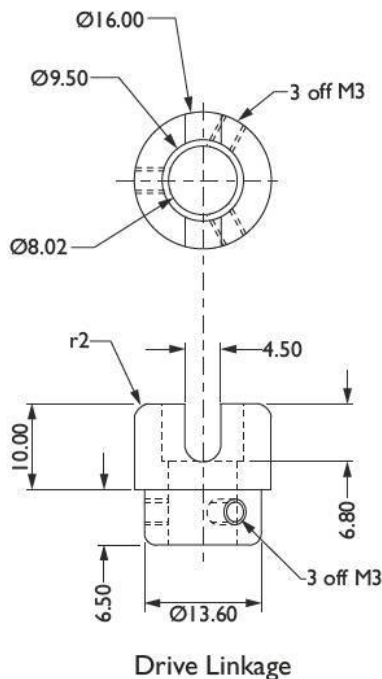
After adjustment there shouldn't be any free movement of the barrel within the bearing shell and aluminium insert, neither sideways nor forwards or backwards.

The significance of the tensioning becomes apparent when the pressure of the rotating drill bit comes into contact with the surface to be drilled, as the drill bit might be found to wander off centre and break if the fit of the vertically moving barrel is sloppy or slack.

Secondly the relationship between the rack and pinion must be such that the feed of the drilling assembly is smooth and uninterrupted and that any backlash is taken up by the tension of the spring within the mechanism that causes the vertical return of the barrel.



The rack and pinion assembled.



FURTHER INFO.

Motor and electronic items were obtained from; 4-Max
www.4-Max.co.uk

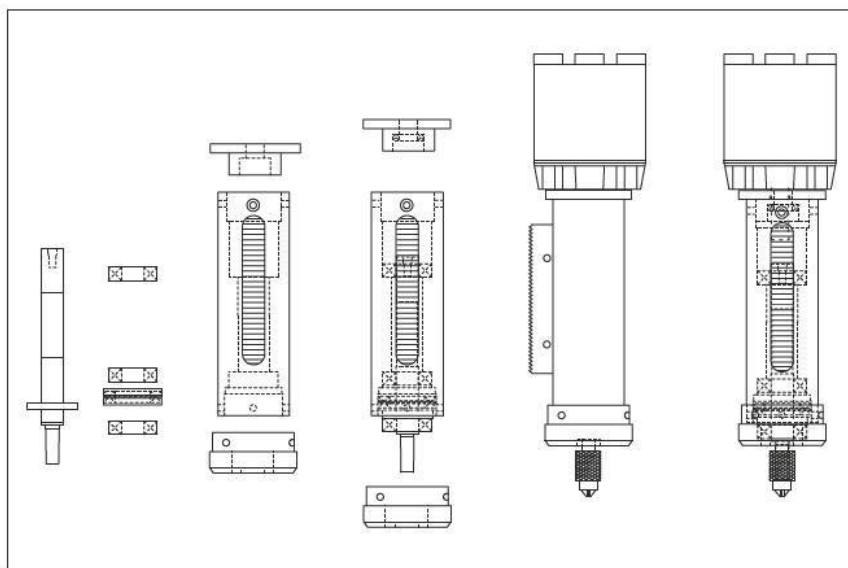
Editor's note: The power specification of the motor is correct. However, the maximum power is at a much higher voltage than the 12 Volts used here. If you have a need to run this motor at full power you must upgrade the wiring etc. to suit the working voltage and amperage drawn by the motor.

Accuracy is required

Machining measurements must be accurate in order to allow the moving parts of the quill assembly to reciprocate and function efficiently.

The pitch of the pinion must mate to the correct depth with the teeth of the rack to provide a smooth feed for drilling, without excessive backlash. Tolerances for this purpose are quite small and accurate fitting of the component parts is necessary if the following drilling action is to be completed with efficiency when power from the drive motor is applied.

To be continued...



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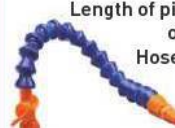
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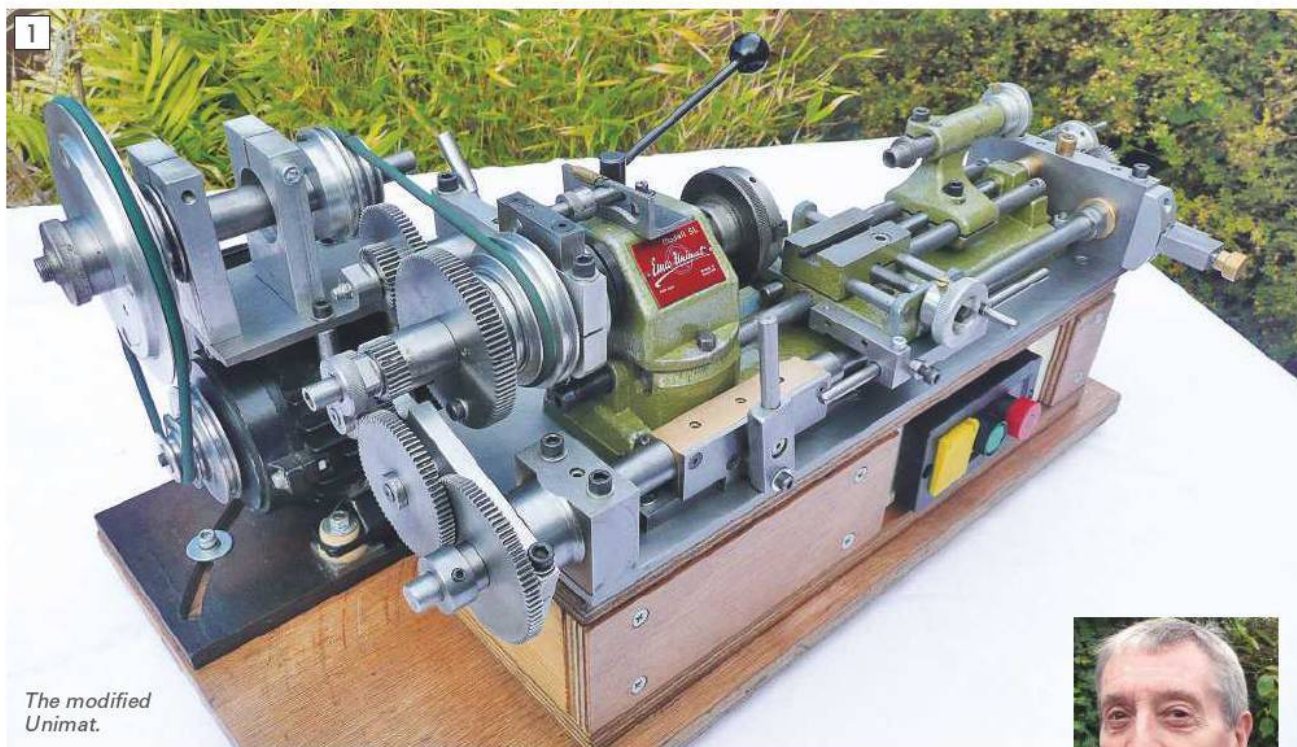
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The modified Unimat.



Unimat SL Lathe Modification

Terry Gorin adds back gear to his Unimat lathe.

Construction details shown on the drawings included with the articles are the result of many pencil sketches and/or modifications during fabrication and whilst the end result has proved more than adequate for my purposes, I have commented where dimensions, etc. might be modified to advantage.

It is important to re-emphasise here that none of the modifications compromised the

original lathe design nor were intended to increase the lathe's cutting capability, which is limited by the headstock spindle and bearing design and rigidity of the round bar bed rails. The method and sequence of machining, drilling and screwcutting of components shown on the drawings will be self-evident to experienced readers and I have only commented on the method and sequence of specific operations.

An earlier article (ref 1) gave an overview of my reasoning and methodology in modifying my Unimat SL to perform as a conventional screwcutting lathe. In this and following articles the modifications have been grouped into modules and presented in the sequence in which they were constructed in the prototype.



The new spindle components.



The back gear components.



Spindle and back gear subassemblies.

Headstock

The satisfactory completion of this module was a first essential in the modification of the lathe. Figures 1 and 2 show constructional details for the components mounted on the spindle extension (screwed to the rear of the original spindle after removal of the existing cone pulley). Figures 3 and 4 show constructional details for the backgear components mounted on a new bracket at the rear of the spindle sleeve which replaces the original motor bracket. Figure 5 shows the general assembly of all components, which are



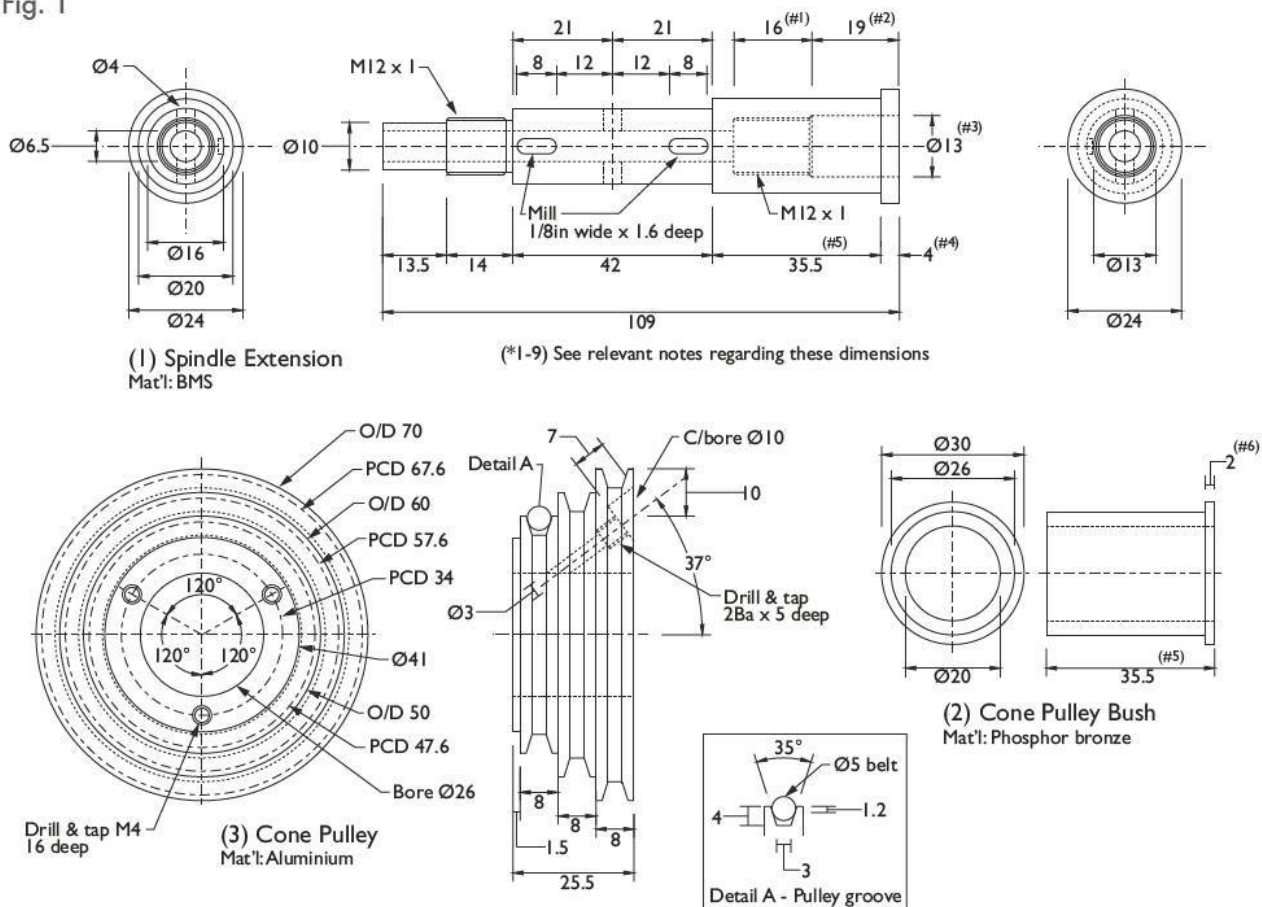
The assembled headstock.

shown separately (photos 2 and 3) as sub-assemblies (photo 4) and assembled to the Unimat headstock (photo 5).

The original Unimat spindle return spring and flanged washer, shown in the latter photo, was refitted during the headstock re-assembly. All materials were

obtained from Rapid Metals Ltd (ref 2). Free cutting mild steel was used for all circular components and all machining was carried out on a Myford ML7 lathe. All gears were obtained from HPC Gears International Ltd (ref 3) and further machined as described.

Fig. 1



Spindle components

The components are numbered in the order in which they were fabricated. The spindle extension (1) was fundamental to the success of the project and only when this had been fabricated and performing satisfactorily could the remainder of the headstock be completed and the following modules made. The completed extension, with keys fitted (photo 2) was a second attempt to achieve acceptable running concentricity (run-out is within 0.001 inch on the cone pulley bearing diameter nearing 0.004 inch at the power take-off gear bearing). These limits are acceptable for my purposes but a more able engineer might achieve greater accuracy. This second extension was fabricated from a 150mm length of 25mm bar. Using the Myford lathe, a fine line was inscribed on the circumference at 30mm from one end and a further line inscribed 109mm from the first. These lines denote the longer temporary work holding stub at one end, the finished overall length of the component and a shorter temporary stub 11mm long at the other end. Using the three-jaw chuck the bar was then machined in the following stages:

Stage 1 – The longer stub was chucked with the inscribed line protruding 2 or 3mm from the jaws. The shorter stub end was then lightly faced and centred for tailstock centre support. Only a small central area needed facing and a steady was not

needed. All diameters and shoulders were then machined to within approx. 20thou or ½mm of the finished sizes.

Stage 2 – The part machined bar was removed from the chuck and the long stub sawn off 2mm or so from the inscribed line. As a ship modeller, first and foremost, serious parting off is not on my agenda! The bar was then reversed, with the chuck now gripping the '20mm' diameter shaft and the '24mm' diameter collar tight to the jaws. The protruding end was then faced full width, the finishing cuts up to the inscribed line being the final facing this surface will receive, and the 13mm bore and M12 x 1 female thread cut. Good engineering practice dictated that the thread should be machine cut to part depth with final cleaning up with a tap. Lacking the expertise and confidence, however, to attempt this on a deep 'hidden' thread I resorted to the following alternative method. The full length of the bore and thread were initially drilled and bored to the M12 core diameter. The bore length was then increased in diameter to a close running fit to the M12 tap when inserted, the bore both centralising and supporting the tap, the end of which was then gripped in the tailstock chuck. Thread cutting commenced by hand turning the lathe and finished and bottomed out by a tap wrench and tailstock centre support. Finally the bore diameter was increased to the closest possible sliding fit to the 13mm spindle diameter, but still allowing the

spindle shaft to be drawn into the bore by the thread. The 19mm (#2) bore and 16mm (#1) thread lengths ensure that when the spindle extension is fully tightened to the rear bearing inner race the spindle shaft remains clear of the bottom of the bore and the spindle thread is not clashing with the shoulder at the end of the female thread. The near finished extension was again removed and the remaining stub sawn off short of the inscribed line.

Stage 3 – In order to maximise concentric running of the extension, when screwed to the lathe spindle, a mandrel to replicate the pulley end of the Unimat spindle was turned as fig 6. The part machined extension was then screwed onto the mandrel, tight up to the shoulder, the sawn end faced up to the inscribed line, centred for tailstock support and all diameters and shoulders machined to final dimensions. To avoid problems later the 4mm (#4) collar and 35.5mm (#5) shaft lengths should be as accurate as possible. In this instance the M12 x 1 thread and all other male threads on this project were machine cut to part depth and finished by die.

Stage 4 – For the remaining operations, milling the keyways and cross drilling the 4mm tommy bar hole, the extension was held in a previously made centre drilling fixture (MEW Issue 113) clamped to the cross slide. Centre finding was unnecessary and only minimal longitudinal and cross feed was needed to

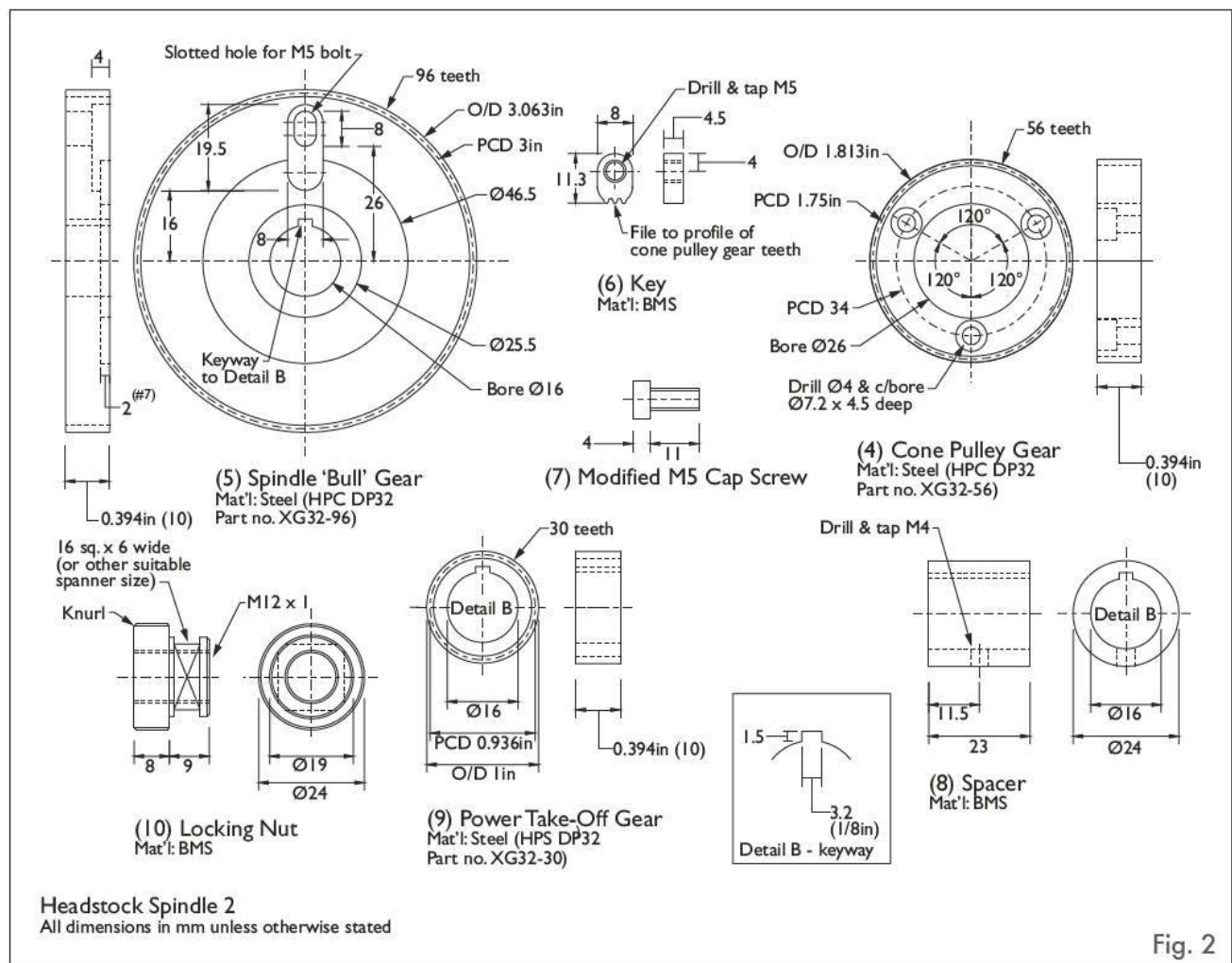


Fig. 2

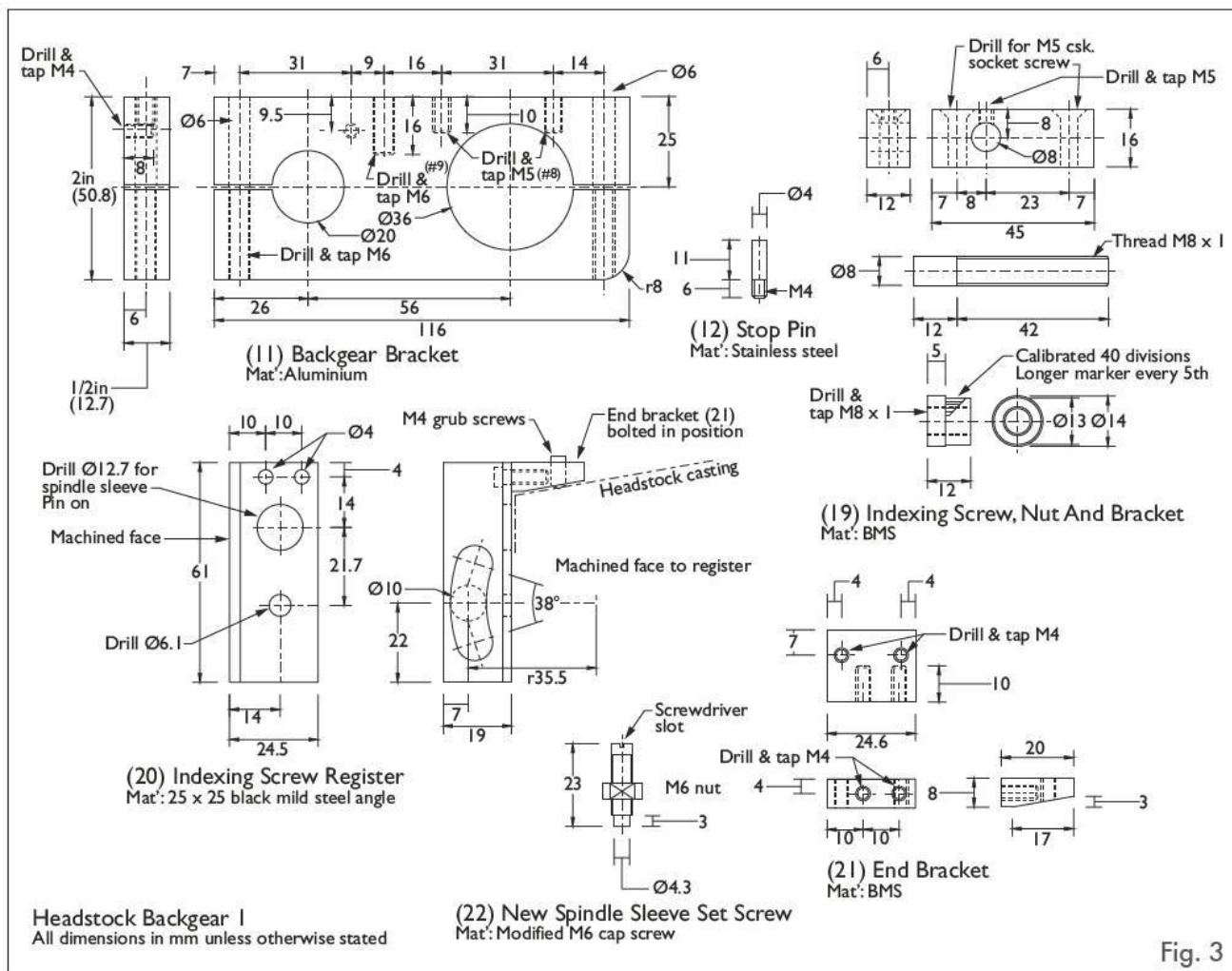


Fig. 3

complete the machining of this component. All shaft keys on this project were cut from an existing scrap length of 1/8 inch thick brass bar. Some 3.5mm wide strips of appropriate length were cut, the ends profiled to shape and then soft soldered to the keyways. Any protruding solder was removed and the final key heights adjusted, by filing, to achieve a sliding fit with matching components.

Cone pulley bush (2), cone pulley (3) and cone pulley gear (4) together form a sub assembly freely rotating on the 20mm spindle extension shaft. The cone pulley bush was machined from phosphor bronze cored bar. The external diameters of the bush and collar were machined to reasonable accuracy, but the bore was carefully finished to a very close running fit to the appropriate spindle shaft. The 35.5mm (#5) overall bush length needed finishing as accurately as possible to ensure that when the spindle bull gear (5) was clamped tight to the shoulder at the end of the 20mm shaft, the bush could rotate freely with negligible end play. The bush overall length needed a further 0.001 inch removed to achieve this. Any inaccuracy in the 2mm (#6) shoulder length would have needed compensating for when machining the circular recess in the spindle 'bull' gear.

Cone pulley (3) was machined from a 35mm length of 3 inch diameter aluminium bar held in the reversed jaws of the chuck. A line was inscribed close to the

jaws to denote the start of the larger pulley and then all of the pulleys and the 1.5mm long spigot were turned to finished sizes. I decided early in the project design to use 5mm round belting in preference to small section Vee belting.

Power transfer has proven adequate for the size and cutting loads of the Unimat. This belting is widely available and easily joined by thermal welding. Belt circumferences can be tailored as required and the flexibility of the belting, together with flexible motor mountings, enables easy belt changing without the need for any belt tensioning device. The belt grooves were machined with a 6mm square HSS form tool ground to Detail A with front and side rake and corner edges lightly rounded. The included angle of the Vee groove is the same as the original Unimat pulley but with groove depth and width increased to accommodate the larger diameter belting. Although not shown in the detail the top width of the groove read on the CAD drawing as just under 5.5mm and two lines, at this distance apart, were centred on and inscribed on the circumference of the larger pulley nearest the chuck thereby denoting 1.5mm shoulders each side of the pulley. The tool was advanced to contact the pulley and note taken of the cross slide dial reading. Using the lowest backgear speed the tool was then progressively advanced and moved from side to side to cut on alternate faces. On reaching the point when

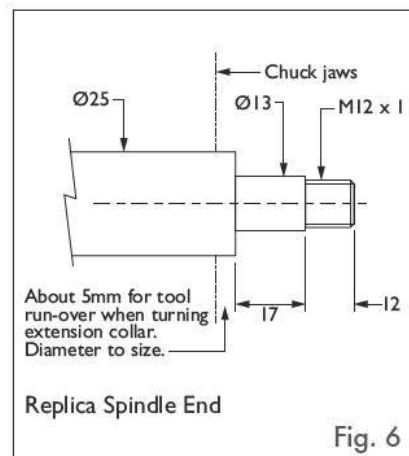


Fig. 6

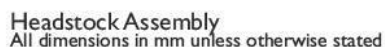
both guide lines were about to be obliterated with the tool about to cut on both faces and chattering just noticeable, power was switched off and machining of the grooves finished by hand pulling. The tool was again advanced until the 4mm groove depth was reached and, at the same time, keeping an eye on the shoulder widths to maintain a centralised groove. This last stage was laborious but produced smooth, ripple free grooves; the same procedure was followed for the remaining grooves on this and all of the pulleys on this project.

To be continued...



Fig. 4

Fig. 5



1. A Tale of Two Lathes MEW Issue 197.
2. Rapid Metals www.rapidmetals.co.uk
3. HPC Gears International Limited
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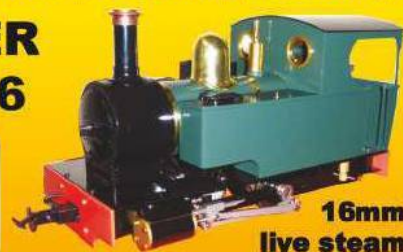
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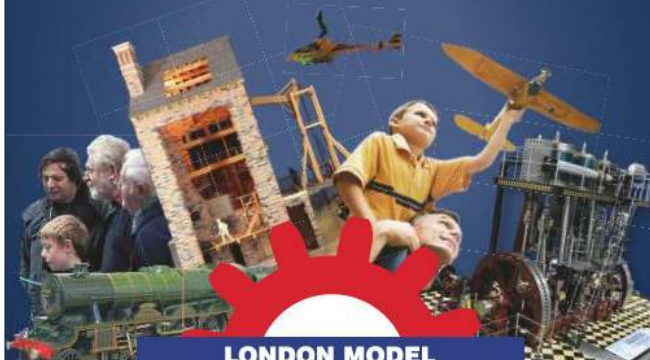
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A beginners' guide to Home Metalworking



David Clark looks at setting up a home workshop from scratch.

Having moved around the country for various reasons I have set up and used several workshops. Most of these were based in a wooden garden shed although one was in a brick outbuilding (photo 2).



First we will look at planning permission, buying a wooden shed, erecting it and installing the electrics. Then we will look at purchasing hand tools, a workbench and the lathe. The use of the lathe and hand tools will be looked at in detail from a beginners' point of view.

Later in the series, we will look at purchasing and setting up a milling machine and learn how to use it.

I have a lot of experience in using machine tools. A lot of it was gained in an industrial environment but it is still relevant to the home workshop.

The most important part of this series will be the feedback. Like most people with expert knowledge, I may overlook the obvious (I will try not to) so please feel free to contact me about anything you don't understand or if you have any questions. Anything relevant can be added to the next article in the series. I will also set up a thread on the Model Engineer website where readers can ask questions about the series.

Planning permission

OK, let's look at planning permission for the humble garden shed. Please remember that I am not a town planner so the information that follows is given in good faith. If in doubt, check with the relevant local authority.

The first stop for planning permission in England is:

<http://www.planningportal.gov.uk/permission/commonprojects/outbuildings/>

There is also a link to the Welsh planning site at the top of this site and the allowed permissions are very similar the England ones. Readers in Scotland should check with their local authority for planning permission.

For those readers without Internet access, I will summarise the important information here.

The following rules are general guidelines for councils. If in doubt give them a friendly phone call as it's better to be safe than sorry.

Rules governing outbuildings apply to sheds, greenhouses and garages as well as other ancillary garden buildings such as swimming pools, ponds, sauna cabins, kennels, enclosures (including tennis courts) and many other kinds of structure for a purpose incidental to the enjoyment of the dwelling house.

Under new regulations that came into effect on 1 October 2008 outbuildings are considered to be permitted development, not needing planning permission, subject to the following limits and conditions:

- No outbuilding on land forward of a wall forming the principal elevation.
- Outbuildings and garages to be single storey with maximum eaves height of 2.5 metres and maximum overall height of four metres with a dual pitched roof or three metres for any other roof.
- Maximum height of 2.5 metres in the case of a building, enclosure or container within two metres of a boundary of the curtilage of the dwelling house.

- No verandas, balconies or raised platforms.
- No more than half the area of land around the 'original house'* would be covered by additions or other buildings.
- In National Parks, the Broads, Areas of Outstanding Natural Beauty and World Heritage Sites the maximum area to be covered by buildings, enclosures, containers and pools more than 20 metres from house to be limited to 10 square metres.
- On designated land** buildings, enclosures, containers and pools at the side of properties will require planning permission.
- Within the curtilage of listed buildings any outbuilding will require planning permission.

*The term "original house" means the house as it was first built or as it stood on 1 July 1948 (if it was built before that date). Although you may not have built an extension to the house, a previous owner may have done so.

**Designated land includes national parks and the Broads, Areas of Outstanding Natural Beauty, conservation areas and World Heritage Sites.

Please note: the permitted development allowances described here apply to houses not flats, maisonettes or other buildings.

Building Regulations

If you want to put up small detached buildings such as a garden shed or summerhouse in your garden, building regulations will not normally apply if the floor area of the building is less than 15 square metres.

If the floor area of the building is between 15 square metres and 30 square metres, you will not normally be required to apply for building regulations approval providing that the building is either at least one metre from any boundary or it is constructed of substantially non-combustible materials.

In both cases, building regulations do not apply ONLY if the building does not contain any sleeping accommodation.

This section provides you with general information to help you comply with the Building Regulations when constructing a new outbuilding within the boundaries of an existing property, such as:

- Garage or carport
- Summerhouse or shed
- Greenhouse

Building a new garage attached to an existing home would normally need building regulations approval.

Building a detached garage of less than 30 square metres floor area would not normally need building regulations approval if:

- The floor area of the detached garage is less than 15 square metres.
- The floor area of the garage is between 15 square metres and 30 square metres, provided the garage is at least one metre from any boundary, or it is constructed from substantially non-combustible materials.



However, if erecting a garage, do check the planning Portal website regarding regulations for the foundations.

Obviously, if you rent from a council, housing association or private landlord, you will almost certainly need their permission and I would make sure it is in writing stating the size of the shed and if necessary where it will be erected.

Purchasing a shed

There are two basic types of shed, the apex roof shed and the pent roof shed. The apex has a pointed roof, basically a roof panel at each side meeting up at the centre, the apex (photo 3). The shed shown in photo 3 is ideal for a new workshop. This shed is not as small as it looks, it is 8 feet long x 6 feet wide and the headroom is adequate in the middle where you would be working.

The door could do with stronger hinges secured with a couple of coach bolts as well as screws but other than that it will do fine. I know other people may have smaller workshops but I consider an 8 x 6 is the absolute minimum for a decent workshop. This size of shed allows you to put a workbench at each side of the shed and still have room to work in the middle.

A pent roof is a flat roof; normally this sort of roof runs downhill from the front of the shed to the back (photo 4). I have had two pent roof sheds and both made ideal workshops. One was sold when we moved and the other was left when we moved house. There was nothing wrong with either of the sheds, I just don't want to keep taking them down, moving them around the country and erecting them again.

View before you buy

If at all possible you should try to see the shed you are thinking of buying and walk around inside it. Some sheds have sufficient headroom but others are not as tall so your head will bump on the roof. Slightly low headroom at one or both sides will be fine if you have a workbench against the side(s) as you will not be standing close to the edge in this case.

Another reason to see the shed is to ensure the construction is done with a good thickness and grade of wood. I purchased a shed online from a large supplier and basically it was a kit of parts made out of what could only be described as matchwood. A shed should comprise a floor, two sides, two ends and one or two roof panels, not a pile of wood that needs to be used to fill various gaps.



Fortunately, as I purchased online, I phoned the company and they collected the shed and gave me a full refund.

The door

The shed door should be substantial as it is a security measure as well as a door (photo 5). However, the door in photo 1 has found to be perfectly adequate although it could be strengthened if necessary. We will cover workshop security later in the series. I prefer a single door although sheds with double doors are available. I had to get a large machine into a shed a few years back where double doors would have been useful but we managed to get the machine in by removing the side of the shed.

To be continued...



COMING UP...

Next time we will finish our look at sheds and take a quick look at a preformed concrete workshop and some concrete and wooden garages.

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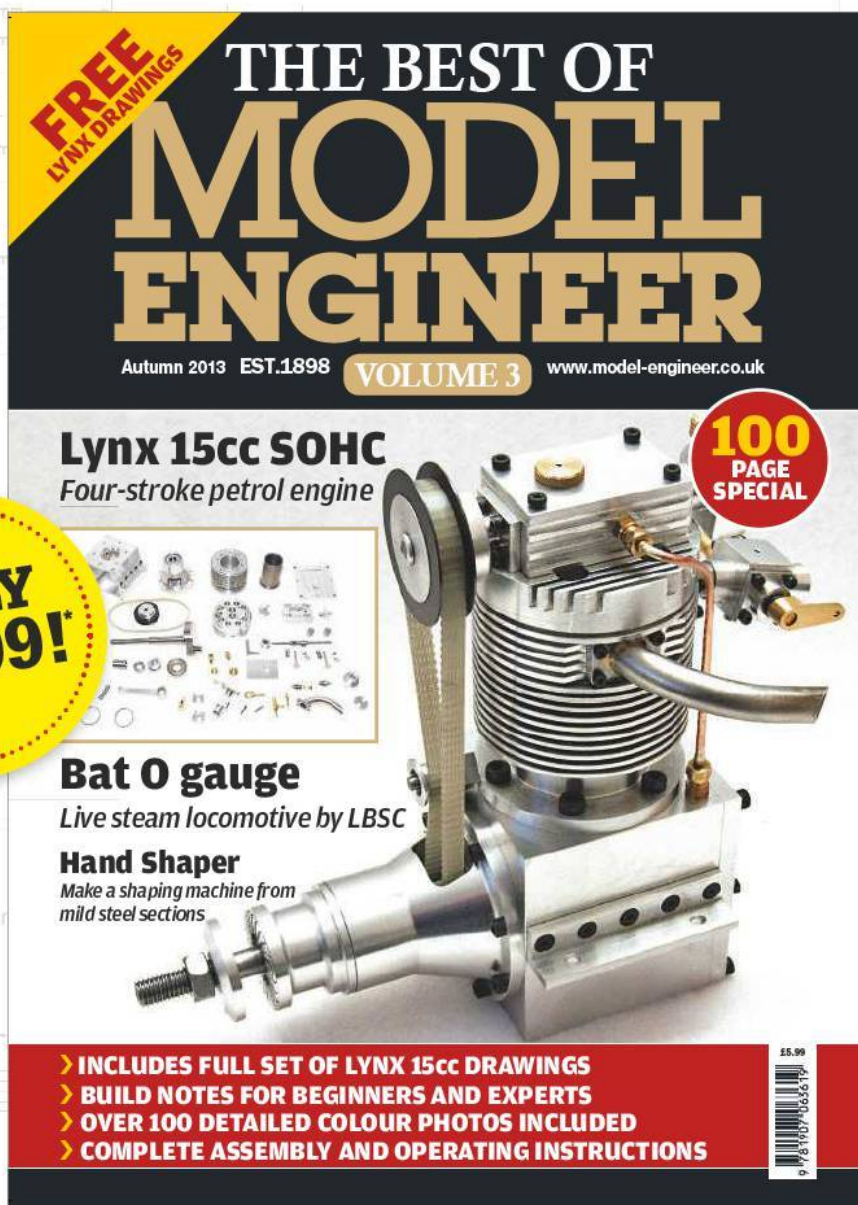
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Enhancing a Centec Vertical Head



Gary Wooding adds a depth stop to his mill.



The completed project.

I purchased my Centec 2B mill about 6 years ago; it came with power feed, Mk 3 Vertical Head, 30 International taper sockets and 415 Volt 3phase motors running from a rotary converter. My first change to it was to convert the motors to delta and feed them from a pair of 220Volt inverters. This was not a trivial task because the motors hadn't been designed for delta. The second change was to fit a three axis DRO, but these are separate stories.

It occurred to me that, while the quill was removed, I could also fit a Chinese digital scale as a depth gauge. I also took the opportunity to fit a rather novel, but effective, work light.

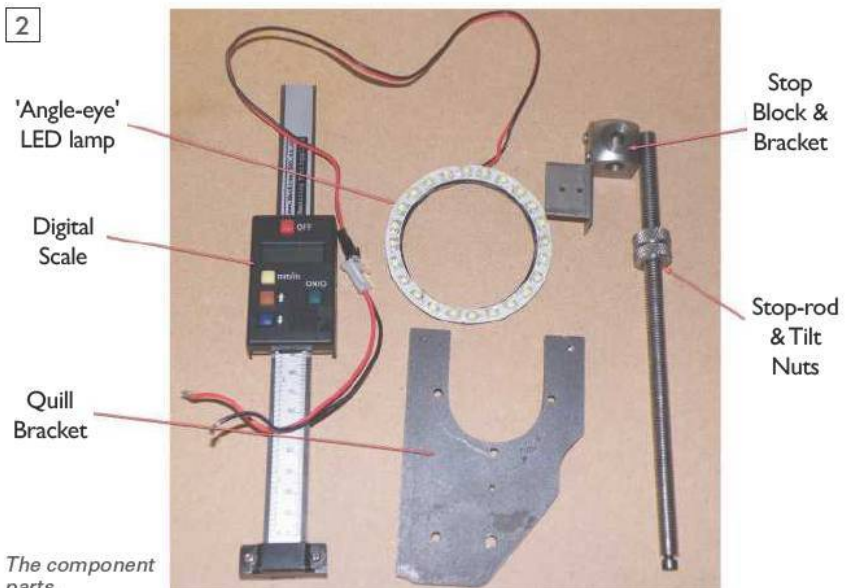
The finished project

Photograph 1 shows the finished project on my Centec while photo 2 shows the component parts. Photographs 3 and 4 show the effectiveness of the new work light. Photograph 5 shows the machine before the modifications were made.

Removing the quill

This turned out to be much easier than I expected. However, before removing the quill, and thus rendering your mill unusable, read the whole article first as you may need to make a few simple tools.

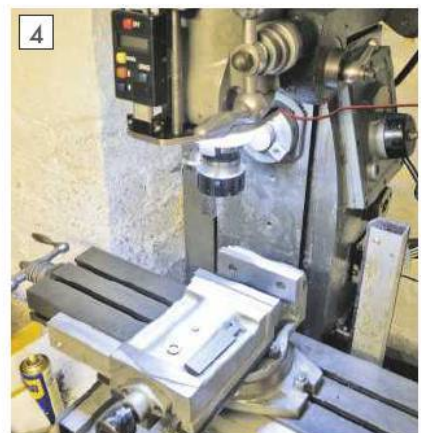
The Centec Mk 3 VH (vertical head) is beautifully made, with a drilling quill and fine feed, but it always bugged me that it had no depth stop. Since I couldn't think of any way of attaching a depth stop without removing the quill, it remained a pipe dream until I eventually plucked up the courage and attacked the quill. The only change was to drill and tap three M4 holes in the end of the quill.



The component parts.



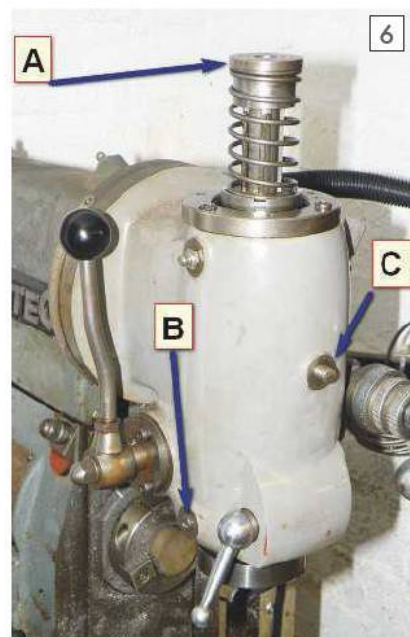
The LED lamp from below.



The LED lamp from above.



The Vertical Head before the modifications.



Identifying the parts for quill removal.

The aluminium cover over the top of the quill comes off quite easily to reveal the large spring and retaining nut shown as A in photo 6.

The spring is quite tough, so I made a couple of simple coil clamps from pieces of clothes hanger wire. Use the quill lever to compress the spring and position the clamps to hold it compressed enough to safely remove the nut (photo 7). Don't forget to remove the drawbar; I forgot when I took the photograph.

To unscrew the nut you need a pin spanner. I didn't have one so I made one from an odd steel strip and a couple of turned pins (photo 8).

The Centec uses Imperial sizes, so the pins are 0.2 inch diameter x 0.15 inch long spaced at 1 inch centres.

Unscrew the spring retaining nut. Mine was a very tight fit, so tight that I suspected a left-hand thread, but don't worry, it's a normal right-hand thread.

With the nut removed, the spring can be removed. The up/down quill movement is constrained by a socket head grub screw on the side of the vertical head casting (B in photo 6). It's on the left of my Vertical Head, but a friend has it on the right. Remove this, together with the one it reveals and, using the lever, carefully lower the quill until it can be removed

from below the casting. Be very careful because the quill is hollow and doubles as the oil reservoir. Pour the oil into a suitable container before continuing. Incidentally, there is no seal between the quill and casting and this, rather than failure of the spindle oil seal, is the source of many oil leaks.

To be continued...

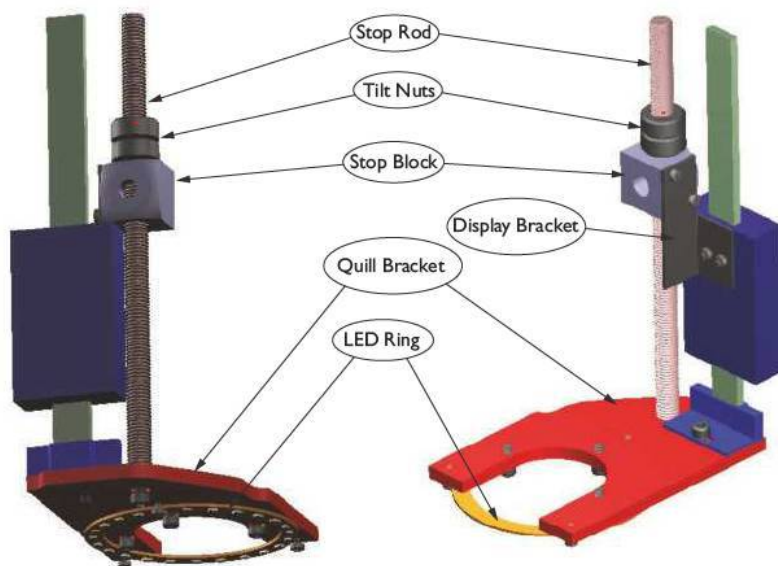


Simple spring clamps.



The pin spanner.

Fig. 1



General Arrangement

Fig. 2

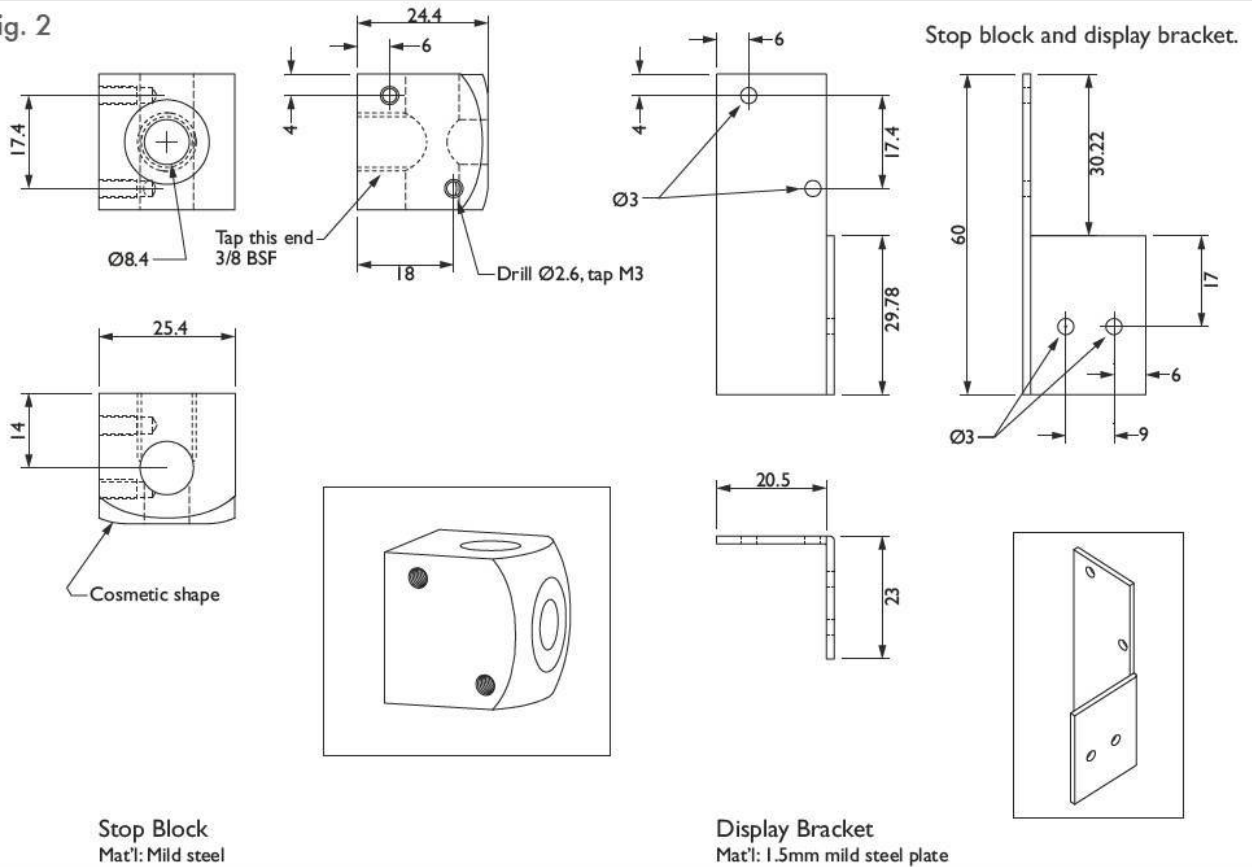
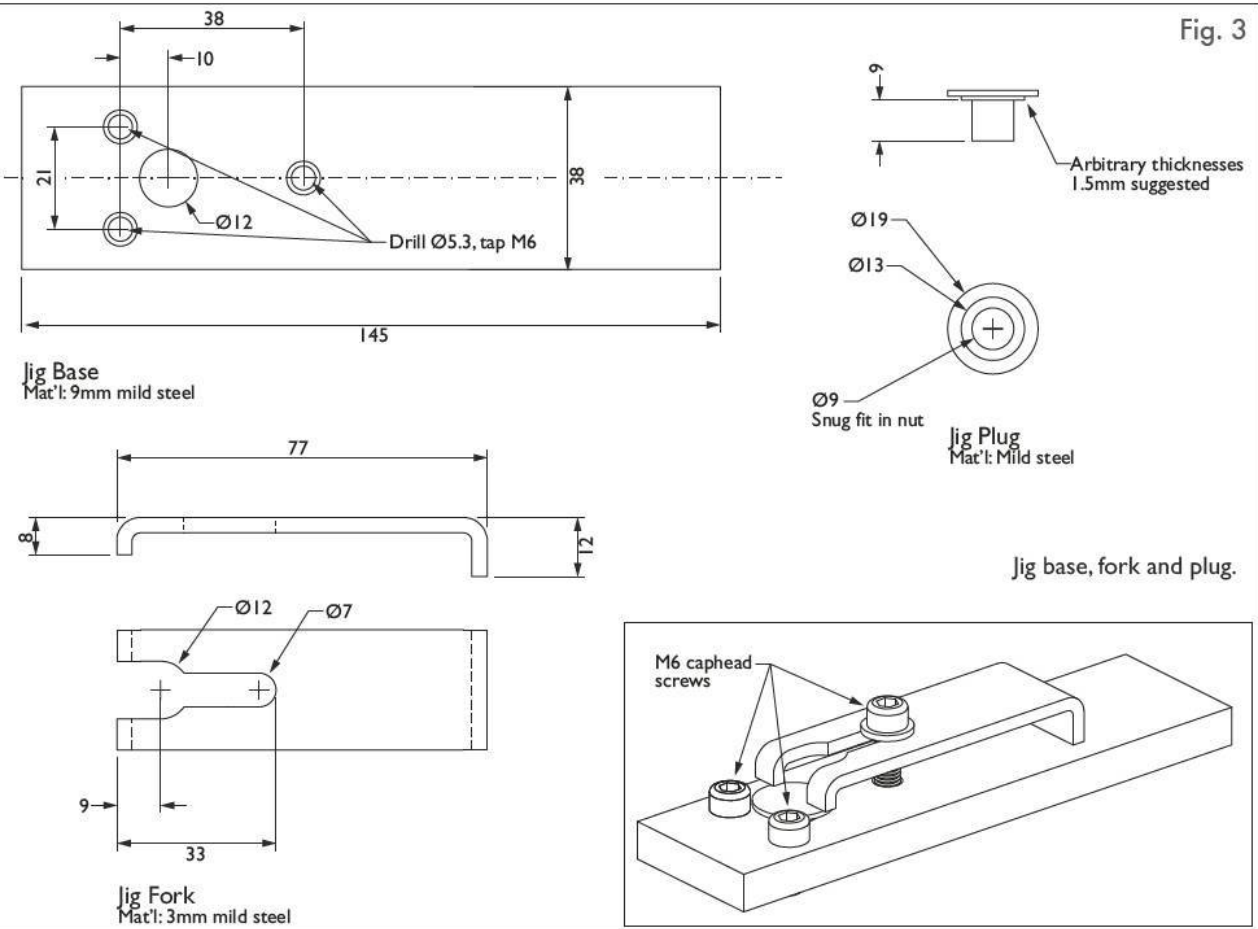


Fig. 3

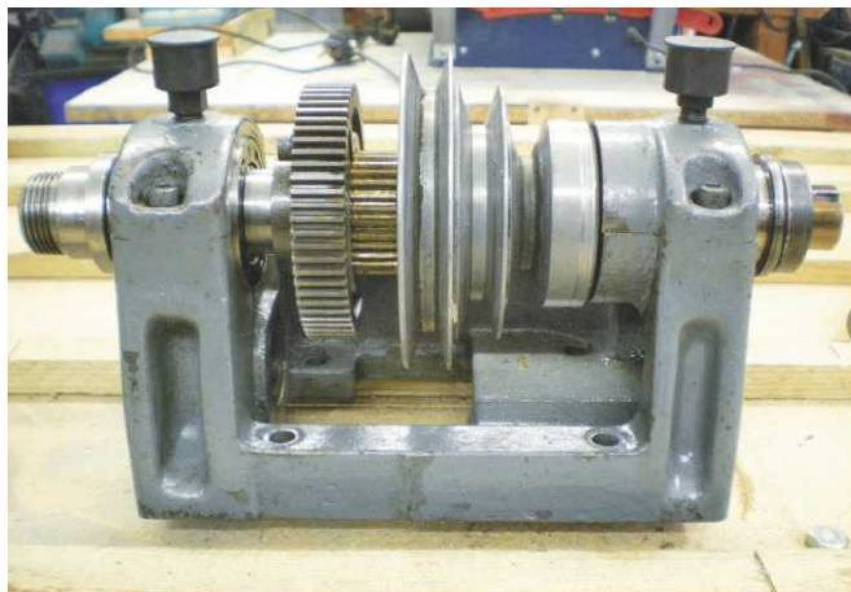


Replacing Lathe Bearings Part 3



Alan Hearsom Fits Taper Roller Bearings to a Myford ML7 Lathe.

This article explains how to replace the original whitmetal bearings (or alloy of same) on a Myford ML7 lathe using taper roller bearings in their place. The completed project is pictured right. The only external aesthetic difference is the presence of lithium grease cups in place of the traditional glass oil feeders. Observing more closely there is the outline/shape of an oil/grease seal protruding from or flush with the side of a bearing cap.



The finished headstock.

Preparing the completed bores for assembly

The first stage of cleaning was washing away the cast iron particles and dust in a paraffin bath (photo 27). The ring of each bearing was used to ensure the bearings could be assembled from above and then the end caps providing the closure forming the complete housing. It was necessary to remove burrs from the edges, particularly on the joints. This was done with a rotary toolmaker's file sometimes referred to as a 'rotary tool' to make use of a tungsten or diamond burr. This involved simply testing the ring until it would enter the half housing from above and if not I continued the filing process



Cleaning swarf and muck off.

using the bench vice to hold the headstock firm. A similar operation was performed when fitting the oil seals to see that they seat properly in the bores from above. It is important that the bearing caps are a close fit so that grease does not spew out from the gap (split) between the top and bottom halves of the housing.

Photograph 28 shows the bearings and oil seals in their respective bores. **Photograph 29** shows a close up of the bearing assembly from the rear of the headstock. **Photograph 30** shows the front of the headstock housing. The oil seal nearest the chuck on this housing was replaced with a 0.31 inch wide one instead of the 10mm wide oil seal to provide a bit more clearance between the oil seal and



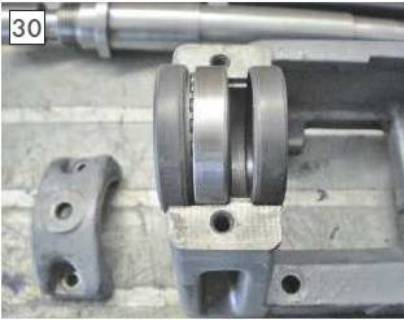
Trial fit of bearings and seals.

the bearing (photo 30). **Photograph 31** shows the finished machining of the bores on the bearing at the chuck end. The bore on the left is slightly bigger to accommodate the 2.000 inch diameter oil seal compared with the bearing which is 1.98 inches bore. **Photograph 32** shows the bores relative to the machining of the bores at the changewheel end.

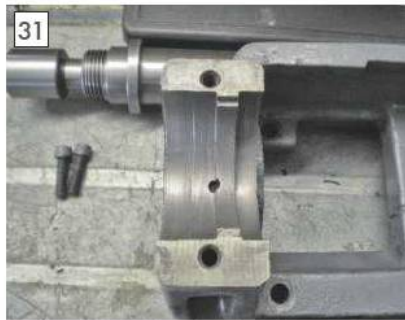
Photograph 33 is a final check on the lengths of the mild steel bushes. The spindle is placed back into the whitmetal bearings after the bores have been machined. A measurement is taken with the spindle pushed up against the whitmetal bearing from the flange to the taper roller bearing bore shoulder to deduce that the length of the mild steel



A view from the back of the changewheel end.



A view from the back of the chuck end.



Finished bore, headstock end.



Finished bore changewheel end.



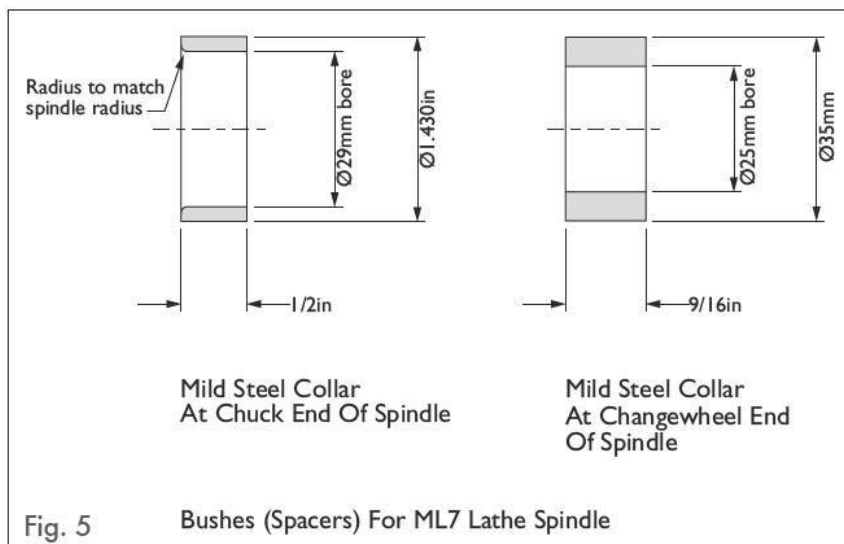
Checking length for mild steel bushes.



Bushes and seals temporarily fitted.



Skimming the spindle to fit.



bush needs to be a push fit on the machined spindle with a 1.417 inch bore x 1.43 inches outside diameter x 0.5 inches long. A similar measurement is deduced at the rear bearing to ensure a spacer/bush is made to allow the nut to tighten the bush against the bearing and leave enough thread for the nut to work. This bush is 25mm bore, a push fit on the spindle x 35mm outside diameter and 0.56 inches long. The original peg and locking collar are reused prior to the nut being tightened to preload the taper roller bearings. Photograph 34 shows the bearings and oil seals temporarily in place prior to machining the spindle.

Machining the spindle to fit the taper roller bearings

Prior to machining the spindle the two bushes are made from mild steel (fig 5). The dimensions for machining the spindle are shown in fig 3. Photograph 35 shows the

spindle held in a four-jaw chuck and at the other end in a tailstock held with a rotating centre. The spindle has a taper machined in the end which requires a larger than normal, 0.875 inches diameter, tapered rotating centre (photo 36). Photograph 37 shows the spindle being machined for the bush and the hand held push fit of the taper roller bearing at the chuck end. The finished diameter is 1.1417 inches diameter with a radius blended into the existing radius on the spindle.

Assembling the spindle components

Photograph 38 shows the mild steel collar as a hand held press fit on the spindle. Press fit means the collar will push on by hand and does not need excessive force as it may need to be replaced in the future. It is better to apply some Loctite 641 medium strength retaining compound than drive the collar on with excessive



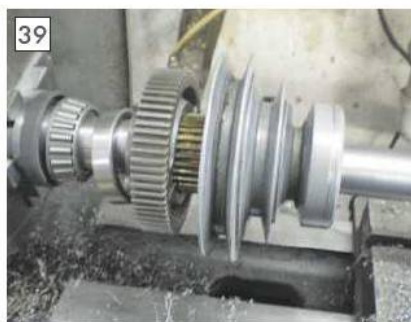
The running centre.



Skimming spindle headstock bearing diameter.



Starting the assembly.



Cone and backgear assembly.



Turning the circlip groove.



Circlip and brass washer fitted.



A close-up view of the assembly.



The completed assembly...



...with the bearing caps fitted.

force. This collar will be tightened on its faces in any case when pressure is applied through the retaining nut at the other end of the assembly. The retaining nut has a copper pad inserted into the $\frac{1}{4}$ inch BSF original tapped hole with a $\frac{1}{4}$ inch BSF half dog grub screw to force the copper pad onto the bearing retaining screw. The next to go on is the oil seal which is 1.43 bore x 2.00 inches outside diameter x 0.31 inches wide. The smooth or flush surface of the oil seal faces the flange. The taper roller bearing is the last to go on and again only needs to be a hand push fit provided by the hands and NOT knocked on with a hammer and piece of pipe/tube.

The bearing should have been tried for fit before the spindle is taken out of the lathe so that it hand pushes on easily and can be drawn off easily by hand. There has to be some evidence of an interference fit even when pushed on by hand. The ring of the taper roller bearing is the last to go on in order. The bull wheel, part of the back gear of the Myford ML7 lathe is next and that is a push fit on the 1.125 inch diameter spindle which has not been machined as part of this assembly. The Woodruff key needs to be in place on the spindle so the bull wheel can be pushed over it. The bull wheel is a good example of the type of fit to be experienced in fitting the taper roller bearings and their mild steel bushes. The Woodruff key may have some burrs on it which will need filing off.

The pulley assembly

Next to go on the spindle is the Vee cone pulley assembly shown in **photo 39**. As the assembly has changed with the

removal of the whitmetal bearings and the thrust race, there is a need to place a brass retaining washer and circlip on the spindle to hold the Vee cone pulley assembly in place. **Photograph 40** shows the machining of the circlip groove in the spindle. The brass washer is 1.5 inches diameter and $\frac{3}{16}$ inch wide shown fitted on the spindle in **photo 41**. I removed around $\frac{1}{8}$ inch from the shoulder as I felt there was too much linear movement/play of the Vee cone pulley assembly. An alternative would be to make a steel washer to take up the slack on the $1\frac{1}{2}$ inch diameter part of the spindle. **Photograph 42** gives a clearer position of the circlip, brass washer and the Vee cone assembly in place on the spindle. There is however excessive play between the Vee cone pulley and the shoulder where the brass washer fits. This play I imagine helps with the alignment of the Vee belt pulleys, although I have commented on a solution to this problem above. The complete assembly with the remaining bearing and oil seals is shown in **photo 43**.

The first oil seal to go on at this end (the change wheel end) is 25mm bore x 53mm outside diameter x 10mm wide. The smooth side is placed towards the Vee cone pulley assembly. The taper roller bearing 0.9843 inches bore must be a hand press fit onto the spindle in a way where it can be removed with a firm pull but is easy to remove without hammering or pulling it off with mechanical pullers.

The next item is a spacer bush 25mm bore x 35mm outside diameter which is a push fit by hand onto the spindle. The final oil seal, which fits over the bush, is 35mm bore x 50mm outside diameter and 7mm wide. The smooth or flush side of the oil seal faces outwards. The final assembly includes a peg that fits in the spindle and a thrust washer and a screwed locking collar held in place with a copper pad down the collar's tapped hole and capped with a $\frac{1}{4}$ inch BSF socket setscrew. The copper, being a soft material, embeds itself into the

thread under pressure from the half dog pointed grub screw. The locking collar is fully tightened and then the $\frac{1}{4}$ BSF half dog grub screw is forced on the copper pad that locks it onto the spindle thread. This is done when all the components are fitted in their respective bores and the bearing caps are fitted as shown in **photo 44**.

The completed headstock assembly does not look externally that much different from the assembly with the whitmetal bearings in place other than there are grease cups used and not glass oilers. The grease used is lithium based, black in colour, and of a very smooth consistency similar to slightly warm spreadable butter.

There is a screw that needs to be removed in the Vee cone pulley to allow for a temporary grease nipple so that the spindle can be greased periodically. The grease nipple is removed after greasing and the screw replaced so that if this section of the pulley is used it does not interfere with the Vee belt drive. Originally oil was the lubricant of the rotating headstock components. Grease is simply oil in a different form that will adhere to the moving parts.

The bearing caps also have a temporary $\frac{1}{8}$ inch BSP plug with a 2BA grease nipple to fill the bearing housings with grease. The bearing housing should not be over-packed with grease. The grease cups shown in **photo 1** are used to add grease if needed on a continuing basis and for that matter, with patience, they can be used to load the initial quantity of lithium based grease into the two bearing housings.

Conclusion

The taper roller bearing assembly has been tested on a Myford ML7 lathe and the performance is excellent particularly when machining at high speeds. There is no noticeable heat generated or vibration, noise or detrimental finish on the work being machined when compared to the original whitmetal bearings. ■

Converting a Warco GH1000 Lathe to CNC

Part 4



Some model engineers feel that CNC is a bad thing and takes away some of the skill in engineering and model making. However, if used intelligently CNC can fill the gap between manual machining and those jobs that are a little tricky of even impossible to do.

John Pace increases his CNC machine capacity.

The nylon drive gear is fitted to a steel hub. The bore of the hub is machined to be a close fit on to the stepper motor shaft. At each end of the hub the diameter is reduced and the ends cut with four slots. A split collar is fitted at each end and clamps the split bore to the shaft. As all of the important diameters and the bore are machined at the same setting concentricity is certain; this is important with this gear drive to maintain minimal backlash and a smooth drive. The hub is shown in drawing 13.

The bearings are fitted and adjusted to the bracket and the end float checked (photo 18). The nut housing should rotate freely with no end float. In photo 19 the stepper motor and drive gear are fitted, the slotted hub and collar can also be seen in the photo.

The spacer ring, also fitted on the main body, is made to provide the best alignment of the gears.

Next, the leadscrew is Loctited into the short extension shaft (photo 20). This is the same shaft as seen in photo 11. The end is

bored about an inch deep for the leadscrew. Photograph 21 shows the components for the saddle drive. This early photo used a different stepper motor and gear set. The motor had to be changed as it had developed a problem and was replaced by a

new Arc Euro Trade one. The main components have remained unchanged. An additional support strap not shown in this photo is required to counteract the thrust on the support bracket (drawing 9) shown later on the machine.

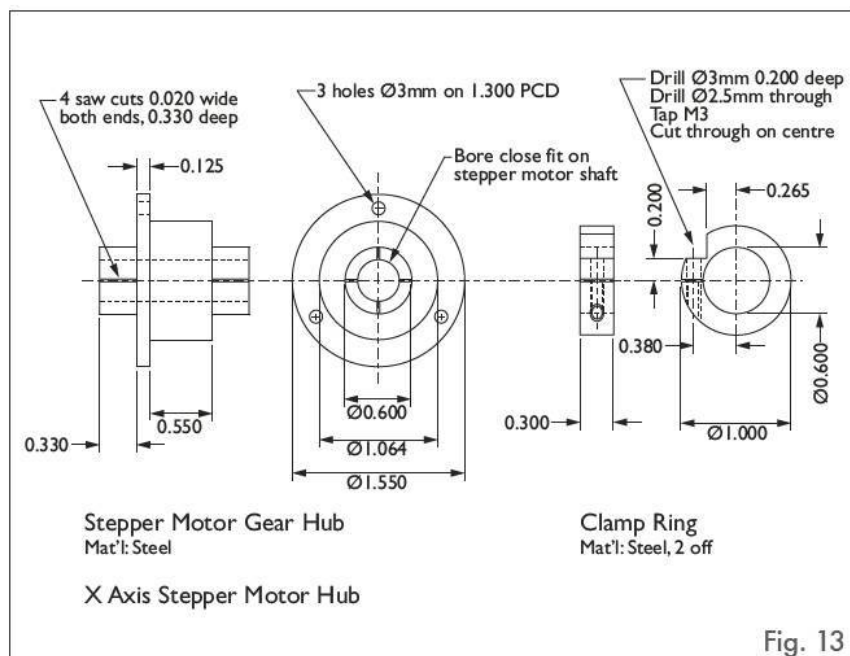


Fig. 13



Checking the end float.



The X axis drive assembly.



The modified leadscrew.



The saddle drive components.



Positioning the fixture.



Milling the cover plate.

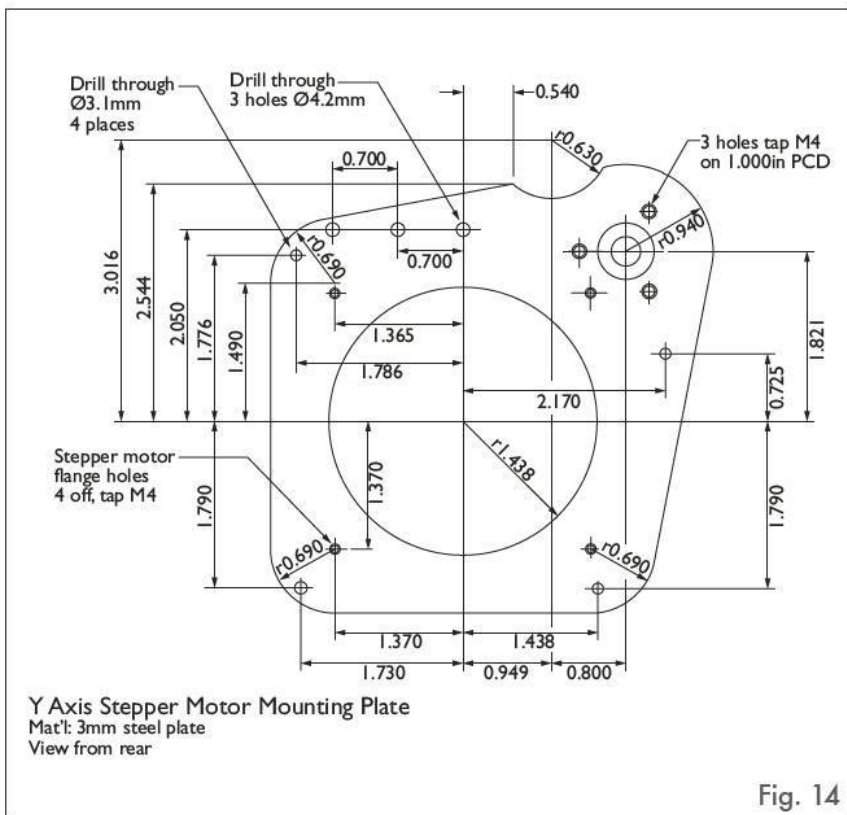


Fig. 14

The cross slide mounting parts

The stepper motor drive for the cross slide has less room to fit as it has to fit in the space between the apron and the end of the cross slide leadscrew bracket. The stepper motor used as indicated in the earlier description is a single stack size 34 motor. This motor only just fits in the space the gears fit into housing which forms the motor mounting and attaches to the leadscrew bracket.

Drawing 14 shows the mounting plate and drawing 15 the cover plate. The plate and cover plate were CNC milled. The plate and cover plate are held on the milling machine by some small fixtures. The hole positions are drawn in as part of the CNC file to miss the cutter path. This part of the file is used to drill the hole locations and also to position the fixtures on the milling



Milling the mounting plate.

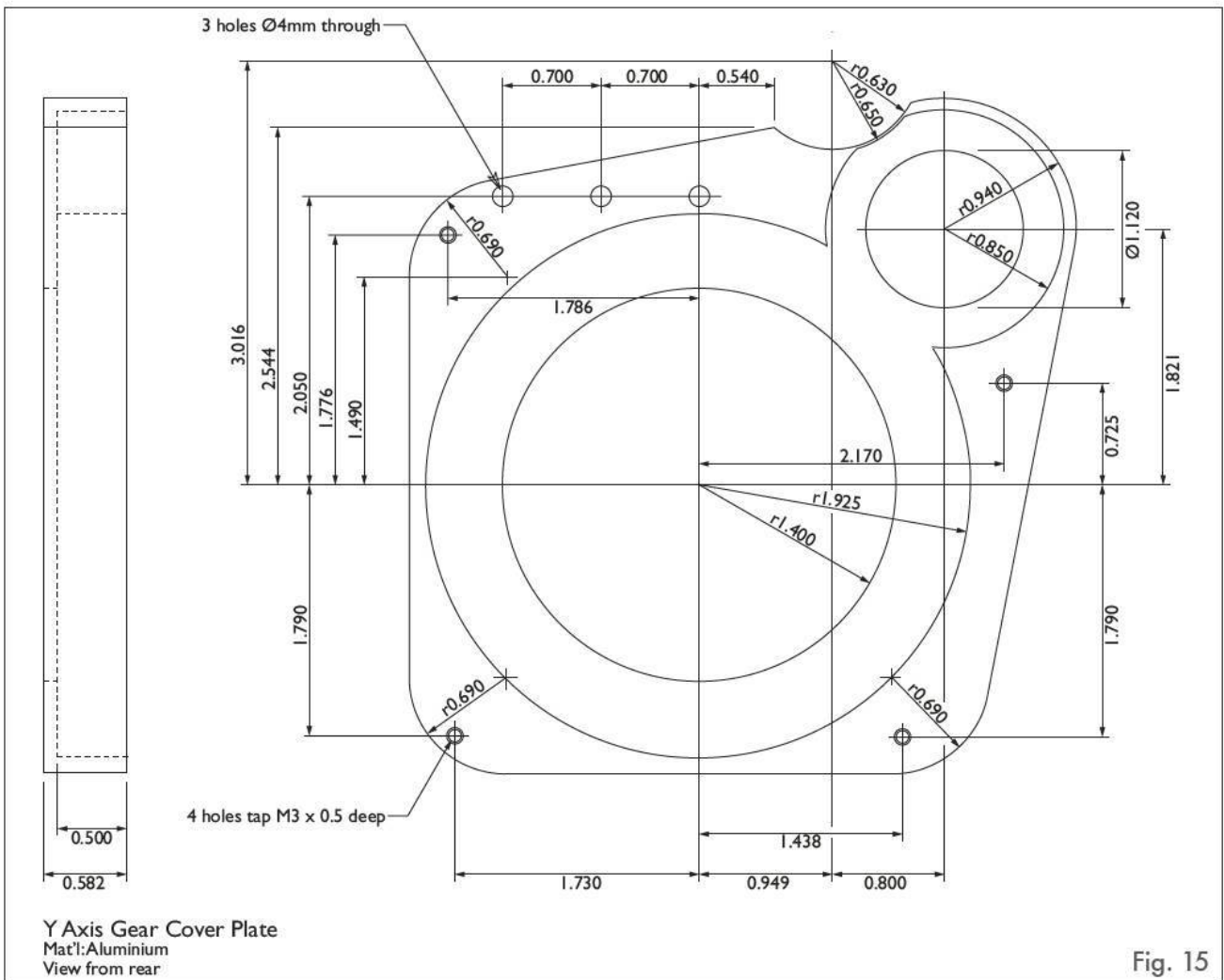


Fig. 15

table. **Photograph 22** shows the fixtures being positioned, the table moves to the location, the fixture held in the chuck is bolted down and the chuck, released and then moved to the next location. **Photograph 23** shows the milling of the cover plate and **photo 24** the mounting plate. The driving spider seen off to the right was milled at the start of the file from the hole in the centre of the plate. In **photo 25** the cross slide leadscrew bracket is being modified. This consists of machining a flat perpendicular surface and drilling two holes and machining the area behind the indexing collar. These dimensions are shown on **drawing 16** and include the main securing plate which attaches to the stepper motor mounting plate.

To be continued...



Machining the cross slide leadscrew bracket.

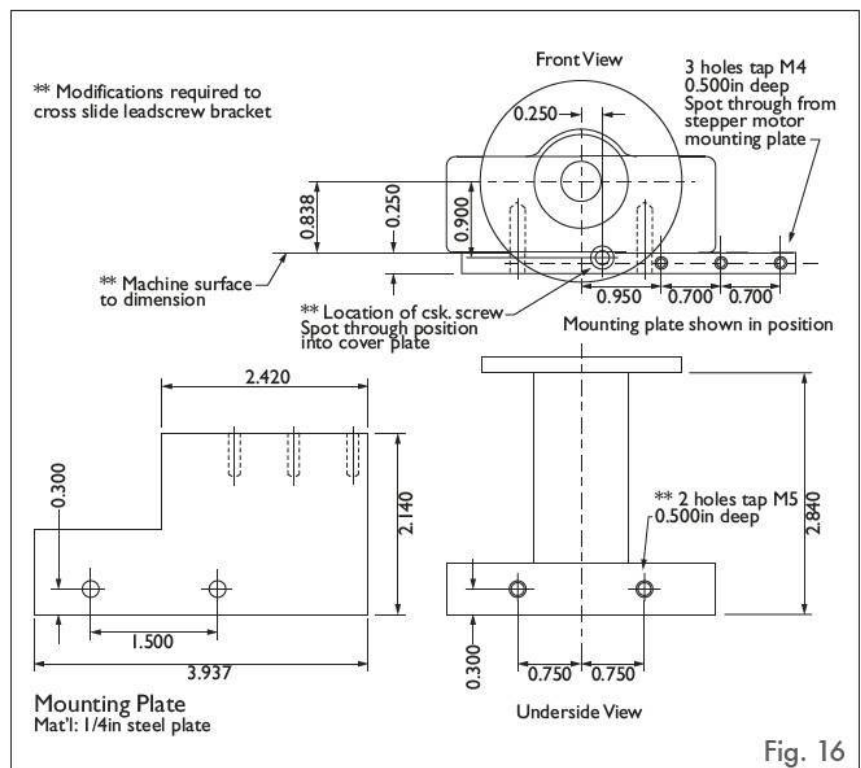


Fig. 16

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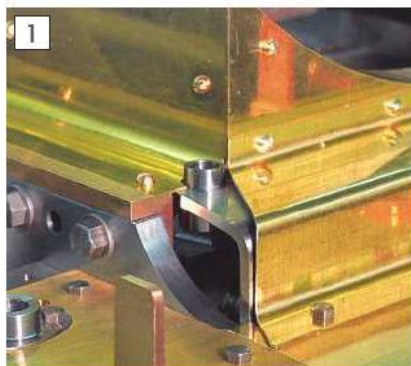
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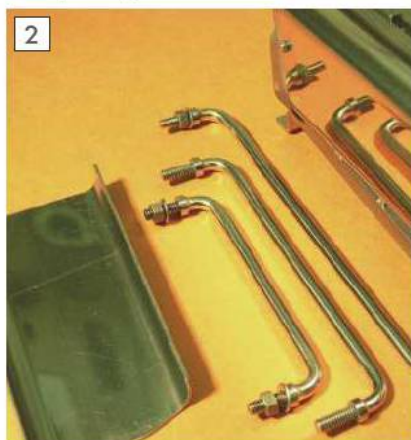
In Praise of the Humble Fly Press



John M. Smith shows you how to select a press and make a simple Vee bending tool.



The operating rod cover.



Finished handrails.



A typical fly press.

It is a truth universally acknowledged that a single part in possession of a good deal of complexity must be in want of a tool (or jig, or fixture). When I can, I buy (rather than make) tools, to maximise the time spent actually building my 7 1/4 inch gauge GWR 1400 class locomotive. But it is not always possible. The time spent making just the right tool or fixture is amply repaid when perfect and identical parts result. I recently needed to make the cover for the front sandbox operating rod on the loco (photo 1). This features three bends in alternate directions which must be positioned close together and to quite close limits to fit over a bracket and underneath the smokebox. There is no way that this could be done on a box and pan folder but it can be done on the fly press, with the right Vee bending tool.

The fly press is regarded as a tool more for the blacksmith than for the precision engineer, but it can produce work to fine limits. It can also tackle jobs that cannot be handled easily by other tools. It can punch holes of any shape and size (within reason). It can bend and shear sheet material and rods and it can cut louvres. All with the right tools, of course. I have used it to make precisely-dimensioned handrails for the locomotive. I have also used it to produce large-radius curves, such as for the covers on the 1400's screw reverser (photo 2).

Around WWII, tens of thousands of fly presses were in use, making everything from radio set chassis to tin-plate trains. This work was later taken on by power presses. There are many fly presses that are now surplus to requirements. Silly prices are sometimes asked, but you should be able to get a good used fly press, on a stand, for around £180 and you can make it as good as new. The most plentiful British makes are Norton, Sweeney & Blocksidge and Denbigh.

Two words of advice. Firstly, only buy a press which comes with a steel stand. Presses are heavy beasts and a sturdy wooden stand, or a fabricated and welded steel one, is going to cost you almost as much to make as the press will cost you to buy. Secondly, try to find one on sale direct from an engineering firm. This not only avoids high-priced 'reconditioned' presses (which have been attacked with a wire brush and had a coat of gloss paint applied over decades of grease and dirt) but also increases the likelihood that the vendor might include some tooling in the

sale. Make sure that the Tee slots are not broken, that there are no cracks in the frame, and that the lead-screw is in good condition. Also ensure that at least one weight is present, although most fly press work is undertaken by pulling quite gently on the handle rather than by spinning the press so that a frightening amount of angular momentum can dissipate its energy into the workpiece.

I bought a No 2 press, which is small enough to get into a hatchback. But I made the mistake of buying a press without a stand. So I sold it on and bought a No 5 press with a stand. This is a really useful size, capable of doing heavy work. You will need to hire a Transit-sized van, but the vendor will normally have the means to load the press, on its stand, into the van (top of the press facing the front). When you get home, two people can slide the press down two heavy timbers onto the floor of the garage/workshop. Stripping and repainting the parts is very satisfying; it's a substantial piece of British engineering! The next task is to have the sides of the ram ground by a friendly precision engineering firm, together with the corresponding working surfaces of the side-cheeks. These can then be assembled so that the ram operates silkily and completely linearly, without any shake. Treat yourself to new nuts and bolts all round, two huge Tee nuts for the slots in the bed and some industrial-strength 'dogs' and you are ready to rumble (photo 3).

Now for the Vee bending tool. The part clamped down onto the bed is the die. I made one 8 inches long from 1/2 x 1 1/2 inch BMS. The narrower you make the die, the closer together you can position bends,

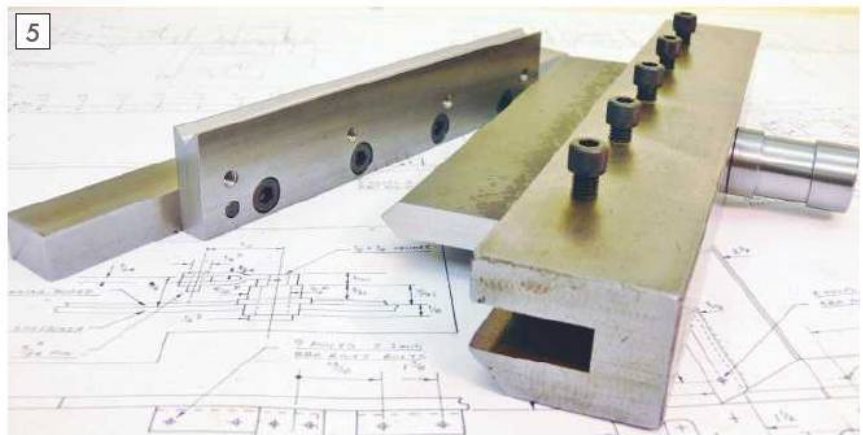


Machining the angle on the Vee tool.

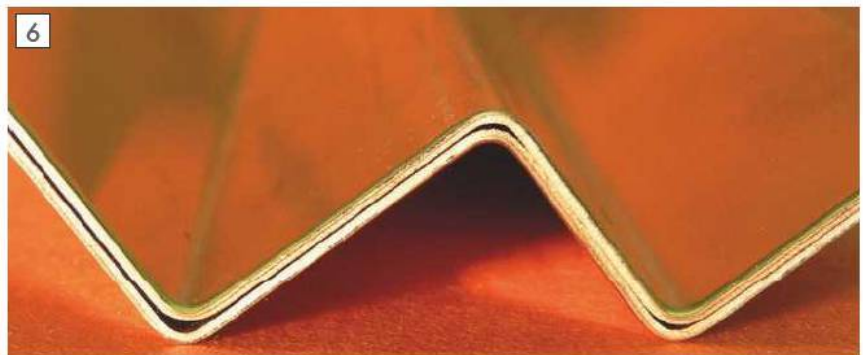
but you will limit the thickness of material that you can bend. The die is attached to a 12 inch length of $\frac{1}{2}$ x 1 inch BMS bar which can be clamped to the bed. The extra length allows a toolmaker's clamp to be employed at each end to hold a stop against the rear vertical surface of the die. Dowell and screw the two parts together, only counterboring for the 8mm Allen screws if your drill press is sturdy and has an ultra-low speed. Put a few 6mm tapped holes along the centre-line of the die to enable a stop to be clamped to the rear vertical face as an alternative to the clamps.

The Vee in the die is 90 degrees and does not extend to the very edges of the top of the die, thus avoiding sharp and easily-damaged edges (and unsightly marks on the workpiece). If you have access to a swivelling angle plate, machining the Vee is simple. A good investment is a digital protractor, with which you can set angles to 0.1 of a degree.

I made the Vee tool from a piece of 80 x 12mm black steel, but BMS would be equally suitable. Industrial dies and tools are usually hardened or made from high speed steel (HSS). For the number of parts we are going to make, mild steel is fine. Both the tool and the die can be



The completed tool and die.



Sheet metal bent with the press.

remachined very easily when wear occurs. If you have to do a lot of bending of rod or bar thicker than $\frac{1}{16}$ inch, then use (an old!) hardened precision Vee block as a die.

The angle of the Vee on the tool is 88 degrees. The one degree of clearance each side allows the very tip of the tool to work at the point of the bend. Even so, you may find that bends come out a shade over or under 90 degrees, requiring truing up in the vice. **Photograph 4** shows the angle plate set at 44.0 degrees to the horizontal to mill the Vee on the tool.

I have acquired a few second-hand fly press tools, including two tool carriers. These fit into the 1 inch diameter hole in the ram to carry tools of any length. If you don't have a carrier, you will need to make, and weld to the tool, a 1 inch diameter spigot. **Photograph 5** shows the completed tool and die.

The radius on the tip of the Vee tool is what determines the radius in the workpiece. The tightest radius you can achieve is about 60% of the thickness of the material you are bending. Use a

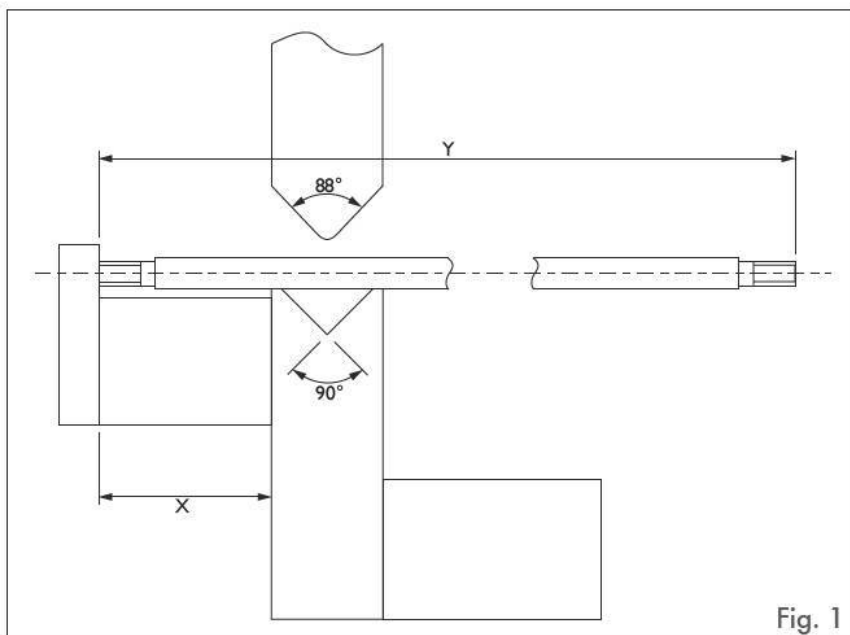


Fig. 1

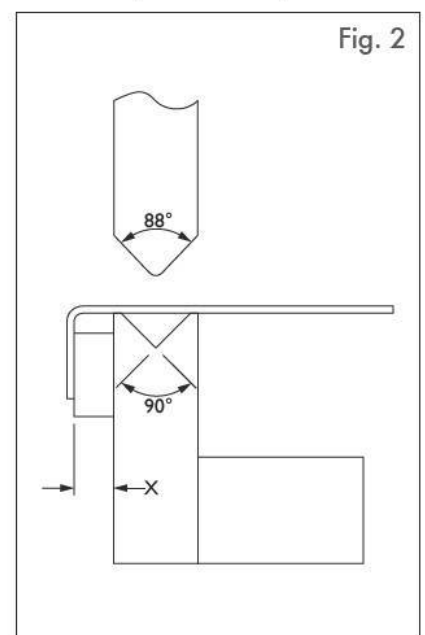


Fig. 2

smaller radius than this and the material will shear. A radius of $\frac{1}{2}$ to $\frac{3}{8}$ inch works for most materials and thicknesses of sheet that we need to bend. If you need a radius of (say) $\frac{1}{4}$ inch, you will need to put a $\frac{1}{4}$ inch convex radius on the tool using a corner-rounding cutter. These precision-ground HSS cutters are available for a wide range of metric and Imperial radii and are not too expensive. (They also make excellent profile tools for the lathe.)

Now, let's assume that we need to make a part with similar geometry to the sandbox rod cover. Put a first bend in a piece of scrap material of the same thickness as the sheet to be used for the cover, using the set-up shown in fig. 1. Make the distance from the edge to the first bend about $\frac{1}{2}$ inch, so X would be $\frac{1}{4}$ inch. Then, using the set-up in fig. 2, put a second bend in the test piece using a piece of $\frac{1}{4}$ inch thick material, clamped to the rear of the die, as a stop. Measure the distance between the two bends and adjust the thickness of the stop (X) to give the exact dimension you need. This will also inform what thickness of stop you need for the final bend. Photograph 6 shows the repeatability achievable.



A complex shape done on the press.

To make a handrail, use the set-up in fig. 2 with a packing piece (X) of $\frac{3}{8}$ inch thickness. Bend a test piece of $\frac{1}{8}$ inch diameter rod (I used 303 stainless steel) without the turned and threaded end. Compare the length of the leg with what you need. Adjust the stop (X) accordingly. Now turn another test piece to a precise but arbitrary length in the lathe, again without waisted and threaded ends. Bend both ends and true up the angles in the vice and then measure the distance

between the leg centres. Compare this with the dimension you need and this tells you what precise length (Y) you need. Now you are ready to go into production with properly shouldered and threaded ends. Bend the handrails, fit collars (push-fitted) and silver solder the collars in place. Job done.

I'm sure that you will find the press and the Vee tool of use in the workshop again and again. ■

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Building a Plastic Injection Moulding Machine



Trevor Ford makes a useful machine.

How it works

The machine comprises of a number of interrelated parts mounted within a three tiered frame (photo 1).

The base level supports the mould and the clamping system. The second level supports the injection cylinder and the electrically heated heat sink unit mounted below it. The ram lower support and lever support components are carried above the platform. Note the use of the drop arm to allow radial and lateral movement of the lever pivot as the ram moves in a straight line.

The top level carries a support guide for the top of the ram and a retaining device for the lever when at the top of the stroke.

At this stage it would no doubt be helpful to differentiate between the two terms 'mould' and 'moulding' as used in this article.

The 'mould' is the block unit with the desired shape formed as a cavity within it. The 'moulding' is the item produced by injecting the plastic into the 'mould'.

The operating sequence is as follows: The electrically heated jacket around the cylinder is raised to the correct temperature to melt and inject the plastic. A steel faced tapered wooden block is wedged beneath the nozzle to prevent melted plastic extruding during the heating phase (photo 2).

Thermoplastic strips, cut to a width and length to suit the cylinder, are fed into the mouth of the cylinder and allowed to become 'plastic' with a thick paste like consistency (photo 3).

The wooden block is removed and replaced by the mould which is then clamped tightly onto the nozzle, this needs to be carried out quickly to prevent plastic oozing into and blocking the mould cavity (photo 4).

The plastic is injected into the mould, pressure is applied by the lever operated ram and is sustained for about twenty seconds to allow the plastic to solidify and to remove any possibility of the plastic contracting within the mould (photo 5). Note the lever is horizontal and the ram is at the bottom of the stroke.

The mould is released and the wooden block is again clamped under the nozzle to

During 1976, as part of a Design Technology teacher training course, the construction of a steel mould for plastic injection moulding formed the basis of a practical assignment. The mould that I designed and made was used to produce a series of two and one half inches wide caterpillar track links. It was anticipated that a set of links so formed would provide the tracks for a radio controlled, one metre long model tracked vehicle to be built as a final year practical project.



Front view ram and lever at the top of the stroke.

The plastic links were ultimately rejected in favour of gravity die cast Aluminium ones as described in MEW No. 208. The steel injection mould was thus mothballed for over fifteen years.

Moving on to the early 1990s a design technology course that I taught at that time required that pupils be given knowledge of and an experience of plastic injection moulding. A newly produced commercial machine was acquired on a test and evaluation basis and the link mould and several supplied moulds were trialled. The machine exhibited a number of design and construction failures and was returned to the manufacture.

As a result the machine described in this article was manufactured during the following summer break. The original commercial design was analysed, improved and simplified where required. As no photographs of the manufacture and assembly exist, photographs of the assembled machine, sketches and component drawings are used to illustrate the processes used in the construction.



Steel faced wood block closing nozzle.



Plastic strips loading into cylinder mouth.



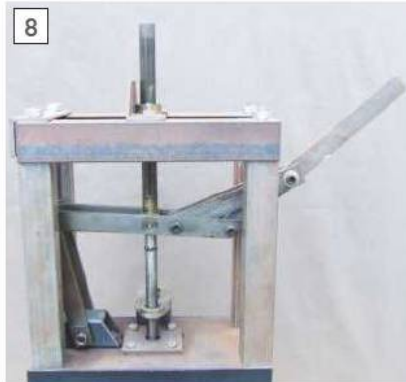
Mould clamped in position under cylinder.



Ram in lowest position, note lever extension tube.



Ram at top of stroke, note drop arm angle.



Ram at mid stroke, note drop arm angle.

prevent any remaining plastic extruding from the nozzle.

The mould is opened and the component removed either by ejector pins fitted within the mould or levered out with small screwdrivers or similar devices (photo 6). This in essence is the process, but further details will be given later in the article.

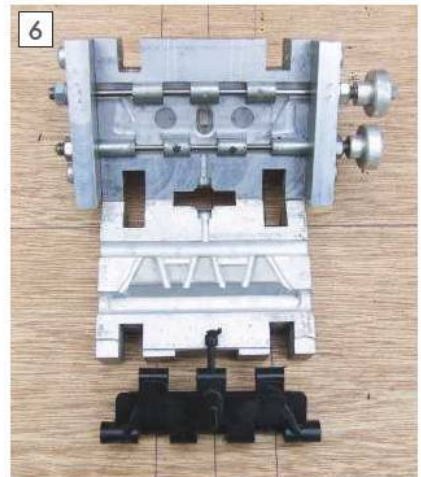
At this point it might be instructive to define the term 'plastic'. Injection moulding requires the use of Thermoplastics. These are plastics that may be heated to a point where they become semi fluid, rather like a very thick grease and then they can be forced into a mould. Upon cooling to normal temperature they retain the mould shape, but if reheated they will return to the



Ram at bottom of stroke.



Rear view of middle platform, ram at bottom of stroke.



Opened mould and extracted moulding.

semi fluid state and lose their form. Thermosetting plastics such as Polyester, Polyurethane and epoxy resins require a catalyst to change from a liquid to solid state, but once cured cannot be changed as heating generally destroys the material.

The components

Most of the components are of simple construction and only an outline of manufacture for each is given.

Photographs 7, 8 and 9 show the ram at the top of the stroke to the bottom.

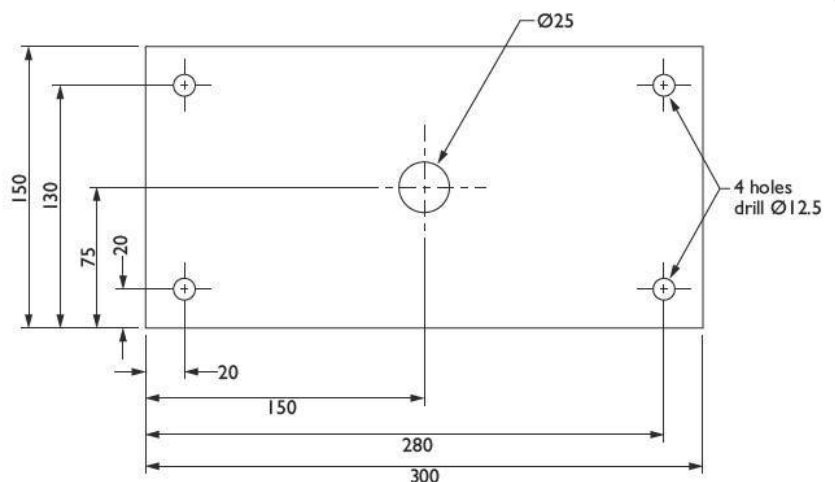
Photographs 10 to 19 illustrate the arrangement of the components described below. Many of the stock material sizes are Imperial but the nearest metric equivalent could be employed.

The lower and middle platforms (Parts 1 and 2)

These are two $\frac{1}{2} \times 6 \times \frac{3}{8}$ inch or 12 x 150 x 305mm bright drawn mild steel plates drilled as shown in drawings 1 and 2.

The cylinder locating hole in the centre of the middle platform should be of a large enough diameter to allow for cylinder alignment on assembly. I have located one supplier of this plate size, as noted at the end of the article.

To be continued...



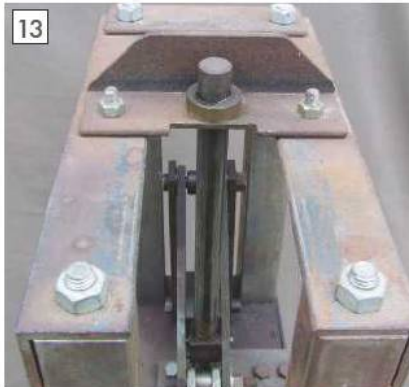
Part 1. Lower Platform
Mat'l: 12mm mild steel, 1 off



Details of drop link mounting and lever pivot, note spacers.



Details of lever arm, tie link and upper lever.



Top platform showing upper ram bushing.



Detail of middle platform.



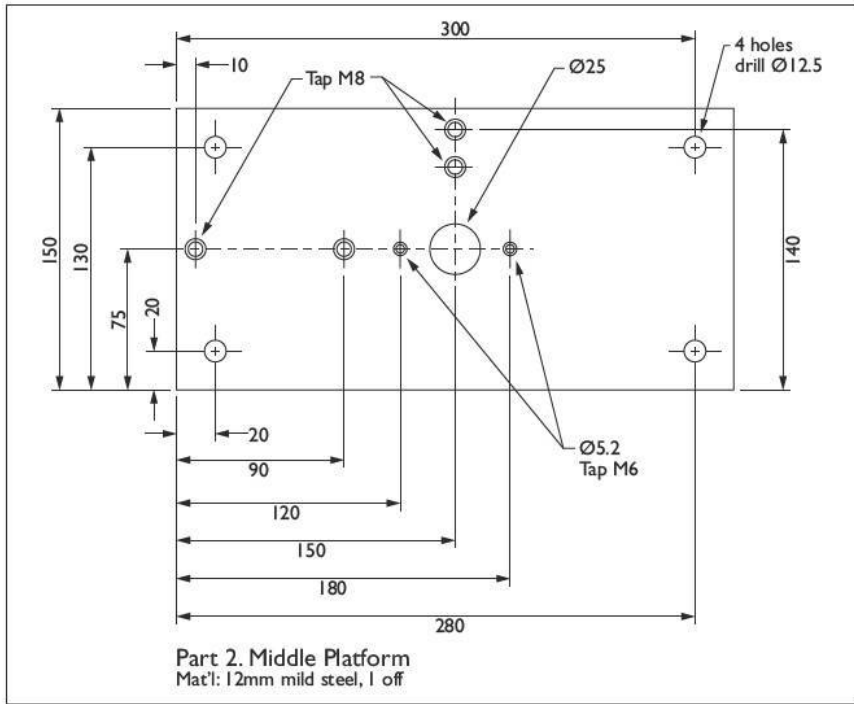
Middle platform detail.



Cylinder top plate, note four bolts rather than the two shown on drawing.



Detail of middle platform.



Detail of middle platform.



Lower ram bushing and support plate, note bushing retaining screw.

Renovating a Cowells lathe



Tony Jeffree adds the final touches to his Cowells lathe.

Having re-instated the missing dog clutch, change-wheel banjo, studs and bobbins, the final stage of re-instating the fine feed and auto-trip features of the lathe is to make the set of fine feed gears.

Earlier articles in this series have described how I restored a very sad looking, rusty and grimy Cowells 90 E Basic lathe to something rather closer to its former glory (photo 1). So far, I have described the process of renovating the lathe hardware itself, both cosmetically and functionally, mounting the lathe on a new base, replacing the geriatric and potentially lethal $\frac{1}{4}$ th HP single phase motor with a shiny new 90 Watt ($\frac{1}{4}$ th HP) 3-phase motor and matching Variable Frequency Drive (VFD), and retro-fitting the lathe with a dog clutch, banjo, and the studs and bobbins to fit the banjo. The final piece of the jigsaw, at least for the present, is to make the change wheels necessary for a fine saddle feed.



The first abortive attempt at gear hobbing.



The renovated machine awaiting the fine feed.

My collection of 'round tuits' ran out soon after completing the banjo and dog clutch and it has taken a while to find a fresh supply. However, this week I finally managed to find the time to complete the renovation project, at least to the point where the fine feed is operational; at some point I may make myself some further change gears to complete the screwcutting gear set, but for the moment, this will be the last article in the series.

The standard gears for the Cowells betray the machine's Imperial origins; they are 32DP, 20 degree pressure angle, bored $\frac{1}{4}$ inch and with a keyway to fit a $\frac{1}{2}$ inch square key. I did a fair amount of trawling of the usual suppliers, Google, eBay, and such before concluding that gear cutters for 32DP 20 degree PA were made of 24-carat *Unobtainium*. Plenty of opportunities to buy 14.5 degree PA cutters, but that would not be ideal as the tooth form would be rather different. However, it turns out that 0.8 Mod is close enough to 32 DP as makes no odds, and 20 degree PA cutters in 0.8 Mod are far more readily available, so I decided to go with that.

Free hobbing?

I bought a 0.8 Mod hob from Arc Euro Trade, and a No. 8 (135T to Rack) 0.8 Mod multi-tooth gear cutter from someone on Ebay, with the intention of trying a variant on the free hobbing approach to gear cutting, the idea being to use the

multi-tooth cutter instead of a slitting saw to gash the gear blanks before using the hob. My thought was that the 'gashed' shape would be pretty close to the final tooth shape and the hob would then only have to do the cleaning up. My initial attempts at this approach simply didn't work. I think this was probably because the setup I was using. My trusty wheel cutting engine built from Taig lathe parts, described in MEW issue 92 and also on the web here: <http://www.jeffree.co.uk/pages/cnc-wheel-cutting-engine.htm> really isn't rigid enough to cope with hobbing a gear. Photograph 2 shows about the best of my attempts using this approach but they are really not suitable for prime time I'm afraid. I'm sure free hobbing can be made to work, and can produce good results, but I haven't managed to get there myself as yet. So, it was back to the drawing board.

Variations on a theme

In issue 131 of MEW I described a novel (to me, at least!) approach to gear cutting, using a home-made rack form cutter. The article is on the web here: <http://www.jeffree.co.uk/pages/multi-tooth-gear-cutter.htm>

I realised that I could use a very similar approach to the one described in the article, but use the commercial 135T to Rack cutter instead of making my own. As I mentioned in the article, it takes relatively few cuts to make gears with quite a close approximation to the ideal Involute tooth

form, and the obvious advantage is that, as with a hob, you can get away with using a single cutter to make a gear with any tooth count.

The variant of this technique goes as follows:

- 1) Set up the gear blank and cutter as you would if you were planning to cut a gear conventionally using a multi-tooth cutter; i.e., set the rotational axis of the dividing/indexing head that carries the gear blank to be in the plane of the gear cutter, and set the depth of cut to the desired tooth depth, so the setup will cut each tooth space in a single pass.
- 2) Cut the gear, using the appropriate tooth count for the size of blank.
- 3) Shift the axis of the gear blank by exactly the pitch of the gear (i.e., the distance between the tooth tips of a rack with the chosen pitch), and repeat the cutting pass on all teeth.
- 4) Shift the axis of the gear blank back in the reverse direction by exactly 2 pitches, and repeat the cutting pass.
- 5) Shift the axis of the gear blank by ½ of a pitch in the direction you chose for step (3), rotate the gear blank by ½ of a tooth, and then repeat the cutting pass on all teeth (using a full tooth space between cuts).
- 6) Shift the axis of the gear blank by a full pitch in the direction you chose for step (3), and repeat the cutting pass on all teeth.

Photograph 3 may help to visualise what is occurring here. The gear cutting engine is basically a Taig lathe with the headstock

rotated by 90 degrees, and a vertical slide used to carry the dividing head. Alignment of the dividing head axis with the plane of the cutter is achieved using the cross slide of the 'lathe' and the depth of cut is adjusted using the vertical slide. The saddle is moved towards the cutter to pass the blank over the cutter, hence cutting the space between adjacent teeth.

If the movement of the cross slide and the dividing head were geared together so they were perfectly coordinated, then moving the cross slide by one pitch would rotate the dividing head by one tooth as if the gear blank were rolling in mesh with the single tooth of the cutter. If you were to pass the blank across the cutter in this way while the cutter was spinning, then the result would be that the cutter would cut away the necessary relief on the tooth to create a proper Involute tooth form. The approximation described in the steps above is to make five cuts; one at the 'normal' central position, two at ½ of a tooth pitch either side, and two at a full tooth pitch either side, which cuts away most (but not all) of the necessary relief. Now clearly, this doesn't result in a perfect Involute tooth form, but in practice, the gears I have cut this way mesh together just fine (and mesh with commercially made gears too), and you don't have to invest in a full set of gear cutters in order to achieve usable results.

As with the approach described in MEW 131, you could take smaller steps, maybe making cuts at every ¼ pitch; however, you will need to be particularly careful about coordinating the direction of rotation of the ¼ tooth steps and the

direction of the associated axis shifts. Get that wrong and you will end up destroying the tooth form instead of cleaning it up.

The Cowells fine feed train

The gears needed for the standard Cowells fine feed are as follows:

- A 20T gear, attached to the back end of the spindle, driving:
- A 32T gear, coupled to a 16T gear, on the first stud, driving:
- A 56T gear, coupled to a 24T gear, on the second stud, driving:
- A 64T gear attached to the left-hand end of the leadscrew.

The overall effect is a reduction of nearly 15:1, resulting in a saddle movement of 0.067 mm per spindle revolution, or approximately 2.5 thou per rev, which is about right for a fine feed on a lathe this size, so there was no good reason to choose a different combination.

Cutting the gears

The gears are nominally ¼ inch thick, with a ⅜ inch bore. Blanks can be made up by taking slices off suitable bar stock, turning down the OD to the size needed, and then drilling and reaming to ⅜ inch. Photograph 4 shows the blank for the 64T gear being faced off prior to boring; the two larger gears I made from aluminium because I didn't have any steel bar stock big enough, but the remaining gears I made from steel offcuts that I found in the scrap box. The following table shows the appropriate outside diameters for the gear blanks; with module sized gears, the OD in mm is Module size times (Tooth count + 2).

Tooth count	Outside diameter
64	52.8mm
56	46.4mm
32	27.2mm
24	20.8mm
20	17.6mm
16	14.4mm

As I had bought a 20T gear from Cowells, I only had five of these gears to cut. The cutting depth needed for these cutters is 2.157 times the Module size, which in this case means a cutting depth of 1.7256mm, or 68 thou. The pitch length needed for the offsetting is simply Pi times the Module size, which is 2.512mm or 100 thou.

Photograph 5 shows my daughter cutting one of the gears, using the wheel cutting engine and one of my DivisionMaster controllers to take the pain out of driving the dividing head. Most of the gear cutting is straightforward; however, as I intended to bore and keyway the gears, the 16T gear is somewhat problematic, as a 16T gear is so small that there is almost no room to fit a ⅜ inch bore and the keyway through it without breaking into one of the tooth spaces. To get around this, I made the 32T gear as normal, and then machined a roughly 3



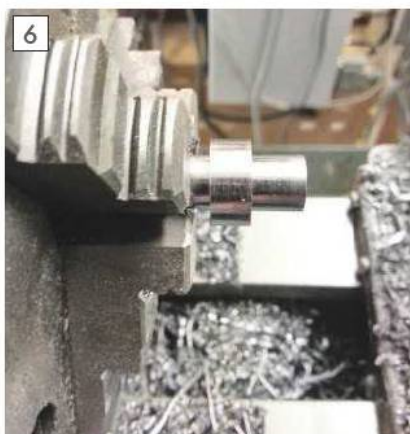
The gear cutting machine.



Facing a gear blank.



The author's daughter cutting a gear; mind the sleeve please.



Blank bobbin being machined.



Bobbin with gear trial fitted.



Cutting the 16 tooth gear.



Parting off the gear assembly.



Slotting a gear.

this need, described in my article in *MEW* issue 196 and I have to say, it works very well indeed. **Photograph 10** shows one of the larger aluminium gears having its keyway cut. The cutter that I had fitted to the slotter proved to be a tad undersized to cut the $\frac{3}{32}$ inch keyway, despite it being made from nominally $\frac{3}{32}$ inch round bar, so a little adjustment was necessary to get the bobbin to fit properly, the keyway can be widened ever so slightly just by rotating the lathe spindle a tad and then giving it another stroke with the slotter. The gear is lightly gripped by the chuck jaws; mostly I was relying on the gear being pressed against the chuck body, so the jaws are there to hold the gear in position rather than for grip, so the gear teeth don't suffer any damage.

Photograph 11 shows the 24T gear after the keyway had been machined, with the bobbin inserted to check for fit. The centre bore of the 4 inch chuck is larger than the OD of the gear, so I borrowed one of my Taig chucks and held this in the 4 inch chuck jaws, so it in turn could give support to the gear while the keyway was cut.

inch length of bar stock down to $\frac{1}{8}$ inch for most of its length, with a $\frac{1}{4}$ inch wide 14.4mm diameter 'gear blank' at one end, and a final $\frac{1}{8}$ inch section at the very end long enough to carry the 32T gear, plus about 1mm (i.e., about 7.35mm long). **Photograph 6** shows this 'blank' being machined. Before removing it from the lathe, I drilled and reamed it $\frac{1}{8}$ inch. **Photograph 7** shows this blank with the 32T gear trial-fitted on the short $\frac{1}{8}$ inch section; **photo 8** shows the 16 teeth being cut, with the longer $\frac{3}{8}$ inch diameter length held in an ER16 collet chuck

attached to the dividing head. After cutting, the 32T gear was Superglued in place, and the 16T/32T cluster parted off just behind the 16T gear (**photo 9**). The overall length of this cluster matches the length of the bobbins described in the previous article and this cluster replaces the bobbin on the first stud.

Cutting the keyways

This was the first time that I had used the Hemmingway 'Keyway Slotting Attachment' that I built in anticipation of



Checking the gear's fit on a bobbin.



The gear train from the end of the lathe.



The gear train from the front of the lathe.

All that was left to do was to fit the gears to their respective bobbins, adjust the studs for good but free meshing of the gears, and test it out. **Photograph 12** shows the gear cluster viewed from the side. The bobbin on the leadscrew is the same length as the stud bobbins (½ inch) so it is necessary to use a spacer to hold the 64T gear firmly in position. This is just a ¼ inch length of bar stock bored ⅜ inch with an internal key slot. If you were going to make the full set of change gears, an easy alternative would be to use a spare change gear as the spacer. **Photograph 13** shows the cluster viewed from the operator's position. You can see from this photo that the 64T gear is slightly thinner than the nominal ¼ inch; when parting off the blank I made it a shade too thin. However, this doesn't matter at all, and in some ways, is an advantage, as there is a bit of daylight between it and the 56T gear.

Parting comments

In operation, the gear train is surprisingly quiet; I was fully prepared to find that there was too much noise to leave the train permanently engaged, but in practice, it really isn't a problem. Engaging/

disengaging the dog clutch is easy, and the operation is nice and smooth. All in all, a very satisfactory conclusion to what has been a rewarding series of projects, and which has resulted in a very usable machine to add to the collection. ■

SUPPLIERS AND OTHER CONTACT DETAILS

Cowells Small Machine Tools, Tendring Road, Little Bentley, Colchester, Essex, CO7 8SH, U.K.

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Holding short ends for cutting with a bandsaw



Brian Wood offers a woodworking solution to a metalworking problem.

How often do you go to the offcut box for a short piece of bar which is just right for the job in hand and then struggle to find a safe way of holding it for sawing to size?

The method described here is suggested as a better way of holding offcuts and short ends of bar before sawing without messing about with clamps or unstable gripping in a vice.

I make no apology for lifting this idea straight out of the woodworking world. It is really an extension of the concept of a glue chuck, which itself has been freely adopted in the metal working world by using double sided tape on faceplates to hold things like washers for facing and shaping.

I now use a piece of wood of whatever shape is suitable to make a handle with the end cut square. Onto that I glue the clean end of the piece to be sawn using a modern polyurethane adhesive (ref 1). This glue has the added advantage of foaming as it sets to enhance the gap filling properties in the joint. When set after a few hours at room temperature, it will resist shear forces across the joint face and washer thickness slices can be sawn off with confidence.

I recommend the final cut is made into the wood side of the glue joint, it leaves the stick ready for use on the next job. Glue and timber residue on the joint can easily be turned off on the lathe.



A typical joint all glued up; the swollen appearance of the glue is from the foaming action.

Joint strength is improved with gentle heating; I leave things overnight, and clamp if necessary, above the workshop storage heater ready to cut the next day.

The joint is best arranged so that the bar to be cut and the stick to which it will be bonded have at least one common face to support the joint from the forces generated by the saw blade. The usual requirement of having clean surfaces applies. Sticks of oily wood like teak are best avoided; I find soft wood is just fine.

Job support is enhanced with a piece of angle iron and bits of sacrificial packing if needed to resist the horizontal drag loading from the saw blade. The blade is allowed to cut into the rear upright of the angle and the cut is stopped as soon as it is obvious the sawn piece is free.

The method is really intended for use on bars of 1.5 inches and above in diameter, the smaller diameters are probably better held in a bench vice and cut with a hacksaw.



Sawing in progress, note the angle iron support.

Photographs 1, 2 and 3 are respectively of a glued joint after curing, a cut partway through (note the angle iron support into which the blade is cutting) and the 3mm thick piece of the residue left over together with the 12mm slice I needed. Photograph 4 is the joint face after separation.

The joint in this example needed a hammer and chisel to separate the residue from the handle. For this job I was cutting a piece of 50mm diameter cast iron. Despite a 1 inch dimple from a big drill on the bonding face, there was still ample strength in the joint. ■

REFERENCE

1. (Usual Disclaimer) Everbuild Gator Glue. It claims to bond almost anything to anything and comes in a clean, easy to use squeezable pot with a nozzle and sealing cap. It is also waterproof when set.



The piece required and the residue remaining.



The joint after separation.

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■ Dickson type 4 inch tool holders, one off new to take No2 Morse Taper, five of standard as new, one off parting off blade holder with blade, one off to take 1½ inch tool shank, £18 each or £130 for the lot. **T. 01235 847516 Abingdon.**

■ Warco XJ9512 mill/drill + cabinet, £375. MES plough grinder £250. **T. 01273 461501 Brighton.**

■ Axminster Sieg X1 micro mill, 240 x 145mm table, 2 Morse taper, M10 drawbar, PWM 150 Watt motor, 8mm Tee slots, £160. **T. 01642 886980 Stockton-on-Tees.**

■ Peatol micro lathe 2¼ inch centre height x 9 inch between centres with motor on steel base, 10 speed, vertical slide, collets, tooling, hardly used, £240. **T. 01789 778174 Alcester, Warks.**

■ Myford ML7 screwcutting lathe with clutch, Myford deep tray raising blocks on steel stand, four way tool post, vertical slide, machine vice, little used, £850. **T. 01227 361909 Herne Bay.**

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