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JANUARY 2016

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How to Make a Sacrificial Table

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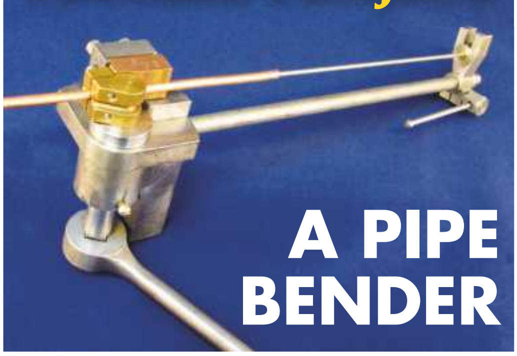

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Model Engineers' Workshop, ISSN 0959-6909, is published monthly with an additional issue in August by MYTIMEMEDIA Ltd, Enterprise House, Enterprise Way, Edenbridge, Kent TN8 6HF, UK. The US annual subscription price is 52.95GBP (equivalent to approximately 88USD). Airfreight and mailing in the USA by agent named Air Business Ltd, c/o Worldnet Shipping Inc., 156-15, 146th Avenue, 2nd Floor, Jamaica, NY 11434, USA. Periodicals postage paid at Jamaica NY 11431. US Postmaster: Send address changes to Model Engineers' Workshop, Worldnet Shipping Inc., 156-15, 146th Avenue, 2nd Floor, Jamaica, NY 11434, USA. Subscription records are maintained at dsb.net 3 Queensbridge, The Lakes, Northampton, NN4 7BF. Air Business Ltd is acting as our mailing agent.

On the Editor's Bench

Happy New Year

This was MEW's twenty-fifth anniversary year, I think most readers will agree it has been a pretty good one, though it was a shame that the changes to the Model Engineer Exhibition meant it did not happen in 2015.

Looking back over the last twelve months, modelling hasn't been my main activity. I have made 'incremental progress' with the Adept lathe and a couple of stationary steam engines. Rumours that I am planning to finish the Lady Stephanie beam engine in time for the opening of Heathrow's third runway are entirely unfounded!

Most of the jobs in the workshop have been making various bits and bobs for my other hobbies, not least astronomy including a tracking drive for my mount and a 'side by side' adaptor for a camera and scope. I've also had to do a fair bit of car maintenance, not least rebuilding the top end of an Astra engine after a cambelt failure (ouch), but I can now claim to being able to change a Mondeo drive shaft in under 25 minutes! These days car work seems to be mostly finding faults and replacing parts. I have to look elsewhere for places to exercise my new MIG skills.

Using the side by side telescope mount.

As for machining tasks, I have had a good balance between milling and turning jobs to do. Particularly satisfying have been a few threading jobs. I would encourage anyone with a workshop to try their hand at threading and gear cutting as there's a real satisfaction in making such parts to a standard, in contrast to my usual practice of making things to fit each other.

This year I also put in some effort to get used to using small carbide-insert tooling. Like many people who have struggled with brazed carbide tools or random inserts from a boot sale, I have previously only used carbide for 'getting through the skin' of tough castings, and accepted a poor finish in exchange for simply being able to do a job at all! Using small CCMT and CCGT inserts that are well matched to smaller lathes has been a real eye-opener. It does take a few jobs to get used to using these, but when get your hand in, they work really well. If you haven't used them before, have a try – don't be shy about using a decent depth of cut and plenty of RPM – just watch out for hot flying swarf!

I have also started tackling rather bigger tasks on my milling machine and again I have been trying out solid carbide cutters with success. The importance of the milling machine to our hobby has really come home to me this year. In the first ten years of *MEW* there was very little content on milling machines, but it seems that the majority of hobby workshops now have some milling capabilities. I have even come across one or two people who have stated they have a small mill, but no lathe!

My New Year's resolution for 2016 will be to complete at least one stationary steam engine (That will give me the excuse to start at least two new ones) and have the 'Mega' Adept lathe ready for show at MEX2016.

I hope that you have had a productive year too, now what do you plan to achieve in 2016?

Happy New Year!

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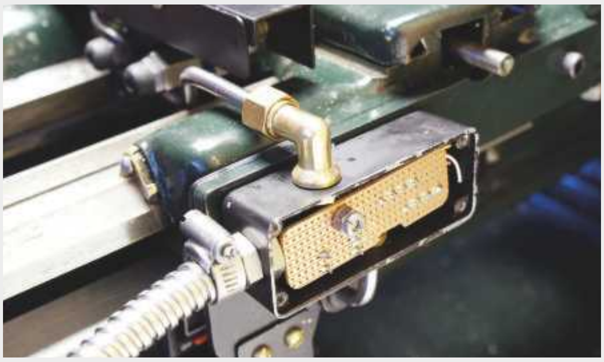
in the February issue



KNOWING WHERE YOU ARE
Tony Hills fits digital read outs to his South Bend lathe.

PLUS Alan Wain converts an aged drilling machine into a new mill and a machinery tale to chill the blood – Gary Ayre's Frankenstein.

Regulars

ON THE COVER »»

Marcus Bowman tackled a challenge in 3D to help out a friend who was fitting Yamaha forks to his Harley.

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The Duke of Edinburgh at the 1952 Model Engineer Exhibition
Many readers will be familiar with the Duke of Edinburgh trophy, a hotly contested award competed for by previous Model Engineer Exhibition medal winners. His visit, in the year of the Coronation, was what inspired the Duke to set up the trophy. Follow the link below to see unique archive footage of the event.

tinyurl.com/DUKEMEX

Other hot topics on the forum include:

- **Pressure Gauge before 1850** – what did engineers use before Eugene Bourdon invented his pressure gauge?
- **Hook Rule** – nothing to do with Peter Pan, but as the post says "never seen one of these before. Anyone used one?"
- **Photos of my Henry Milnes Lathe** - have you ever wondered what sort of lathe LBSC used? It was a Milnes and you can see one here.
- And of course, the legendary **'What did you do today?'** Thread – now with over 3,000 postings!

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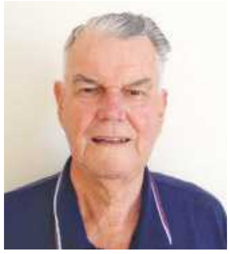
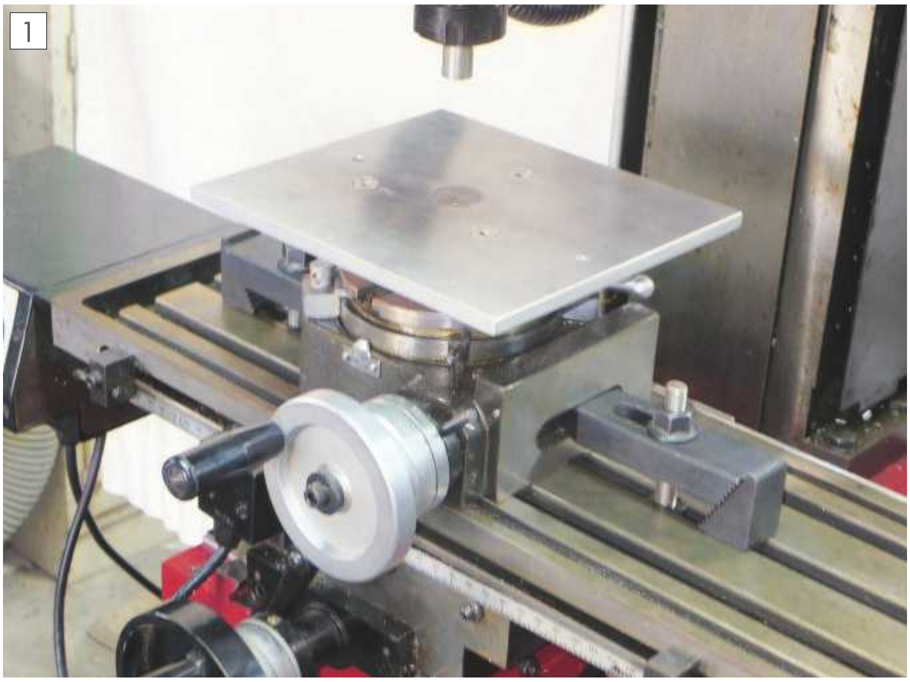
A Sacrificial Work Table for a Small Rotary Table



Get the most out of your rotary table with this handy idea from Bill Adamson.

Rotary tables can be very useful in a Model Engineer's workshop but they are usually small and the accurate mounting of work pieces can be difficult to locate accurately and hold securely. A work table fixed to the top of the rotary table that can be drilled for holding screws or even milled to accommodate protrusions on a work piece can make a small rotary table very versatile.



The new table mounted above the rotary table.

Why a work table

For many years, I resisted using my small 100mm rotary table (RT) unless it was absolutely necessary. I often went to great lengths to make elaborate jigs if I thought I could avoid getting the old RT out of the cupboard. This was solely due to the difficulty I found in fixing and holding down small work pieces on the table, getting them square with the X and Y-axes and trying to space them above the table so that the drill or cutter didn't damage the table itself.

One day I thought that if I put an aluminium top on the RT it might make it easier and that led me to develop a design for a suitable work table fixed to the RT top to mount my work pieces. Every time I thought I had developed the perfect solution to solve my problems, I would think of some other feature I could add and therefore another modification would evolve. The end result was so successful that I now look for jobs I can do with the RT (**photo 1**).

To avoid confusion in this article with the constant use of the word table, I have adopted the convention that 'RT' means rotary table or the table of the rotary table, 'table' or 'work table' means the table being built and 'machine table' means the work table of the milling machine being used.

What I needed

I was really looking for a work table I could use on my milling machine. Using a RT with an elevated work table does reduce the clearance you have available above the work piece and with small mills this is often limited. I have an X3 machine and it is adequate but I think the use of this table would be limited on a X1 or X2 machine.

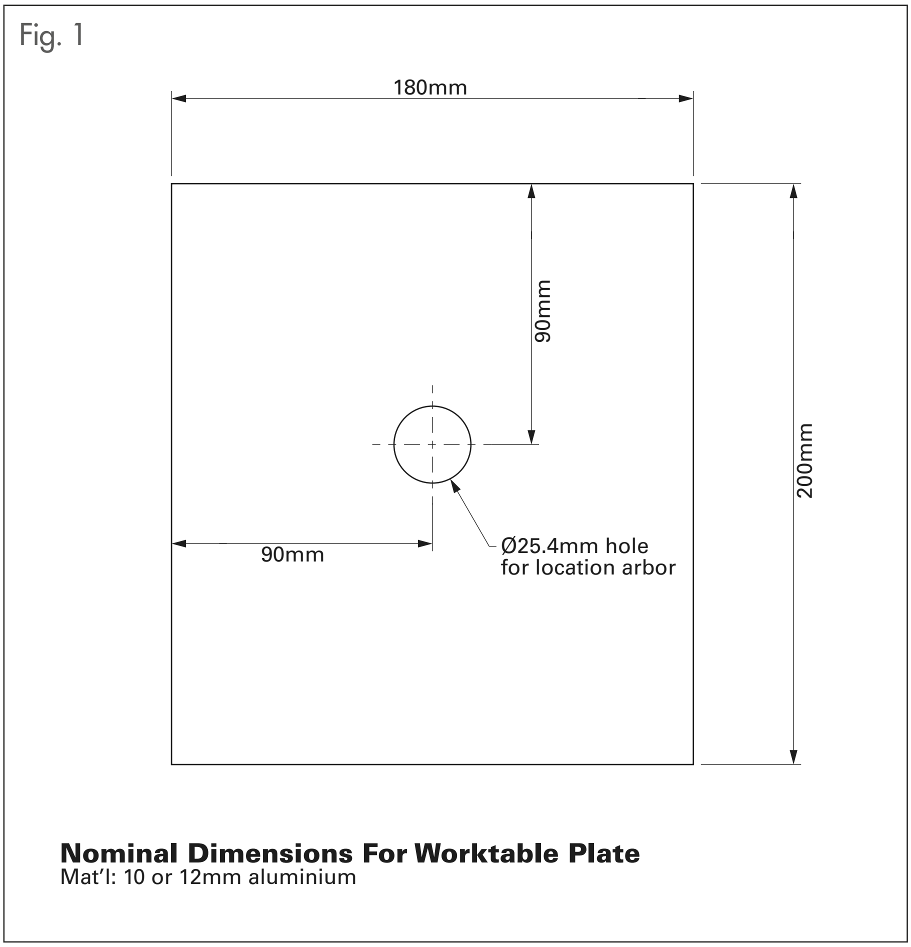
I listed out the criteria that I considered essential for a useful work table and tried to incorporate them all into the design. They included the following.

1) The four sides of the table need to be true to the X or Y-axes and the table surface needs to be perpendicular to the Z-axis.
2) The table needs to be 'sacrificial' in that it can be drilled or recessed to suit holding down screws or bolts or even protrusions on the work piece. It should preferably be of light material to facilitate cutting, drilling and milling.
3) The table should be elevated from the RT itself to allow metal thread nuts to be used under the table for hold down screws if required. An elevated table would also keep drills and other cutters away from the RT.
4) Easy removal and accurate replacement is required so that the RT can still be used for other work if required.
5) The table should be capable of supporting work pieces over the full range of machine table movement along the Y-axis.

Listing the requirements of my ideal work table was a good idea as it helped to clear my thinking but it did mean the design became much more complicated than I first envisaged.

The first criterion required a rectangular table with 90-degree corners, ensuring parallel sides and parallel ends and a top surface parallel to the RT top. If the table sides were aligned with the X-axis of the machine table, then a good square could be used to align any-axis of a work piece

MT2 arbour.



with the machine X-axis. If the table surface was perpendicular to the Z-axis, then drilling or milling would be perpendicular to the work piece.

The second criterion could be met by using, say, 10mm aluminium plate. Cutting and machining would be easy and if a replacement table was ever required, it would not be difficult to cut another table using the old table top as a template. The thickness of the plate used for the table is not critical.

The third criterion, an elevated table, starts to complicate the design. While it is not hard to turn up suitable spacers to raise the table above the RT top, being able to repeatedly remove and replace the table quickly and accurately is not so easy if the only means of fixing the table is by using the 3 tee slots available on the RT top.

The obvious fixed reference point for locating the centre of rotation of the RT is the central hole. In the case of my 100mm RT, the central hole is machined for a 2 Morse taper arbour and I just happened to have a MT2 arbour with a 30mm long x 25.4mm diameter shank that fitted well (**photo 2**). The shank had a 14mm diameter hole in the end and it had been used in the tail stock of my lathe to support the stub tails of my die and tap holders when tapping in the lathe.

I tried the arbour in the RT and it provided a good robust location pin for the table plate (**photo 3**). If the table plate had a 25.4mm hole providing a neat sliding fit on the arbour shank it would only require a method of fixing it so it could not rotate but could be aligned with the X-axis of the machine. The 14mm hole in the end of the arbour shank also provided an easy reference hole for the centre of rotation of the RT even with the table mounted on top.

The location arbour

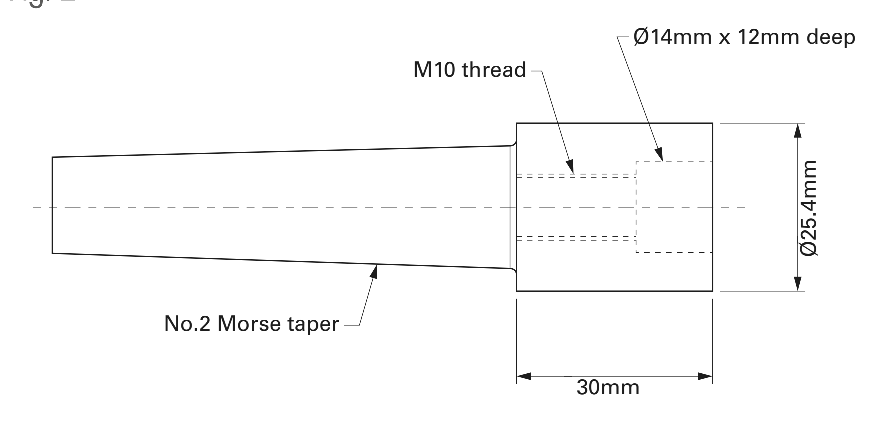
I decided to make a new location arbour as I didn't want to have to get the RT out to change out the arbour when I wanted to use it in the tail stock while tapping in the lathe. A new arbour was obtained from my local engineering supplier for about A$25. The diameter of the shank needs to be larger than the maximum diameter of the 2 Morse taper so that the arbour can be removed from the RT even with the work table in place. The new arbour was fitted into a 2MT/3MT sleeve and then into the 3MT socket of the main drive of the lathe and checked that the shank was running true with a DTI (**photo 4**). I didn't change the outside diameter of the shank, thinking the larger the diameter the more effective it would be in holding the work table in place.

A M10 x 30mm deep hole was drilled and tapped in the end of the shank. The M10 hole was then counter bored to 14mm diameter and to a depth of 12mm with a 14mm end mill (**fig. 2**). This would

Arbour fitted to rotary table.

Checking runout of the arbour.

Fig. 2



Location Arbor

provide an accurate 14mm diameter reference hole at the centre of rotation of the RT. The threaded portion of the hole would allow a M10 bolt to be used to secure work pieces at the centre of rotation if required or assist in removing the arbour from the RT if required.

Machining the plate

To meet the fifth criterion, the width of the table needs to be wider than the total travel of the machine table on the Y-axis. My X3 machine is limited to 140mm cross travel along the Y-axis so I made the table 180mm wide. The length was determined at 200mm so that it projected completely over the body of the RT. Unfortunately, making the table wider than the Y-axis travel does mean the work table is too wide to allow milling of the perimeter of the table with one setting on the machine table. This restriction was overcome as detailed later.

Having the table project over all sides of the RT also allows the table end to be checked against an accurately aligned angle plate bolted to the machine table.

Figure 1 shows the dimensions of the work table and the position of the 25.4mm diameter location hole. The outline of the table was marked on the plate and cut out on the band saw making sure the cuts were well outside the outline. The cut plate was then mounted on the machine table as square as practical and one end milled to provide a true and straight edge, still outside the table outline marks.

To ensure the final table corners were square, an angle plate was bolted to the machine table at 90 degrees to the X-axis to use as a reference. The accuracy of this reference was checked by using a DTI against the reference face of the angle plate along the Y-axis (**photo 5**). The cut plate was then positioned on a couple of parallel spacers to elevate the plate for machining, with the machined edge hard up against the bolted angle plate and clamped rigidly to the machine table. The position of the plate had to be such as to allow one of the sides (front or rear) to be milled full length along the X-axis. This second machined side should be exactly at 90 degrees to first machined end (**photo 6**).

The plate was then released, rotated 90 degrees and repositioned with the second machined side hard against the angle plate so that the other end of the plate could be machined, again along the X-axis. Finally this process was repeated to allow the second side of the plate to be machined.

If this machining procedure is carried out carefully, all four corners should be square. Whether the machining was exactly on the lines is not critical as the size of the table is not critical but all the corners need to be square and this is critical. If all the corners are not square after the first run, then the procedure should be repeated until all corners are square, and then the sides of the work table will be parallel and the ends will also be parallel. Accuracy at this stage is well worth the effort involved as it provides confidence in aligning and using the final work table.

The position of the 25.4mm diameter location hole was marked. The plate was mounted, elevated on parallel bars on the machine table in preparation for drilling. A centre drill was used first to establish the correct centre of the location hole and then the hole drilled with a series of drill sizes up to 13mm diameter. A 16mm diameter end mill (my largest) was then used to bore through the plate. The 16mm hole was large enough to allow the use of an adjustable boring bar to machine the hole out to a neat sliding fit over the shank of the location arbour.

At this stage, the location arbour could be inserted into the RT and the plate fitted over the shank to sit on top of the RT firmly located in the plane of the top of the RT but free to rotate about the centre of rotation.

Fixing the plate

I considered using the Tee slots as the method of securing the table on spacers to the RT but didn't think the accurate location of the table would be easy or positive enough. There would also be difficulty in locating the Tee nuts when bolting the table down. It was with trepidation I finally decided that the best method would be to drill and tap 3 x M6 holes into the RT table top to enable 6mm bolts to be used through the table and spacers. This decision was not taken lightly but the method has worked well and the 3 holes have not caused any problems at all with the RT.

Now it was necessary to establish where the fixing holes in the RT would best be located. The top of the RT is divided into three segments by the three Tee slots, so the best place was considered to be near the outside edge of the top and in the middle of each segment. I carefully examined the

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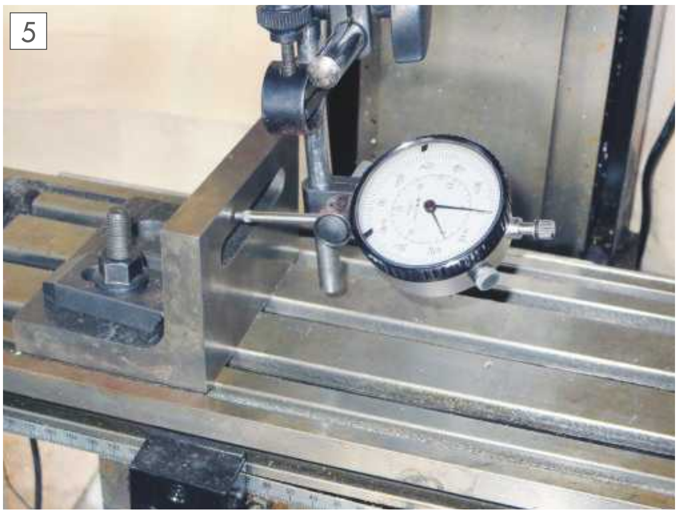


Aligning angle plate with mill Y axis.

6

Machining edge of the table.

positions on the RT and it appeared to be solid metal and clear of any working parts. I was surprised that none of the Tee slots were actually aligned with the zero degree position of the RT top, but one was displaced by about 12 degrees. This meant that holes in the centre of each segment would not be symmetrically spaced around the zero degree setting of RT. On the other hand, if the holes were placed symmetrically around the zero degree setting, they would not be located in the centre of each segment. This did not affect the positioning of the work table in any way and was really only an appearance factor. I decided to be symmetrical on the RT so the first hole was located and marked on an 80mm pitch diameter circle around the centre of rotation and in the middle of segment 2.

The RT was mounted on the machine table, square with the X and Y-axes and locked with the RT set at 0 degrees. The machine table was adjusted to set the centre drill in the mill spindle directly above the marked fixing hole. The machine table was locked in position and a 5mm hole was drilled to a depth of 12mm. This hole was then tapped M6, starting with a taper tap followed by a plug tap ensuring the hole was threaded as deep as possible.

The location arbour and the plate were fitted to the top of the RT, the plate still being free to rotate about the arbour shank. The plate was aligned roughly along the X-axis and an angle plate was set against the end of the plate and locked at right angles to the X-axis such that the plate was exactly aligned with the angle plate. The angle plate should be hard against the end of the plate and securely fixed to the machine table. If the angle plate is exactly at right angles to the X-axis, the plate will be exactly aligned with the X and Y-axes. If the RT is set at 0 degrees, is securely locked and square to the machine table, then the work table is set accurately on top of the RT for the first fixing hole to be drilled in the plate. The drill was still centred over the hole just drilled into the RT. A 6mm drill was used to drill carefully through the plate only to provide clearance and a M6 screw was inserted into the thread in the RT and tightened to hold the plate firmly to the top of the RT.

The angle plate was removed and the RT rotated through 120 degrees in readiness for drilling the second hole this time through the plate and 12mm into the RT itself. The drill size was 5mm, tapping size for a M6 thread in the RT. Before tapping the hole, a 6mm drill was used to enlarge the hole in the plate only, to 6mm clearance. The hole in the RT was tapped to M6, again using a taper tap followed by a plug tap to ensure the thread went as deep as possible. A second screw was inserted into the RT to hold the plate to the top. This process was repeated, rotating the RT around another 120 degrees to the 240 degree mark, drilling and tapping for the third and final mounting screw.

The next procedure was to countersink the three fixing holes. This was done while the mill spindle was still aligned over the third fixing hole. After countersinking, a screw and flat washer was inserted and tightened down. The RT was rotated around to the zero position placing the first screw directly under the countersinking bit. The screw was removed, the hole countersunk and the screw was replaced with a washer. This procedure was repeated to countersink the final screw hole and the screw replaced using a washer again to prevent the countersunk hole from damage. The countersinking of the holes was deep enough to ensure the heads of the final countersunk bolts was below the table surface. This would allow the table surface to be resurfaced with a fly cutter if and when necessary sometime in the future without touching the bolt heads.

Elevating the plate

The work table was now ready for the final stage, the fitting of three suitable sized spacers. I wanted the table to sit 5mm above the top of the location arbour shank so that a plug with a 14mm stub could be fitted into the 25.4mm central hole and would be flush with the table surface. Three 30mm long x 15mm diameter spacers were turned with a 6 mm hole drilled through the centre. It was essential the spacers were all exactly the same length. The spacers were fitted under the table and the table secured to the RT with three M6 x 50mm countersunk head bolts (**photo 7**).

Testing

The work table was finally finished and set up square on the machine table. If all my work had been carried out carefully enough, the work table should now be aligned with the machine axes and perpendicular to the Z-axis.

To check the alignment with the Z-axis, I mounted the DTI in a bracket that fits into the mill chuck or a 10mm collet (**photo 8**). By setting the mill spindle over the centre of rotation and rotating the spindle through 360 degrees, the DTI moves in a circle around the central hole. Any variation in the reading on the DTI indicates that the work table is not perpendicular to the alignment of the mill spindle. Fortunately, there was negligible variation during the test. The DTI was then set near one corner of the work table and the machine table moved so the DTI traversed to each corner of the table. Variation was less than 0.2mm. I was happy with that.

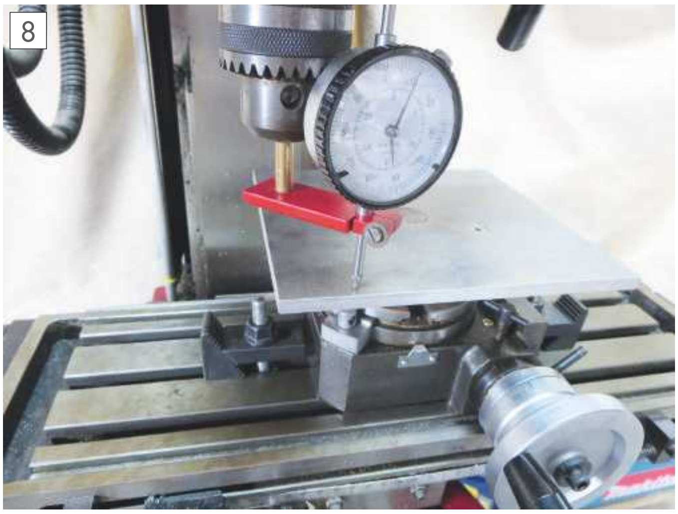
A DTI was assembled to check the alignment accuracy of the front edge of the table while the table travelled along the X-axis (**photo 9**). There was a difference of 0.1mm over the 200mm length of the table. A slight tap on one corner of the table corrected this and I was over the moon. The real test came when the RT was rotated 90 degrees and the next edge was checked. This was so close to being perfect I couldn't believe it and had to check that the DTI was actually touching the plate edge. The remaining two sides were also checked and were just as good. The effort put into getting the table plate square in the first place was well worth it.

The work table was now ready for use.

I wanted to check the accuracy of using the 14mm hole in the location arbour to determine the centre of rotation of the RT. I turned a 14mm diameter pin, 50mm long, tested it to see that it was a neat sliding fit into hole in the end of the location arbour and mounted it in a 14mm collet in the mill spindle. The mill table was adjusted such that the pin could be lowered into the arbour in the RT and the quill locked. The RT was locked down to the machine table and the DROs on the X and Y-axes were set at zero. The pin was raised above the arbour hole and the RT was rotated to 90 degrees and the pin lowered to see that it


7

The table spacers.


8

Testing for level.

9

Testing X/Y alignment.

10

Setting up for use, note the first few fixing holes in the table.

still entered the arbour hole. It did. A similar test was carried out with the RT located at 180 and 270 degrees. The pin entered the arbour on each test (thank goodness) so I concluded the RT was centred and the DROs were accurately zeroed at the centre of rotation. That accuracy has certainly been sufficient for my purposes.

I do have a thing about marking parts so I can reassemble the parts back into their original position. I marked the front edge of the plate and numbered the fixing holes and the spacers after the table had been tested for accuracy. Of course if all the parts are made perfectly, there is no need to do this but we all know that parts that are made exactly the same are not. I do have far more confidence now in setting up work pieces on this work table than I ever had setting up on the basic RT.

Using the work table

I did make the filler plug to sit into the central hole in the table as can be seen in photo 1.

The method I use to locate the RT when I use it is the same as I used for the test. I set the RT on zero and place it on the machine table in the position I wish it to be when machining the work piece, but don't lock it down. I then mount the 14mm pin in a collet in the mill spindle and adjust the machine table so the pin can be lowered into the arbour hole. The spindle is locked in place, not hard on the bottom of the hole. The RT is rotated until it is square with the machine table and lightly clamped down. A DTI is set up to check and adjust the alignment of the front edge of the work table and the RT finally clamped down tight. The DROs are set to zero and the work table set ready to go and aligned with the machine axes (**photo 10**). The accuracy obtained when using the unit depends on how square the corners of the work table are and then on how accurate the alignment of the front edge of the work table is with the X-axis.

Remember, it is a 'sacrificial' work table and can be drilled or machined to suit whatever hold down clamps you require. Even small G clamps can be used to hold reference guides or jigs etc. I am fairly careful with mine in that I don't damage it any more than I need to but if a drill marks it or a cutter touches the surface, it is not the end of the world. If you are not happy with the accuracy of the alignment of the edges or the surface has too many indentations, you can always run a fly cutter over the surface or even mill the edges to align with the relevant degree calibrations on the RT to restore the accuracy. The worst that can happen is that eventually, you may need to make a replacement plate but that is far better than having to buy a new RT. ■

Myford ML7R Power Cross Slide Part 2

Keith Wraight answers a perennial question – can power cross feed be fitted to an ML7R?

Standing at the lathe, a Myford 7R, taking a few thou off the front of a face plate I was thinking how nice it would be to have a Myford super 7 machine with power cross feed.

There seemed no prospect of a mechanical modification as the Super 7's saddle and cross slide is completely different to that on the 7R and it would be a very expensive proposition. However, not wanting to be beaten I then turned to thinking about an electrically powered approach and this seemed to be a much more promising proposition.

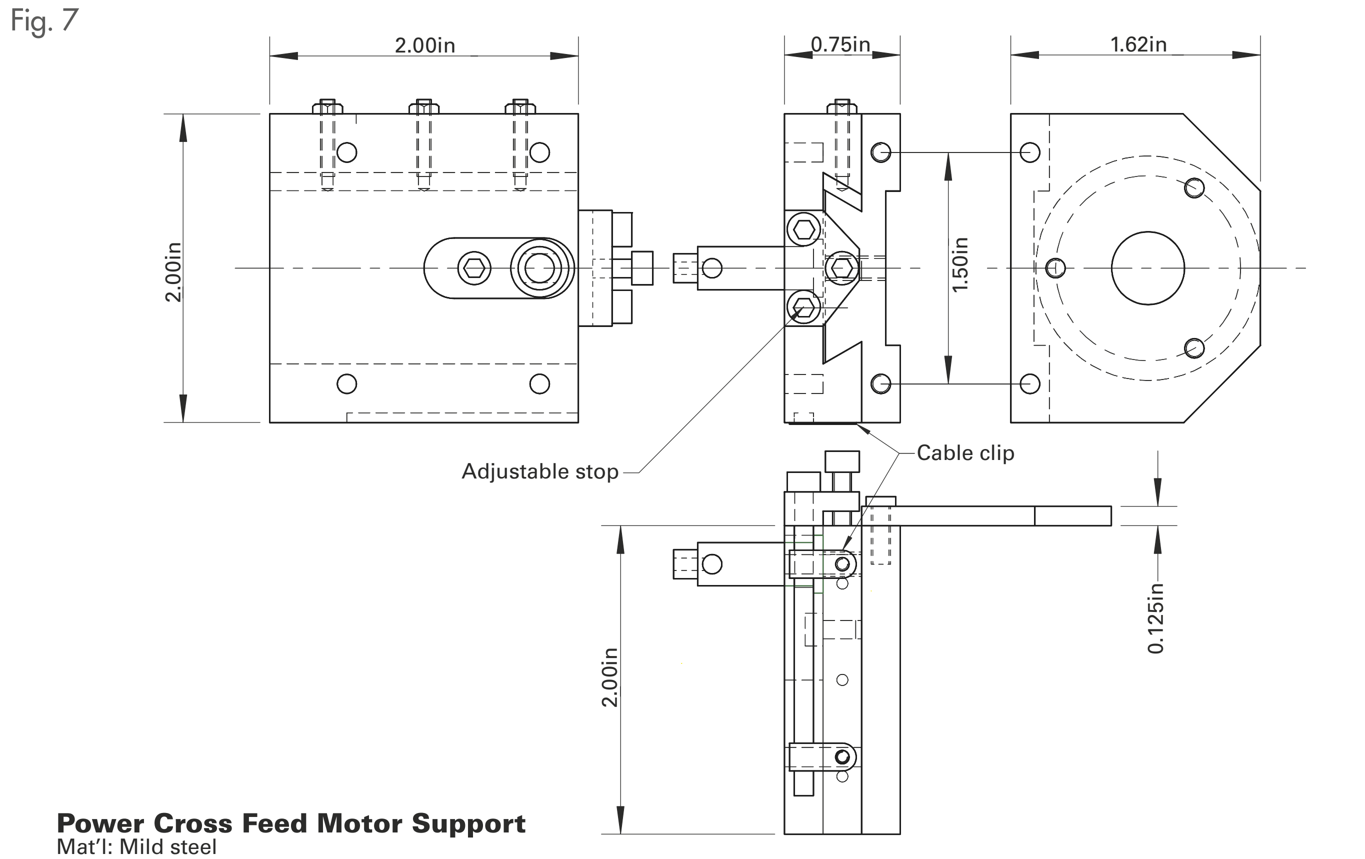
The completed unit ready for painting.

Dovetail slide, motor mount

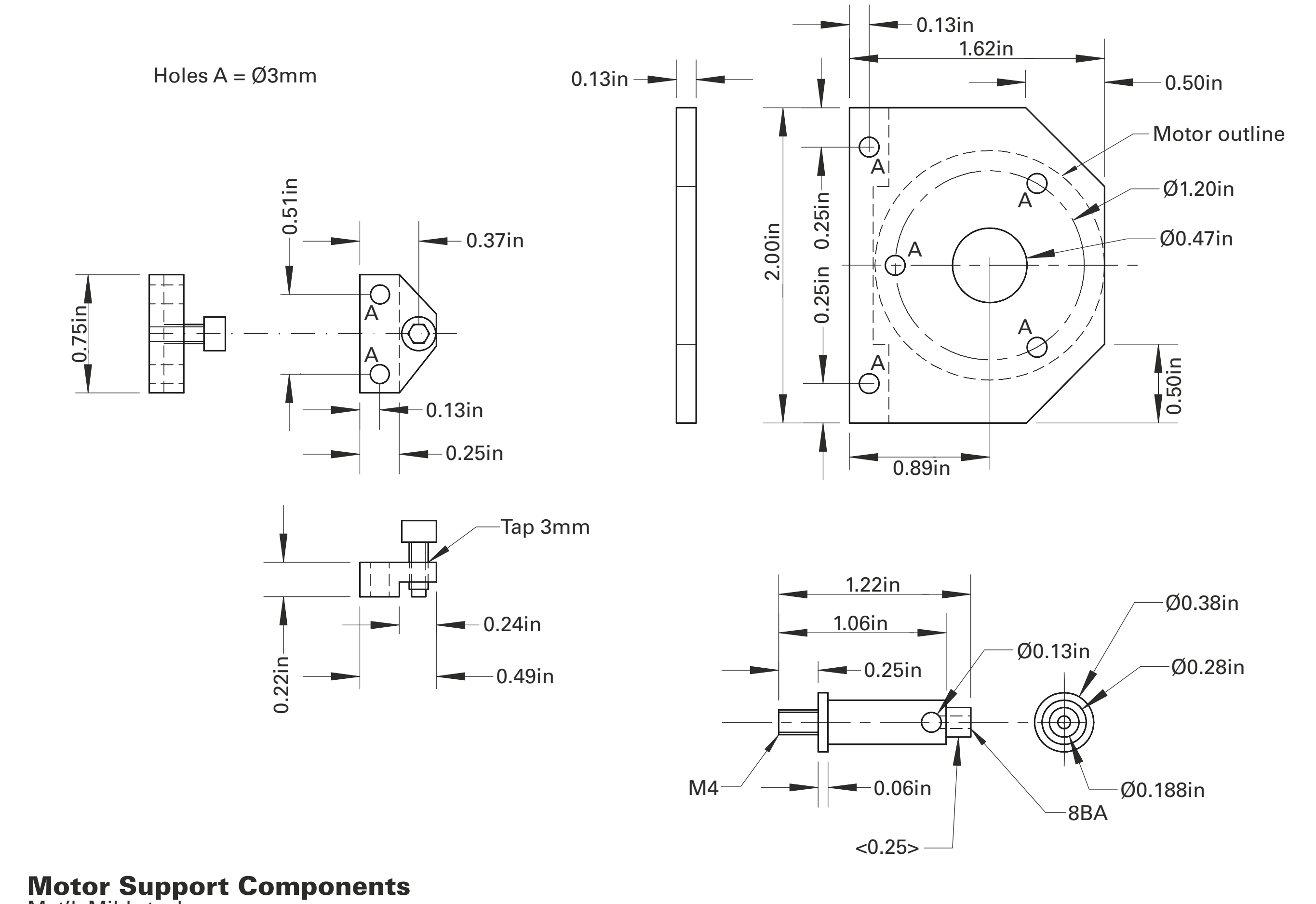
See **photo 5** and **fig. 7**. I chose to use a dovetail slide, to enable the motor and gear to move in and out of engagement, over other more simple forms of slide. The dovetail assembly allows adjustment of the slide on initial assembly. The dovetail unit (**fig 8,** overleaf, and **fig 9**) is manufactured from two pieces mild steel, 2 x 2 x ½ inch. Again try to obtain free cutting steel as it makes the milling so much easier. It will be found much quicker to mill the 60 degree (45 degrees is fine if that is the cutter you have) slides if a slot drill is first used to remove the bulk of the metal, up to and between the slides. The detail drawing fig.8 shows the dimension across two ¼ inch diameter pins inserted against the angled slides (60 degree) as a means of gauging the cuts when milling. The gib strip can be made from brass or steel; either will do. The strip can be held in the female block against the angled slide to mill the edges at the correct angle. Also the three adjuster screw dimples in the strip can be drilled whilst the strip is clamped in the block and a tapping size drill passed through the adjuster screw holes. The overall size of the blocks is not critical so if the two blocks do not fully align on assembly with the gib strip, the adjusting screws and gib strip can be nipped up tight and a cut taken over the edges to tidy them up. The holes and slot can now be marked out with reference to a centre line rather than the edges, to make certain they are in the correct position regardless of the overall size of the assembly. The holes can now be drilled and tapped and the ⅜ inch slot milled as shown. The ⅛ inch slot, used to retain the two wires to the motor, can also be milled in the female block (**photo 6**). The 'Motor Mount (fig.9) is cut from a piece of ⅛ inch or 10 swg mild steel plate and the holes drilled as shown. The motor mount is attached to the top of the male half of the dovetail with two 3mm screws.

Dovetail slide.

Motor wiring.



Power Cross Feed Motor Support
Mat'l: Mild steel



Motor Support Components
Mat'l: Mild steel

Fig. 9

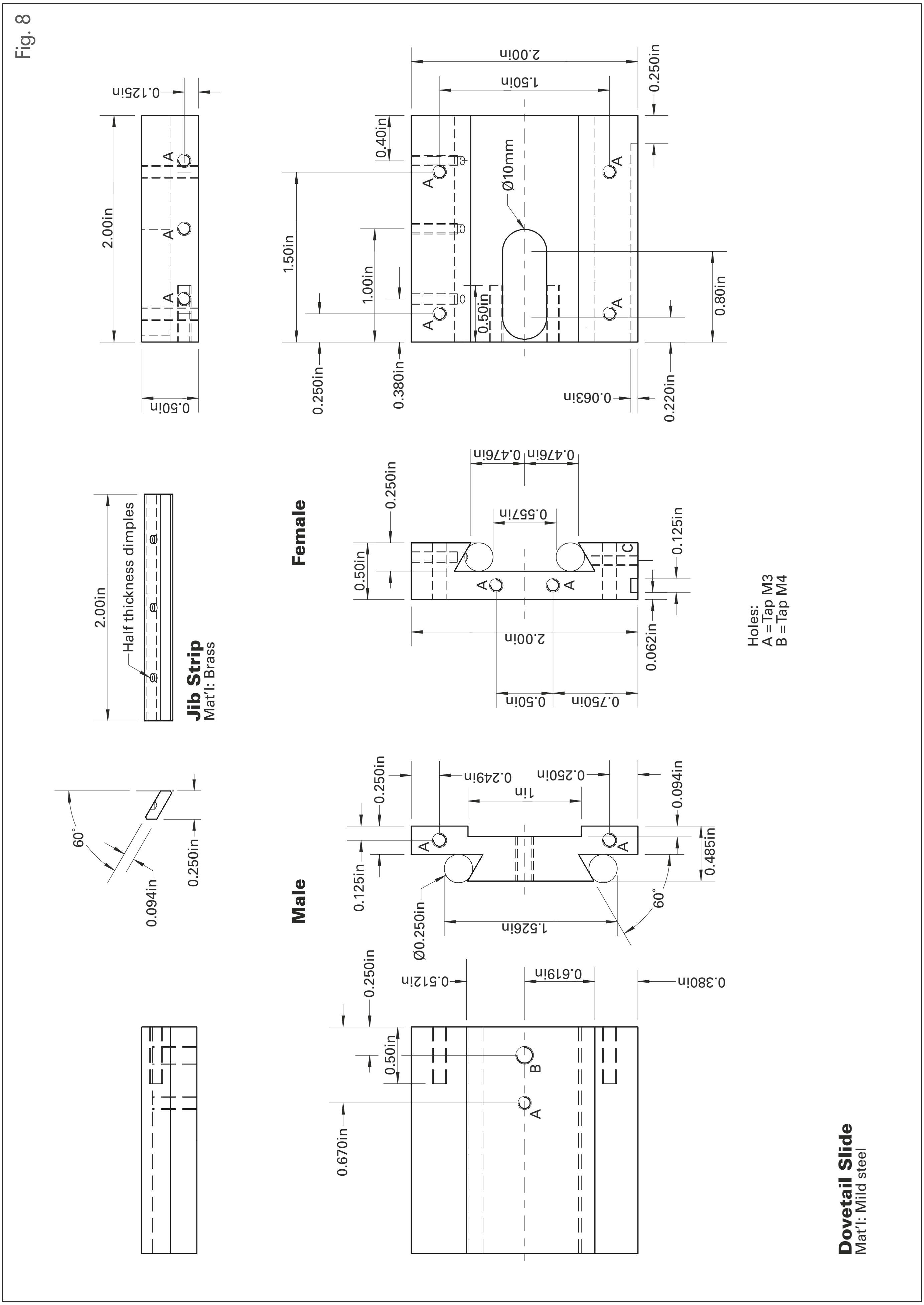


Fig. 8
Dovetail Slide
Mat'l: Mild steel
Male
Female
Jib Strip
Mat'l: Brass
Half thickness dimples
Holes:
A = Tap M3
B = Tap M4

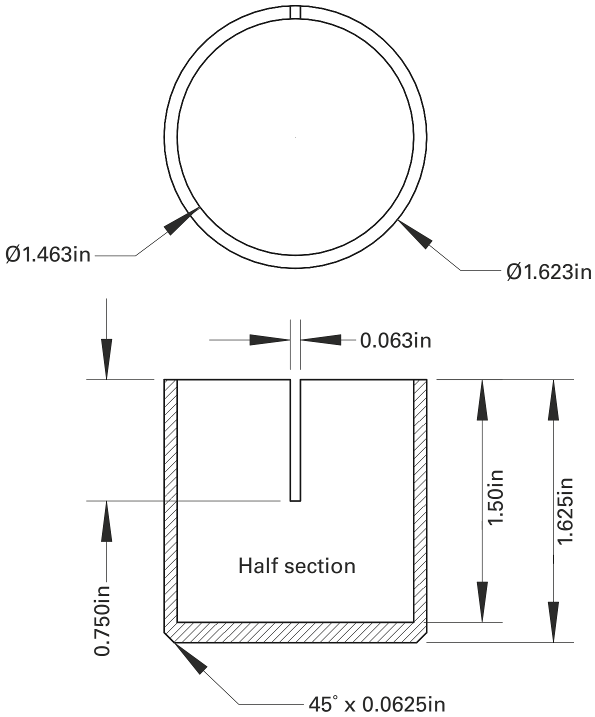
This could be a good time to mention the bevel gears. The steel gears were purchased ready made from 'Davall', as a matched pair of two to one ratio 32DP right angle bevel gears. When it came to opening up the holes in the gears I found that the details of each gear being stamped on their bosses made it difficult to hold them with any precision. This problem was overcome by turning a short stub axle to a good fit for each gear in turn, and the gear held in place by a short grub screw allowing the gear bosses to be skimmed. The gears can then be held in a collet to bore to size. The gears are clamped by short 3mm cap head screws against flats milled on their axles, which allows for ease of adjustment on assembly. The motor drive shaft had to be shortened by a small amount and the flat on the shaft extended to closer to the body. The shaft on my motor was not hardened so there was no problem. A plastic cover is needed for the end of the motor that has the solder tags. This is a simple turning job and also needs a slot to be milled so that a zip tie can close it to fit. A piece of nylon was used for this (**fig. 10**).

Details

The remaining small items for the dovetail slide are shown on the drawing. The adjustable stop is used to set the position of the small gear on the motor when the gears are in mesh. The bracket is made from mild steel and is a simple milling job, fig. 9. The adjusting screw is locked in place by a thin 3mm nut when set. The drive peg, again fig. 9, is a simple turning job and in use transfers movement of the motor mounted block through the slot milled in the female half of the dovetail assembly and is screwed into the tapped hole in the male half of the dovetail slide. The hole drilled radially through the peg is used for a tommy bar when screwing it into the block. The drive peg is turned from silver steel, and the short 3⁄16 in diameter section at the end made a good fit in the latch assembly con rod. A retaining washer is turned from bronze and is held on the end of the drive peg with an 8BA countersunk screw.

A 3mm cap head screw is fitted in the other tapped hole visible through the slot in the slide block. This screw acts as a stop when the gears are disengaged. The complete motor & mount can now fixed to the rear of the aluminium front plate with four countersunk M3 screws with the peg through the slot in the front plate, and located in the upper hole in the connecting rod and retained with the bronze washer and screw. See 'mechanical assembly' later in the article. I chemically blacked all the mild steel parts of the assembly to improve its appearance.

Fig. 10



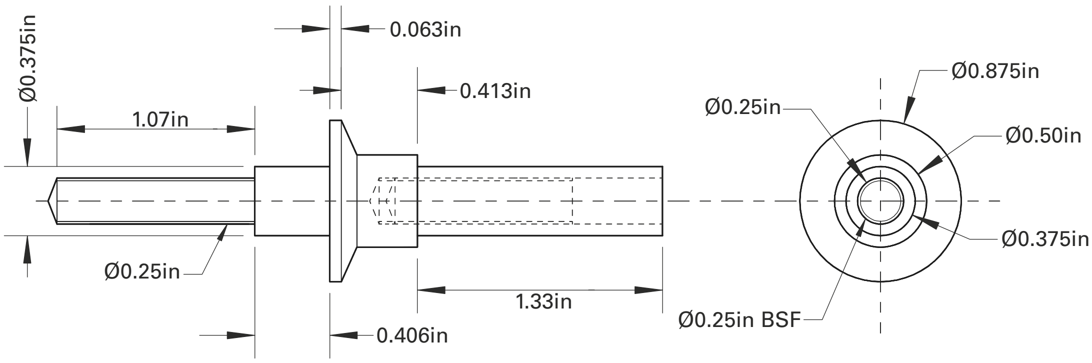
Motor Cover

Lead screw extension

Refer to **fig. 11** and **photo 7**. The extension is required to increase the effective length of the lead screw to take into account the extra length of the cross slide and bearing and provide an axle for the 32 tooth gear wheel. The extension is turned from a piece of one inch diameter EN1A steel. It is important that all diameters are kept in alignment. The 3⁄8 inch end can be turned, and tapped first then reversed and held in a collet by the 3⁄8mm section to complete the 1⁄4 inch BSF end. All that remains is to mill the 0.4375 inch A/F spanner flats and gear wheel lock flat as shown on the drawing, to finish the part.

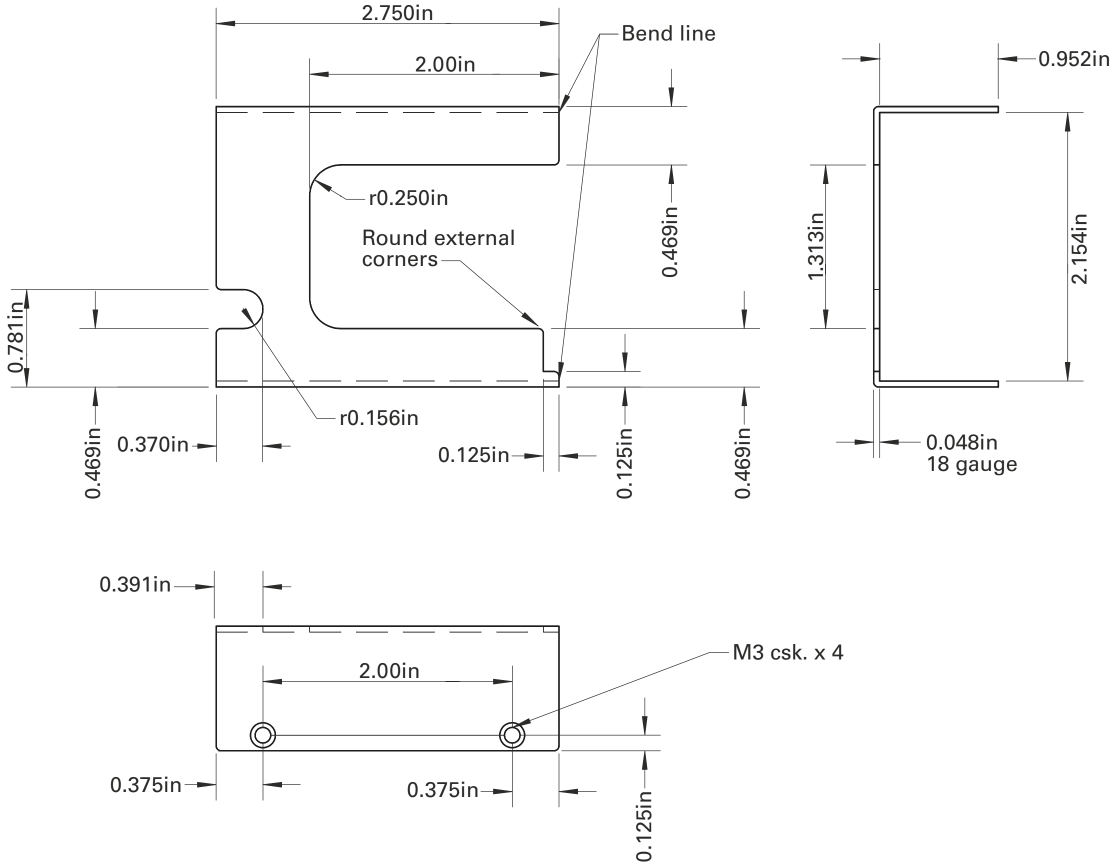
The leadscrew extension.

Fig. 11



Leadscrew Extension
Mat'l: Mild steel EN8

Fig. 12



Case
Mat'l: 18 gauge aluminium, brushed finish

Case

The case is fitted below the main body of the unit to cover up the gear assembly and electrical components and prevent ingress of swarf and oil when in use. There are four 6BA taped holes in the centre block used to attach the case, see **fig.12** for details. I find when making items of this sort that it is best to cut out the sheet material to size and bend it to fit before marking out for the cut-outs and the holes needed to allow access/clearance to parts of the unit. This negates any problems with bend allowances etc. The cover is made from 18 swg/1.2mm aluminium sheet and I used a scouring pad and oil to produce a nice brushed finish which also covers up the small marks made during manufacture. Very handy.

When working on sheet metal I invariably use a bench hook which is a simply piece of plywood about a foot square with a stout piece of wood say 2 x 2 screwed to the back of it to hold in the vice. One edge of the ply has a Vee cut-out in it to be used to support the job when the piercing saw is used. This simple device is invaluable in the normally crowded workshop of the average model engineer. Also a simple pair of bending bares about six inches long with counter bored holes for the heads of the closing screws was used.

To be continued...

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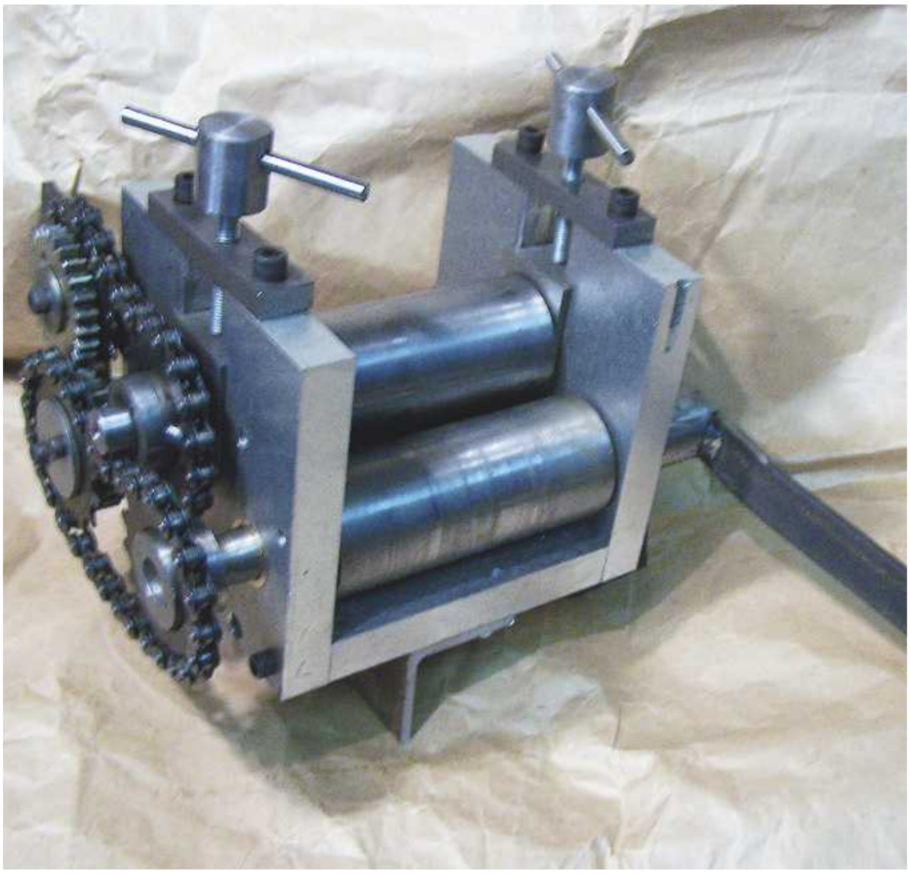
Heavy-duty Rollers Part 2

Will Dogget makes a tool suited to rolling large, narrow wheel rims.

The need for some heavy rollers came about when I wanted to roll some ¼ x 1 inch steel flat for some wheels on a garden trolley that I was going to make. My initial thought was to pull the steel into shape in stages with it in the vice but this ended up with small flats on the steel. As I had already made the workshop rollers by George Thomas (**ref. 1**), I did think of copying his design but after scaling it up I decided it would not be right for this type of job. The only course of action was to design one with the material that I had to hand. The following is how the heavy-duty rollers were developed and made.



Finished heavy roller.

Handle

The handle hub is made from 30mm diameter steel and is finished 30mm long with a keyway in it the same as the gears. **Photograph 41** shows the hub after machining but before being fixed to the handle which is made of ¼ x 1 inch mild steel 12 inches long. **Photograph 42** shows the handle and hub after welding and cleaning up the handle, and **photo 43** shows the completed handle with a wooden grip.

Pressure plates

The pressure plates were made from 20 x 10 x 80mm mild steel with a 8mm pressure screw (**photo 44**). The holding down screws were 5/16 Whitworth socket head cap screws at 60mm centres, the thread for these is being tapped in **photo 45**.

The nearly completed pressure plates are shown in **photos 46** and **47** with temporary pressure screws. **Photograph 48** shows the roller being tested. I thought the only things left to make at this stage were some proper pressure screws so that the pressure can be applied by hand and not with a spanner.

To hold the rollers in the vice for use, I bolted a piece of two inch angle the length of the base and at right angles to it so that the handle was clear of the vice this meant the angle was over to one side this can be just seen in some of the later photographs..

The handle hub.

Hub and handle assembled.

The completed handle.

The pressure plates drilled and tapped.

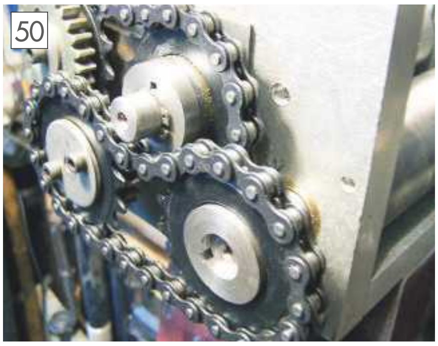
Hold down screws being tapped.

The pressure plates in position.

Temp pressure screws.

The first test roll.

The chain wheels.



Main drive chain.

A rethink

After testing the rollers I was a bit disappointed with the performance, to say the least! The flat that I was trying to roll kept slipping and was not moving as I expected. The bottom rollers moved in unison, but the top roller and the flat did not always move.

After some thought I realised that the top roller could have had roller bearings in the roller support slides, as this would of helped to cut the friction, rather than the plain bearing that I used. I decided to put a drive onto the pressure roller from the lower roller as there was not enough room to put bearings in the pressure roller slides, so it would need a lot more modification to fit roller bearings.

The alterations

The only way I could see to drive all the rollers was to put a chain wheel on both of the bottom rollers and fix a gear wheel to the back of the second driven chain wheel to drive a third gear working chain drive for the top roller (**photo 49**). The reason for the the gears is twofold: they change the direction of the drive, and they make it possible to remove the top roller completely by means of an arm to carrying the last two chain wheels and gear. Note that in the photo the lower chain looks as if it will rub on the shaft above but this is not the case, as the load on the chain when in use is on the bottom run and the top part remains slack as the in the photograph.

The chain wheels

To start the modifications I bought some chain wheels from eBay, at a price better than I could make them for. I also needed to buy some chain to fit. When the chain wheels arrived the centre holes were far to large to fit the shafts so they had a reducing centre made for them. These can be seen in the photos. The centres were turned to size and the centre hole reamed and keyways cut in the same way as for the gears they were then pressed in the chain wheel centres and tack welded as well. The two upper and lower chain wheels on the left of photo 49 are the ones that have the gear wheel fitted to them. The upper gear can be seen with its fixing screws, but the lower gear is hidden behind the chain wheel though you can see the fixing screws. The general arrangement of the new chain wheels can be seen in **photo 50**. The gear to the left is fixed to the chain wheel with M5 socket head cap screws with are counter bored in the gear. There is another gear wheel behind the left hand chain wheel in mesh with the one that can be seen as mentioned before. The reason for the gears is to change the direction of the top roller to help the metal to move through the rollers. The main drive roller, with the handle on the other end of it, is at the bottom and the one nearest to the camera in photo 50.

After testing the rollers I was a bit disappointed with the performance, to say the least! The flat that I was trying to roll kept slipping and was not moving as I expected.

Between the top chain wheels and under the chain in photos 49 and 50 you can just see a piece of rusty steel (I hadn't cleaned it when the photo was taken). This is the arm that supports the upper drive train.

The reason for the arm is as the pressure is applied to the top roller it moves down changing the contact with the lower gear allowing the gears to roll around each other and so maintain the drive. The arm is held on the shaft by the hub of the drive chain wheel on the pressure roller keeping it against the roller slide. This additional arm meant that the pressure roller support slide on required 6mm removing from outer face.

The other end of the arm has the gear/chain wheel hub bolted through a bush with a ¼ UNF socket head cap screw. This can be seen with the large washer to the left, also in photo 49. The unfinished end can also be seen in the photos of the complete machine, sticking out the back. It was made too long in case a fixing was required, but his was not the case so it will be shortened and cleaned up later when the other finishing and painting is done, as it was put to work as soon as possible after it was useable. The other reason for the arm is the pressure roller and the drive chain and gear which are attached to it can be lifted off after the pressure plates are swung out of the way, allowing the rolled ring to be removed.

Testing

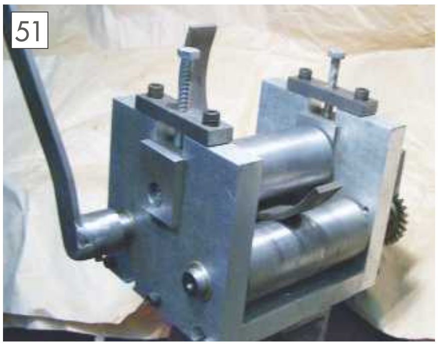
I tested the roller with a piece of 1 x ¼ inch steel. The steel was placed over the two bottom rollers then the pressure roller was tightened down onto the steel and the rollers rotated so that the steel passed through the rollers starting the bending. The handle is then reversed to the start position and the top roller is tightened again. The process is repeated until a circle is formed. The results of the test can be seen in **photos 51** and **52**. The next stage was to move on to a longer piece of material.

After testing

To finish the rollers, the pressure screws were remade with two pieces of M8 threaded rod with a top of steel with a tee bar. Two slots were cut in the pressure plates to allow them to swing out of the way when removing the finished job. **Photograph 53** shows the finished tee bars in position and the cut outs to the left of the pressure plates.

Using the rollers for a real job

The first real test was to roll a piece of 1 x ¼ inch steel flat that was going to be a 10¼ inch diameter wheel rim. To do this the circumference was calculated, and four inches added on the length. The extra material was for the run in and run out, as the way the rollers work the ends are not rolled, as the material has to span the lower rollers so that the pressure roller can do its job. **Photograph 54** shows an end that was cut off the ring after it was rolled. A piece of material was cut to length and rolled in the same way as the test. The results can be seen in **photos 55** and **56**. After rolling the waste was removed and the finished ring can be seen in **photo 57**, and with the size being checked in **photo 58**. The size was a little over but on this job it was not a problem so it was welded up, if it was too long



Test roll piece.

Tee bars in position.

it would be easy enough to shorten the length by cutting some off one end.

Conclusion

After the false start and the extra work that this entailed and the cost of the chain wheels and chain, I did think at one point is this going to be worth the effort? I think if I had started with chain wheels it may have been a lot easier to make. But when I used the rollers for the first time in anger, as it were, I think it was a YES it was worth making, as rolling the rings was so easy. The only shortcoming is the loss of material on the ends but this is only a very small problem. When the only

The finished test.

The waste from the front of the roll.

other method that I could think of was to pull the metal around in the vice with all the little flats, it is a success and worth the extra effort of making the rollers. So it is now time to finish the project, remove the tailpiece and paint it. I suppose the only other thing to do on the rollers would be to fit a guard to cover the chain wheels for safety, but this is a work in progress so may get done in the future. ■

Rolling.

Rolling complete.

The finished ring.

Checking the size.

The pressure roller removed.

Rear of the drive transfer arm.

Readers' Tips

We have £30 in gift vouchers courtesy of engineering suppliers Chester Machine Tools for each month's 'Top Tip'.
Email your workshop tips to **neil.wyatt@mytimemedia.com** marking them 'Readers Tips', and you could be a winner. Try to keep your tip to no more than 400 words and a picture or drawing. **Don't forget to include your address!** Every month we will choose a selection for publication and the one chosen as **Tip of the Month** will **win £30** in gift vouchers from Chester Machine Tools. Visit **www.chesterhobbystore.com** to plan how to spend yours!

Our winning tip from John Garnish is a suggestion for anyone who has runout of hands when tapping from the tailstock. He gets £30 of Chester vouchers.

Tapping trick

A major use of a spring centre is to steady taps from the tailstock but here is a simple technique that I use. I use a lever feed on the tailstock of my ML7, and I find that a length of shock cord (kept specially for the purpose) provides the right amount of pressure to keep the tap wrench aligned. It takes only a couple of seconds to fit or remove.

The picture also shows some of the other additions that I have made to the lathe over the years: a digital readout (made from an old digital calliper) on the tailstock lever, a locking lever for the carriage clamp, a Vernier scale for rotation on the top-slide, and the housing for a glass scale for the cross-slide DRO.

Runner up Graham Burns has a simple tip for anyone who struggles to get their toolpost locked solidly. He wins a digital depth gauge.

Torqueing toolposts

When securing my toolposts to the cross slide I got fed up of really racking the nut tight to clamp the toolpost in position, so along the same principles as the ball bearing nuts on ER collets I bought a small needle roller thrust washer from Arc Eurotrade. Placed under the toolpost fixing nut all that is required to really grip the toolpost is a gentle, but firm, twist on the T bar. The toolpost doesn't move from position and the holder is firmly clamped. Even better, a quick twist and it all comes free.

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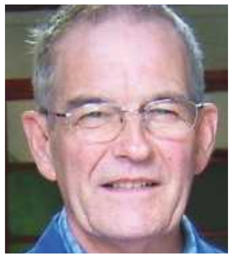
A Review of Pipe Bending Options



Stuart Walker explores some of the many ways in which we can achieve better results without driving ourselves round the bend.

At this year's Harrogate Show. I spotted a rather fine set of pipe-bending tools made by Mike Chrisp. I tried to persuade Mike to write them up but instead he kindly put me in touch with Stuart Walker who had produced an excellent review of the subject for the Society of Model and Experimental Engineers. I felt the article would be of interest to readers and might also be useful in introducing more recent converts to the hobby to the SMEE. If you would like to learn more about the society, please visit www.sm-ee.co.uk/

The purpose of this article was to respond to the suggested use of the new SMEE website to gather and share opinions on a range of topics considered useful by members. It isn't intended to be a static document and through feedback is being modified to reflect alternative views and approaches. The subject has already sparked considerable interest, has been augmented with additional information, and its appearance in these pages follows prompts that it should be shared with readers of *MEW*.

Sooner or later most model engineers are confronted with the need to produce some neat pipework to complete a project but, unlike bending solid section, it is prone to shape loss, over stretching, compression wrinkling and even complete collapse, so it's worth having a look at the challenges as well as the materials and tools that might help achieve our particular needs.

Over the years, a number of commercial tools have been produced and several articles published in the model engineering press showing how similar tools can be made in a home workshop. However, little insight has been given into the design issues and what has been achieved by others. This article seeks to take a wider look at the various challenges and solutions that already exist. Whilst I have some general experience of pipework, I'm not an expert in any way and would therefore welcome the views and experiences of other members to help establish a more rounded understanding.

Before considering the pros and cons of particular benders, it's worth taking a look at the material properties of the pipes we hope to bend as well as the wall thickness and the bend radius, all of which influence success or failure.

To achieve low friction flow for liquid or gas, a gentle bend radius of 3 to 6 x the pipe diameter of the pipe seems reasonable. However, such frictional losses are seldom critical and it might be more important to resolve the demands of space and aesthetics by using bend radiuses down to 1 x the pipe diameter, but wall thickness on the outside of the bend will be significantly thinned, even if one is able to encourage an increase in thickness on the compression side, and it might be better to consider introducing purpose made elbows, or even banjo fittings, at difficult pinch points.

The ductility and ease of achieving and maintaining plastic deformation without loosing shape, work hardening, creasing and even becoming structurally unstable all need to be considered and might require specialist advice and even testing to avoid uncertainty. Useful advice can be obtained from metal stockists like Metal Supermarkets who have branches throughout the UK.

Whilst most small bore pipe work used by model engineers is copper, it's available in both straight hard drawn and soft which is supplied in coils. Generally, the hard drawn tubes are thinner walled and less suited to forming tight bends, whereas the soft annealed tube tends to have a thicker wall and is easier to bend without losing its circular profile. It might be worth mentioning that the soft tube will need straightening before use. For tubes less than ¼ inch diameter, this can easily be hand straightened by rolling with a board on a flat surface, but as the size increases it becomes impractical and a roller guided tube straightening tool will be needed - not difficult to make, typically requiring two groups of 5 profiled rollers set at right angles to one another.

Similarly, aluminium tubes can be purchased in coil form as well as straight drawn with recommended grades of 3003 and 6061 respectively.

Brass tube is supplied in straight lengths and the recommended grades are CZ260 or CZ330.

In the case of steel pipes, the carbon content defines its suitability for bending and this should not exceed 0.3% and should be bent in a soft annealed state. Probably the best known steel pipe is Bundy tube which is a type of double-walled low-carbon steel tube manufactured by rolling a copper-coated steel strip through 720 degrees, and resistance brazing the overlapped seam in a process called Bundywelding. It is normally zinc or plastic coated for corrosion protection. It has been used for automotive hydraulic brake lines in cars since the 1930s.

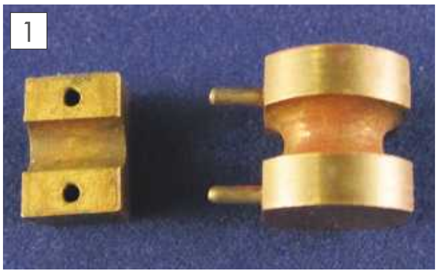
Whilst stainless steel can be problematic, it's generally recognised that 304, 316 and 321 are the preferred grades for bending. They all have good corrosion resistance and are capable of being easily welded and brazed.

Annealing to help the bending process can be simply achieved by local heating with a soft propane flame after marking the pipe with a bar of household soap and heating until the marks turn black, after which it is left cool naturally.

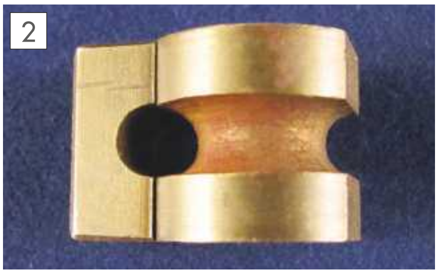
Successfully bending thin wall tube without distortion is more difficult, and internal support is worth considering. This is more problematic for small bore tubes. Bending springs have been used successfully but they are only suitable for large radius bends, and being over optimistic can lead to a situation where they get stuck and both pipe and spring become damaged. Dry sand packing was the traditional method but the pipe has to be ram packed and plugged under pressure to work properly which is not practical for small bore tubes. Filling the tube with a low melting point alloy like Wood's Metal has proved useful in the past, but as it contains unfriendly metals such as lead and cadmium the preference these days is for Field's metal which is a mixture of bismuth, tin and indium. Indium is a metal that looks like silver but is about twice as expensive. It has special uses in scientific apparatus due to its interesting properties, such as its ability to stick to glass. Like Wood's, Field's metal has a melting point of 61 degrees C and can consequently be easily melted in boiling water. It can be purchased in ingot, pellet and wire form, the latter probably making it easier to use when filling small tubes first time round. Otherwise, it has been found best to melt the alloy in near boiling water and use a plastic syringe fitted to the tube that is also heated in the water and allows the metal to be sucked into the tube. The suction must be held until the water cools and the metal solidifies. Field's metal is expensive and difficult to find in small quantities but suppliers can be found on Ebay. The Yorkshire based Bendalloy Company is able to supply Wood's metal which they call "Cerrobend'. More importantly, they market 'Pollybend' which uses a polymer base product instead of metal. This new approach is being used for small tube bending by aero space product manufacturers, as well as model engineers like Mick Knight who recently used some for bending the exhaust pipes for his model Hodgson 9 cylinder radial engine. Some of you may recall seeing his model at the 2014 MEX and his subsequent article in ME 9-22 Jan 2015. Whilst he managed to successfully pour the liquid into his 8 mm diameter tubes, this would be more challenging for smaller diameters and longer tubes where filling bottom up with a syringe drawing the air out of the top might be a better way, along with heated tubes to ensure a solid fill. It's interesting to see that Bendalloy also supply a product called 'Fixture Alloy' which is another low melting point material intended for casting around delicate items that are difficult to hold for machining purposes - they tell me it's rather like machining mothballs!

Before discussing the merits of various bending tools, it's worth saying that several model engineers who produce very good quality work will tell you that it's a waste of time making special tools for bending pipes less than ¼ inch diameter. They say that all you need do is turn up a piece of bar with a groove to fit the pipe at the required bend radius, make sure the pipe is fully annealed and just pull the pipe round by hand. Whilst this might work well enough for soft copper and aluminium, it might be more of a problem for very tight bends and tougher materials. **Photographs 1** and **2** show a rather posh hand bending aid - many are made to suit the work in hand and have no clamping facility

For those with weak fingers or who wish to bend larger and tougher pipes, the following observations on a range of different approaches might be useful. For ease of reference, the approaches have been categorised as:



A simple former for manual bending.

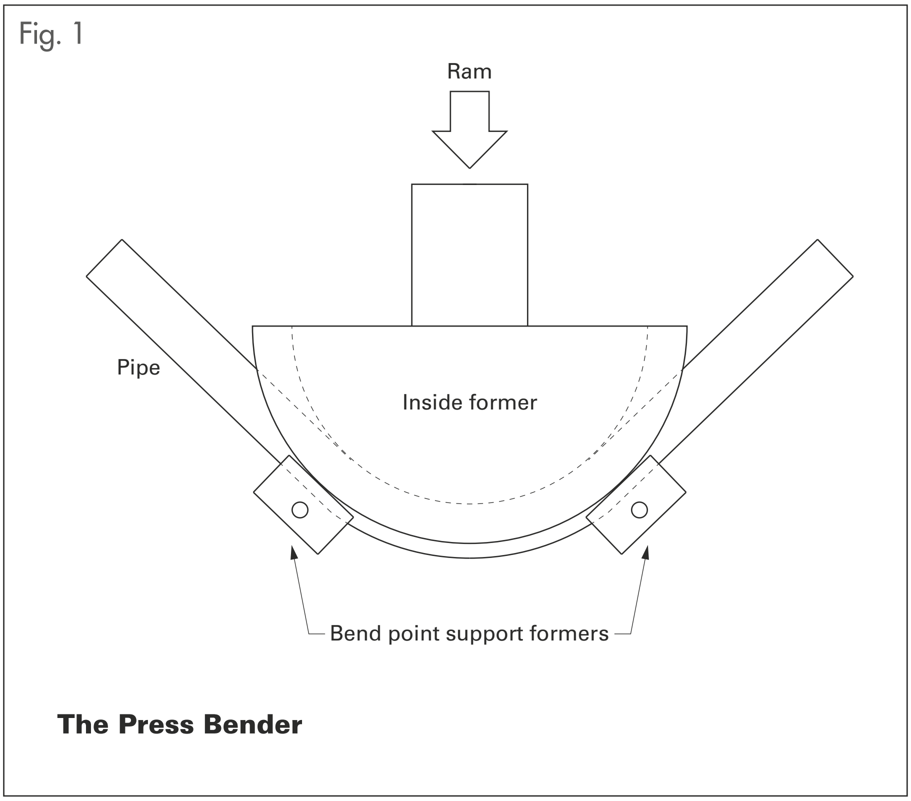


An end view of the former.

- Press bending
- Three wheel bending
- Single wheel bending
- Compression bending
- Mandrel draw bending

Press bending

The bend is achieved by pushing a centre former against the two end supports, as shown in **fig. 1**. The former needs to be a good fit, as do the support formers. The former depth needs to be slightly more than half the pipe diameter with a flared lead-in to avoid chafing and make sure the lateral distortion is contained during the bending process. For bending pipes up to 10 mm diameter, small hand ratchet tools are available, but for larger pipes direct hydraulic jacks are more commonly used within a bench mounted frame. Deformation can be caused by additional tension being generated by the friction at the two support points. Whilst this can be alleviated by using a plain roller to support a flat former, there is little that can be done to better support the bend itself which can lead to a flattening on top of the bend and wrinkling on the inside when trying to achieve a bend radius of much tighter than 4 times the pipe diameter on thin tube. Consequently, it's best to limit the bend angle to 90 degrees. I used one of the hand operated ratchet tools many years ago and remember being rather disappointed - it was expensive, somewhat cumbersome to use and not suitable for pipes with short ends.



Three wheel bending

In essence this is an extension of the press bender but instead of using a static former a central wheel is used, and as the bend load is applied the pipe is drawn in and out rather like sheet metal roller (**fig. 2**). The gradual application of load and free movement to and fro produces the desired bend. This approach produces less distortion than the press bender but the bend radius is normally used to produce long slow bends. However, by changing the roller configuration complete rings can be formed, although the number of useful applications seems somewhat limited. More usefully, it can be adapted to make coils by applying the bend set in a single stroke, rather than incrementally, using a power feed for the three ring forming rollers and adding a fourth roller at the exit point to lift the tube and set the coil pitch. In fact, a fifth roller can be added to form the entry and exit bends as shown on this Youtube video at http://tinyurl.com/oed4jyq

Single wheel bending

Unlike the two proceeding tools, the two formers come together at the point of bend and help contain distortion (**fig. 3**), this being achieved by making the grooves in the wheel formers a good fit and exactly half the pipe diameter. This works well for bend radiuses of 3 x the pipe diameter and can easily achieve 180 degree bends. However, on tighter bends the frictional drag on the outside former can stretch and thin the pipe. Some proprietary benders use two small wheels with one set at the bend point and the other set back to better support the pipe being led into the bend. In common with most benders the end anchor point must be a secure fit to avoid slippage and distortion on the one hand, whilst on the other be short enough to accommodate a double bend that has minimal straight transition between the two curves. A short temporary plug fitted to a short open ended thin walled pipe can provide useful additional support. Alternatively, fill the pipe with Field's metal as explained above.

Derek Brown designed and made a very neat version of this concept which he described in *MEW* 64.

Compression bending

In principle, these work in a similar way to the above but use a roller behind a flat former to exert the pressure at the bend point (**fig 4**). The advantage is that the pipe is better supported at the point of bend with less frictional drag stretching the outside of the bend and balancing the plastic state by imposing compression on the inside of the bend, which enables tighter bends to be formed. Using this approach, a member at my local club made his own bender and was able to pull a 180 degree bend in 304 stainless steel to a radius of 1 x the pipe diameter with very little distortion. However, it should be noted that work hardening and loss of structural integrity can lead to premature failure.

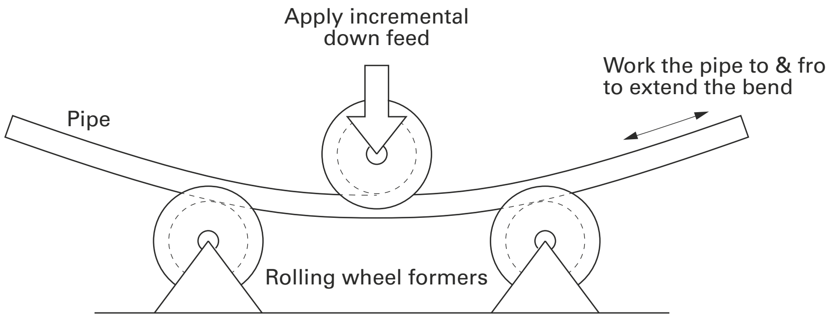
The standard pipe benders for 15 and 22 mm diameter hard drawn copper pipe, as used for domestic plumbing, normally uses compression benders with a fixed radius of 3 x the pipe diameter. From my experience, they work well enough but the former could be a better fit and similarly the anchor point can mark the work and should be improved if higher standards are needed.

Numerous designs have been published for small pipe compression benders, including a simple easy to make and use design for pipes up to ¼ inch diameter, which was recently published on David Carpenter's model engineering website. Unfortunately, it's no longer available on line, but a nice boxed example has been made by Mike Chrisp who recently displayed it as work on the table and shown in the above photo forming a copper tube bend (**photo 3**). Note that the design is based on a minimum bend radius to pipe diameter of 3 and might need to be strengthened to accommodate more ambitious bending. Hemingway Kits use a similar design but the outside former is shorter and fixed, thus producing less compression and more friction stretch by using a wiping rather than rolling action. This wiping action seems to be used by most of the small low cost benders being offered by suppliers like Chronos and RDG. Better quality tools are available in the UK from the like of bwww.toolstop.co.uk but you'll need a much deeper pocket and you might well conclude that it's better to make your own.

3

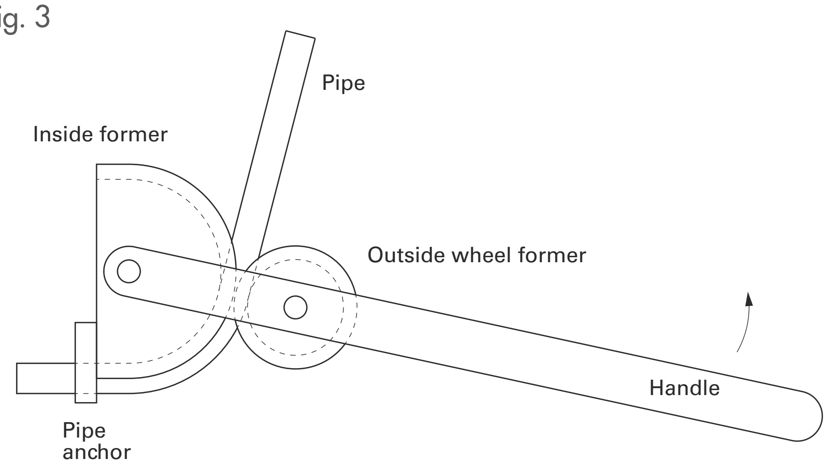
Mike Crisp's bench mounted pipe bender.

Fig. 2



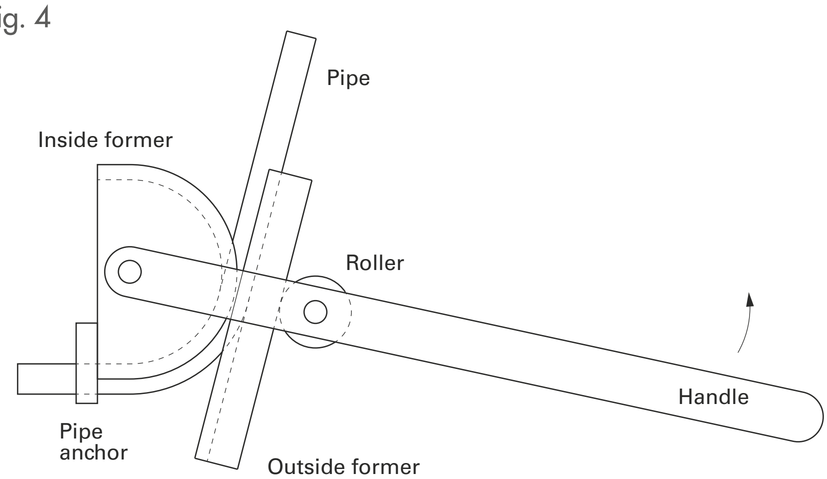
Three Wheel Bender

Fig. 3



Single Wheel Bender

Fig. 4



Compression Bender

Mandrel draw bending

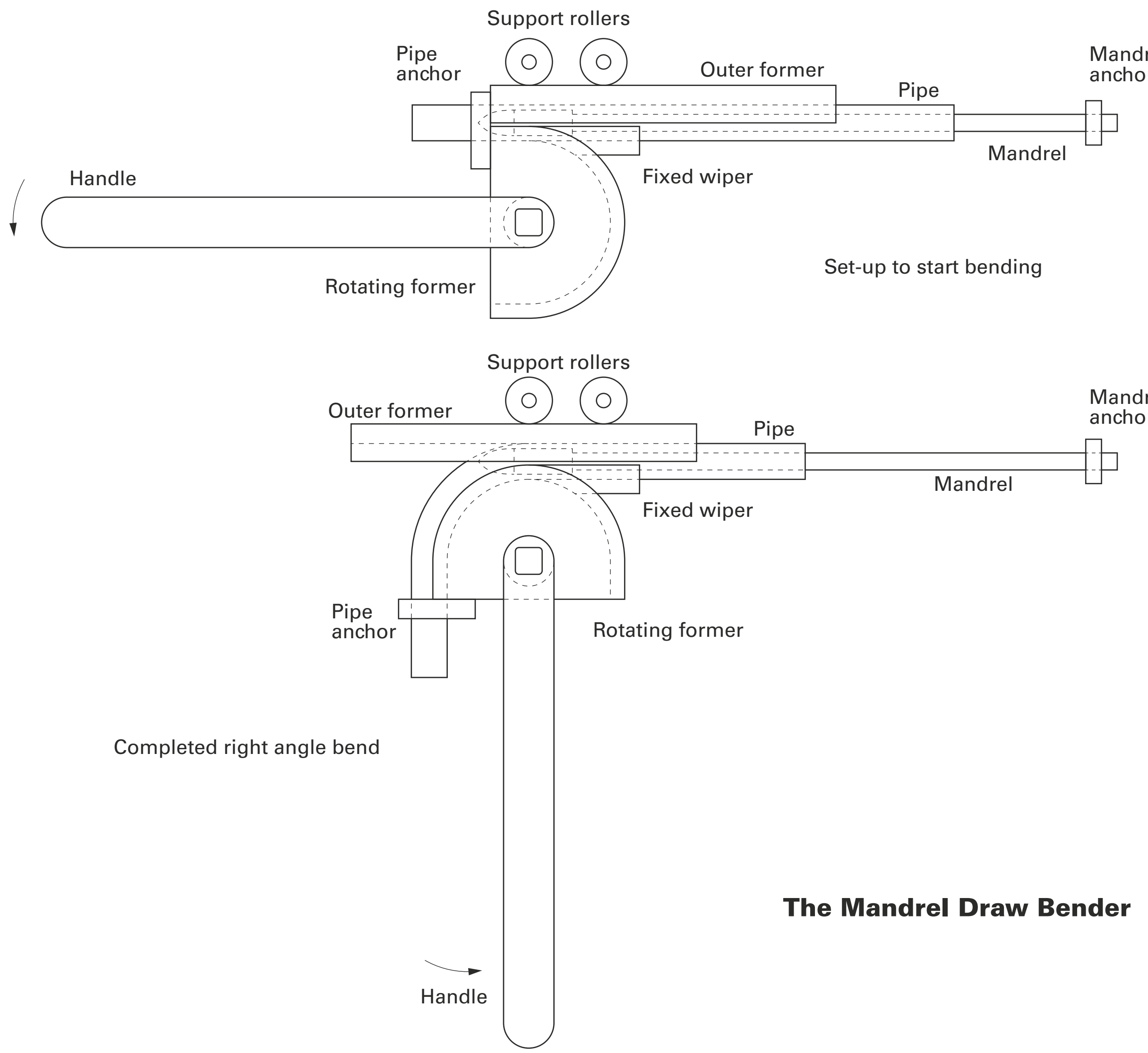
Unlike the above, the pipe is attached to a centre former which is rotated to form the bend (**fig. 5**). At the point of bend, the pipe is supported by an internal mandrel and two external straight formers are used to support the pipe up to the point of bend. One is a static wiper set on the inside face of the bend with a shaped nose that blends into the profile of the rotating core former. The outer straight former supports the pipe on the outer face of the bend and is roller mounted so that it remains in contact with the pipe up to the bend point. The end of the internal mandrel is shaped to fit the bend profile and extends beyond the point of bend. On industrial machines, the mandrel end is fitted with an articulated ball shaped profile which supports the bore well past the bend point. The end of the pipe is anchored with a keep plate on to the centre rotating former at a straight section just past the starting bend point. The depth of grooved profile in the centre former is equivalent to 60% of the pipe diameter to aid profile retention. The external formers fit within the central former to maintain alignment and a true pipe profile. Tight distortion free bends can be achieved down to a bend radius of one pipe diameter but two seems to be the norm. The resultant integrity of the bent pipe seems to be similar to that achieved using a compression bender but industrial precision pipe benders favour this approach and use hydraulic ram to rotate large pipe formers using rack drives. Simple, hand operated versions are made for pipes between ⅜ to 1 inch diameters. The amount of effort needed is reduced by using smooth finished formers and spray applied lubrication. Hard anodising seems to be popular with industrial users today; in the past, hard chromed steel was used for non ferrous piles and aluminium bronze for steel pipes. However, for low volume model engineering it's not critical and the main focus should be on fit and smooth finish.

An example of a good quality industrial bender, along with a video demonstration, can be found at http://www.useful-tools.co.uk

Significant simplification can be made to the design when applying these principles to most model engineering applications where ¼ inch diameter pipework seems to be the norm, and a useful range would be ³⁄₃₂ to ½. Two designs have been published in model engineering publications over the years, with the first dating back to 1947 when SMEE member W T Barker described his design in *M.E.* Volume 96. **Photograph 4** shows the original bender set up to bend a ³⁄₁₆ inch diameter soft copper tube - to form the bend the tool is first secured in a vice. This is a very elegant design and his original equipment is now owned by Ann Hatherill and was displayed on our stand at Guildford Model Steam Rally earlier this year. It attracted much interest and encouraged me to step back and take a more rounded view of pipe bending. It was designed for bending copper pipes up to ⁵⁄₁₆ inch diameter. The ½ inch diameter shaft seems to limit the design and increasing it to ¾ inch dia and enlarging the table

We are pleased to be able to include a 'facsimile' of W. T. Barker's original article from *Model Engineer* volume 96, issue 2383 (opposite). It includes an excellent drawing that contains all the information for someone to make their own version, aside from dimensions which should be chosen to suit the pipe you need to bend.

Fig. 5



The Mandrel Draw Bender

A TUBE-BENDING TOOL

By W. T. Barker

BENDING copper tubes has always been rather a bugbear to me, as it is apparently to many other model makers, to judge from examples of otherwise excellent models impaired by poor coppersmithing, noticeable at any model engineering exhibition. I daresay judges turn a lenient eye on it. I know I should myself, but by degrees I got so fed up with my own efforts in this line that I decided that something would have to be done about it, and the tool now to be described is the result.

It is in no way an invention of my own. I have only simplified and adapted a type of rotary pipe bending machine used industrially for years, and applied it to model making uses. The conditions it was desired to fulfil were :—

(1) To deal with a range of tube sizes up to $\frac{1}{4}$ in. external diameter.

(2) Bends to be as close as practicable to 1-$1\frac{1}{2}$ d radius.

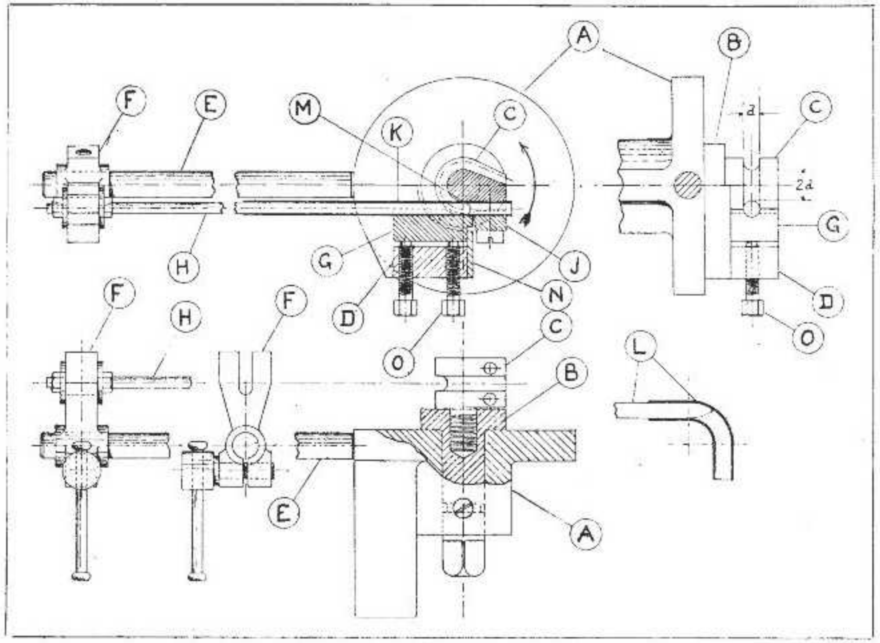
(3) To bend cold and unloaded and without visible flattening or other deformation of the tubing.

The sketch shows the complete tool as finally developed and description and method of operation and setting is as follows :—

The tool consists of a main body (A) of steel or C.I., provided with a lug for holding in a vice, and carrying a movable spindle (B). This spindle is of steel $\frac{1}{2}$ in. diameter with a head 1 in. × $\frac{1}{4}$ in., and a squared end to the shank. The head is tapped $\frac{5}{16}$ × 26 t.p.i., to hold interchangeable formers (C). (A) also carries a stout fixed angle-plate (D), and an arm (E), $\frac{5}{16}$ in. diameter, to which a sliding bracket (F) can be clamped in any desired position. D's function is to hold a pressure die (G) against the tube during bending, while the bracket (F) locates the tube mandrel (H), of which more anon.

A former (C), and pressure-die (G), is needed for each size of tube and for each different radius. An inner bend radius of 1 d (where d is the outside diameter of the tube) is about the safe practical limit for annealed copper. For aluminium or mild steel the minimum should be at least $2\frac{1}{2}$-3 d for cold bending. Considerable force is necessary to make such tight bends, as to 1 d and $\frac{3}{16}$ is about the maximum size safe for an inserted former with $\frac{5}{16}$ × 26 t.p.i. shank. For $\frac{1}{4}$-in. pipe I use a separate spindle (B) with former (C) integral.

From the contour of the formers (C) in the plan view it will be seen that they can bend tubes to a little over 180 degrees. The grooves in both formers and pressure dies must fit tube sections exactly to avoid deformation, and the depth of the grooves must not be less than $\frac{3}{8}$ d



The extension to the right of the former (see plan view) takes a cap (J) which clamps the tube (K) to it. Tubes are under heavy pull during the bending process and may slip unless clamped tightly. It is advisable to insert a plug in thin walled tubes to prevent crushing when making a first bend.

The tube mandrel (H) is a most important part of the tool. The plan view shows a tube in position ready for bending, and the mandrel must be a good close sliding fit inside it and be held rigidly in position by the bracket clamped to the arm (E). A special mandrel is needed for each bore of tube. I use the nearest silver-steel gauge wire. The fixed end has a screwed portion with two nuts and washers to secure it in the slot in the bracket. (E) and (H) can be of any length required to suit the tubes to be dealt with. Tubing must be straight to start off with.

The free end of the mandrel is nicely balled off in the smaller sizes, and the end well polished but when $\frac{3}{16}$ in. or more in diameter, should be carefully curved (see L) to the inside radius of the bend to give more support.

Theory and Practice

Correct setting of the mandrel is most important for making a good bend. In theory, the parallel portion should reach exactly to the bending point (M), and no farther. In practice the best position has to be found by experiment and experience. It may vary a little, depending on how good a fit it is in the tube or on the wall thickness. Usually it must be advanced very slightly beyond the true bend point up to perhaps 1/64 in. or so. Too much advance, however, will produce deformation by over-stretching, just as too little will allow the tube to flatten slightly.

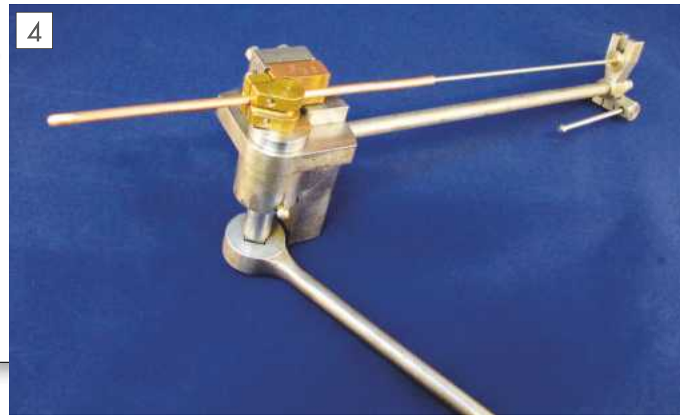
When the right position has been decided, the bracket (F) is clamped to the arm and after all sliding contacts, particularly the mandrel, have been oiled, the tube is pushed on the mandrel into place and clamped to the former by the cap (J). It now only remains to slip the pressure die (G) into place up against the stop (N), and press it lightly, but with no slack against the tube by the screws (O). The groove in the die should also be oiled. The pinching screws must be accurately on the centre line or plane of bending of the tube.

The tool is now held in a vice and a spanner or square hole key applied to the shank end and the spindle turned in the direction of the arrow, sufficiently to make the required bend. To facilitate this the upper rims of the formers are graduated to 180 degrees in 30 degree steps. As the tube is clamped to the former it will, during the turning process, be drawn towards the right and slide along the fixed mandrel, while the pressure die prevents it moving otherwise than in a straight line up to the bend point (M). Bending takes place at this point only throughout the movement, and if adjustments have been well made, a perfect bend with no perceptible flattening or other deformation of the tube will be produced. By careful measurement compound bends can, of course, be added successively on the same length of tube with close positional accuracy, but too closely adjoining bends may need a specially-shaped cap-piece (J).

Bends as sharp as those in question here cannot, of course, be made in soft copper without some thinning of the wall on the outer radius, due to stretch, and some corresponding thickening up of the inside wall by compression. This rotary method, however, has the great advantage over bending done from the centre outwards over a fixed former that thinning is spread equally over the whole length of the outer radius. There is no tendency to concentration or formation of a very thin and weak spot at the crown of the bend.

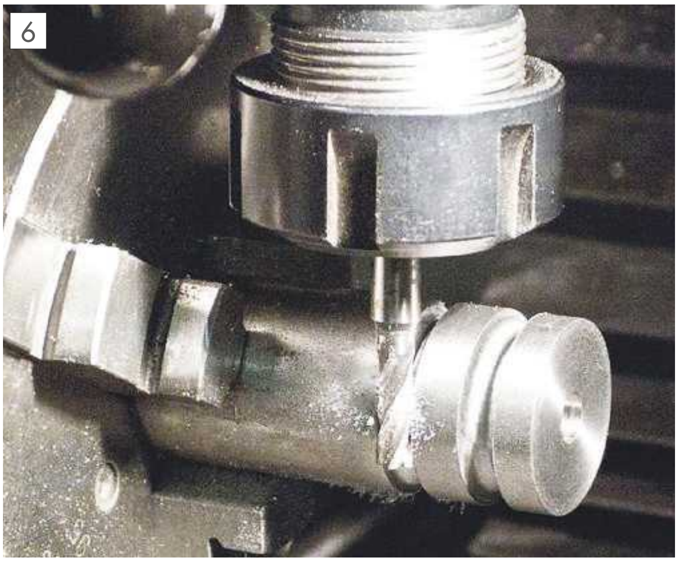
Improved Results

Some readers of these notes may think that all this is going to a vast deal of trouble and elaboration to achieve what is after all a comparatively minor object. It depends very much on the point of view. I can appreciate the outlook that puts performance first and foremost and appearance relatively low in the scale, and I should agree that to such, this appliance would have little appeal, except, perhaps, as a time saver. I am not built that way myself, and no trouble to my mind is too great if it will lead to an improved result, and I am sure many model engineers will understand the thrill of pleasure it gives one just to see and handle the delightfully accurate products of this little tool.



A pipe bender to W. T. Barker's design.

Milling a forming groove.



A closer view of groove making process.

should allow it to accommodate ½ inch diameter pipes. It would more than likely reduce the frictional drag if the fixed external former is replaced with a longer block former that moves with the tube and runs on a roller support similar to the commercial version. It might also be beneficial to provide a short fixed wiper on the opposite face of the pipe.

The other design was published by Ian Hunt in *MEW* during November and December 2002. A more robust design intended for pipes up to ½ inch diameter. Unlike the previous design, the centre former and pipe clamp are made separately and bolted to the centre spindle. The mounting arrangements for the internal mandrel seem a little complex and the external guide doesn't appear well supported for forming tight radius bends.

Making formers

Some might be put off making what, at first sight, seem complex irregular shaped formers which appear to need special tooling. However, if you use a chuck mounted rotary table on a milling machine to hold the blank former, the concave profile can easily be achieved by using a standard straight end mill, as shown in **photos 5** and **6**. Ball end milling cutters are useful for making the straight formers, but if you consider such an investment an unjustifiable expense, then they can be made from an oversized block by drilling and reaming a hole to fit the tube and produce the correct shape former by machining away the excess.

Conclusion

If you do a Google search for 'small bore tube benders' you will find a bewildering array of different designs and Youtube demonstration videos and I hope this short article will help sort the wheat from the chaff and enable you to better assess your particular needs. If you'd like further explanation or you can add additional insight, please let me know.

My thanks to those who kindly helped bring all these thoughts together. ■

In our Next Issue

Coming up in issue 238

On Sale 29th January 2016

A machinery tale to chill the blood – Gary Ayre's Frankenstein «

Tony Hills fits a set of digital read outs to his American made South Bend lathe

« Alan Wain converts an aged drilling machine into a new mill

Scribe a line

YOUR CHANCE TO TALK TO US!

Drop us a line and share your advice, questions and opinions with other readers.

Appeal for Assistance

Dear Neil, I wonder if I might appeal to the readership for help. It occurs to me that some may either work in, or associate with those who work in electrical trades. I operate a small charity, *Water for All*, undertaking water aid projects in 3rd world countries whose engineering activities are entirely dependant on donated materials. I have an on-going, sporadic need for surplus/salvaged industrial switchgear and would like to establish a sourcing relationship with contacts in the larger industrial countries in Europe. Can any reader offer me useful information and contact details for any who may be willing to help? Thanks. (my e-mail address is **pyralog@yahoo.co.nz**).

Andre Rousseau, Papakura, New Zealand

Alpine Feed Nuts

Dear Neil, having received my *MEW* 235 on November 27, I've barely had an opportunity to look through it but I did run across an error in the cited article. May already have been dealt with.

The Alpine Mill feed nuts, and the carriers for them, have a value of 1.821 inches for the PCD for the mounting screws. Since the feed screw nuts have an OD of 1.5 inches this will probably be difficult to accomplish. Taking the data for the distance between the mounting screws and the angles between them, I calculate the correct PCD to be 1.282 inches. ((0.2453 inch/sin 22.5°) x 2) = ((0.2453 inch/0.382683432) x 2) = 1.281999581 inches.

Looks like a case of transposed digits! I hope this is useful.

Anthony Rhodes, Berkeley, California

A Boring Tale?

Dear Neil, I wonder if you can help? On pages 64 and 66 of issue 235, *MEW*, in photos 10, 11 and 20, Rev. Strickland is using a very hefty looking boring bar holder mounted directly to the cross-slide of his lathe. Do you know if this is made to a published design or his own creation? If it is his own design could he be persuaded to write some brief notes about it?

Keep up the good work!

David Byways, by email

Ian Strickland Replies: Dear Neil, thanks for this enquiry. This tool holder was not my design. It was by D.H.Downie, and he wrote it up in M.E. *No's 3465, on page 511 in May 1973, and 3466, page 551.*

I have replied directly to David with copies of the article which should explain everything for him. I hope this is okay with you.

Ian Strickland (Rev.) by email

New Reader

Dear Neil, I'm a new reader of *MEW* but thoroughly enjoy the articles. I have inherited my fathers Smart & Brown Model M Mk1 and a Centrec 2A milling machine, both need stripping, cleaning and some TLC to restore their glory - in particular the lathe which is painted in horrendous gold Hammerite!

My interest in engineering started before I left school when I made a hot air engine from a design in a book by TE Haynes (miraculously this year I found a copy in a school library in Woolongong in Aus and they kindly sent it to me - the miracle of the internet!) I also enjoy technical drawing and have had much success for my house renovation using Sketchup, but wanted something engineering focused and have found www.onshape.com which provides fully functioning software for free the only limit is 5 Active Private models or 5GB in size, neither is an onerous limit. New updates occur every 3 weeks or so and the only requirement is to sign up for an account. I'm still learning, but it appears a highly competent package that includes assemblies and, in due time, the ability to produce 3rd/1st angle projections of parts.

I just thought other readers might be interested - additionally it might be good to have a review of available CAD packages if you have someone who knows enough to do so, or perhaps a series on building CAD models?

Great mag, many thanks.

Peter Morris, Woolongong, Australia

Engineering Videos

Dear Neil, for a while I have been watching videos on YouTube about engineering. I thought I haven't seen anything in *MEW* mentioning these very good websites. There is every thing you want to know and watch about engineering: how to sharpen drills, how to mill, how to set a lathe up, make square holes etc. The one I like most is Doubleboost, very good and down to earth! Another is Tubalcain. There are many more. I hope this is of interest.

John R. Yeoman, Burnholme, York

Anyone looking for further suggestions (or more suggestions of their own) should visit our forum at www.model-engineer.co.uk where they will find several threads on this subject – Ed.

Bushcraft Skills

Dear Neil, I'm into electronics and I hoped *MEW* would help me with my primitive, but often very small, metal part making. It doesn't really, but I'm very impressed with the skills shown. And the advertisements give very useful information. I do wish someone would tell me whether you can punch 12mm holes in 0.5mm aluminium sheet with an arbor press, though. I don't have anywhere near enough room for a fly press.

My father, however, was into cars and I learned some practical mechanical engineering (and blacksmithing) from him. I remember one of his magic tricks.

To extract a bush from a blind hole, select a mandrel that just fits the bore - I suppose any diametric clearance less than about 10 thou/0.4mm will work. Put a splodge of water pump (i.e. thick) grease in the bore, follow with the mandrel and strike the free end of the mandrel sharply (wiv a nammer). This 'percussive hydraulic press' causes the bush to jump out of the hole and up the mandrel.

John Woodgate, Rayleigh, Essex

Rhapsody in Blu Tack

Dear Neil, I was fascinated by Michael Gilligan's article on Blu Tack, and thought that he might like to know that the property of 'negative thixotropy' is known as dilatency, and is where the viscosity (shear stress) increases with shear rate. Other materials that do this are glucose solutions, suspensions of cornflour (or custard powder) in water, and some types of quicksand, where it is possible to run across the quicksand without sinking in, but if you stop, you sink in quickly. Don't try this at home or Morecambe bay either where the quicksand is definitely not dilatent!

Graham Astbury, Skiptonv

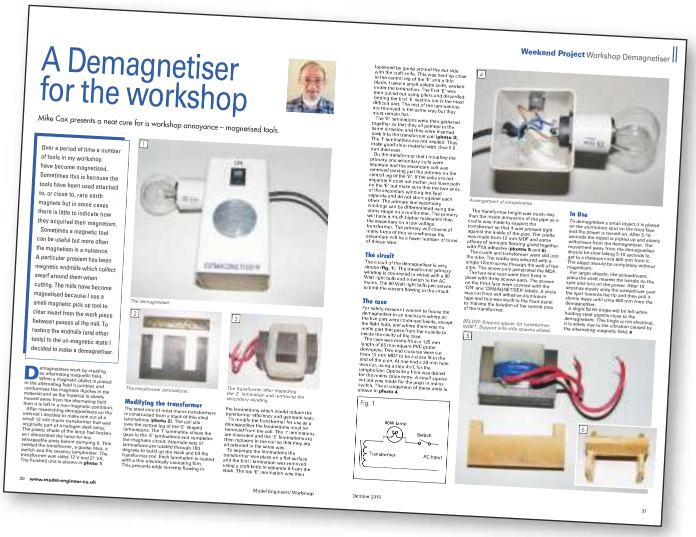
Demagnetiser

Dear Neil, I noticed in the recent demagnetiser article a mention of using a tin as a reflector chiefly to protect the bulb. May I make a couple of observation gained form practical experience?

First the lamp-holder for this application should be an all metal one - the plastic ones seem to embrittle with heat, in fact we recently had one of the "energy efficient" bulbs in failure mode overheat to such an extent that the holder almost powdered, dropping the bulb onto the carpet, fortunately causing only 'hooverable damage' To give the wiring a sporting chance make up a seal where the flex enters the rear of the holder it saves any risk of the flex chafing. I used to conjure up something from cycle inner tube patches. Nowadays I would plump for silicone sealant, or Blue Tack, which I have proved to be heat resistant when making lead hammers.

Second the weakest link on the chain is the point where the tin and the screwed bezel on the lamp meet, if possible claim the tin lid as well as the can and use this as a washer to add a trifle more strength at the joint.

Thirdly make a few ventilation holes as close to the corner joint at the top as you can - I use a centre drill and let it run in. Four equal-spaced holes of around $\frac{5}{16}$ in. dia. seem about enough for a 60w bulb which is on for intermittent usage only.



Weekend Project Workshop Demagnetiser

A Demagnetiser for the workshop

Mike Cox presents a neat cure for a workshop annoyance – magnetised tools.

About 40 years ago I made lamps to illuminate the marker board in the billiard room, and another for the darts scoreboard. They were still there when I left 15 years later for all I know it is still in place.

Ted Jolliffe, Clapham, Bedfordshire

We would love to hear your comments, questions and feedback about MEW

Write to The Editor, Neil Wyatt, Model Engineers' Workshop, MyTimeMedia Ltd., Enterprise House, Enterprise Way, Edenbridge, Kent TN8 6HF. Alternatively, email: neil.wyatt@mytimemedia.com

Designing Springs ~ Visually

Part 4

Linton Wedlock explains the use of a nomogram to find the wire stress in a spring

In the concluding part of this series, a second nomogram for determining the rate of a spring is illustrated. This is followed by a detailed spring design example which uses the four charts shown in these articles.

There isn't much more new ground to cover in this article, as most of the background information on using the charts has already been explained in the first three parts of the series. **Chart 4** (overleaf) is a nomogram which shows the relationship in a spring between the wire diameter, the coil ratio, the number of active coils, and the rate. If the values of any three of these variables are known, the fourth can be found without difficulty from the chart. The nomogram shows in graphical form the mathematical relationship given by equations (7) and (8) in part two, and is many times quicker to use than calculating the same results from the equations.

I found that if the chart is used carefully, it gives results that differ by less than 2.3 percent from their true values. This degree of error is acceptable, because a real spring will often vary from the theoretical prediction by a lot more than this amount. Chart 4 is a replacement for fig 17 in ref 1. This nomogram in the book has some layout errors in its scale lines, and this can produce variable results. Sometimes, the values obtained from the chart are reasonably accurate, but overall, there is an average error of about 10 percent, and some results can be as much as 25 percent out. Because of this, it may be best to use Ref. 1's nomogram only for applications where the rate value is not at all critical.

Chart 4 is used in exactly the same way as was shown for the wire stress nomogram in part three. A small additional step may be required, however, depending on which metal a spring is made from. The rate nomogram has necessarily to be drawn for a single metal - in this case, carbon steel - and a simple adjustment to the values read from the rate scale will be needed for springs made from other metals. This extra step is demonstrated in the next section.

An example

A tension spring made from carbon steel wire has a mean coil diameter of 0.29 inches. What is its rate if it has 30 active coils and is made with 20 SWG wire? How would the rate change if the spring was alternatively made with piano wire, stainless steel, or bronze wire?

From the wire diameter scale in Chart 4, 20 SWG is 0.036 inches, and dividing the mean coil diameter of 0.29 inches by this value gives a coil ratio of (fractionally more than) 8. Place a rule on Chart 4 between the 20 SWG arrowhead on the wire diameter scale, and 8 on the coil ratio (C) scale (**fig 10**, line 1). Mark the pivot point where the rule crosses the reference line. Next, reposition the rule so that it touches this pivot point and also the 30 mark on the number of active coils scale (fig 10, line 2). You should find that the rule crosses the rate scale at 3.5 lbf/inch, which is the rate for carbon steel wire.

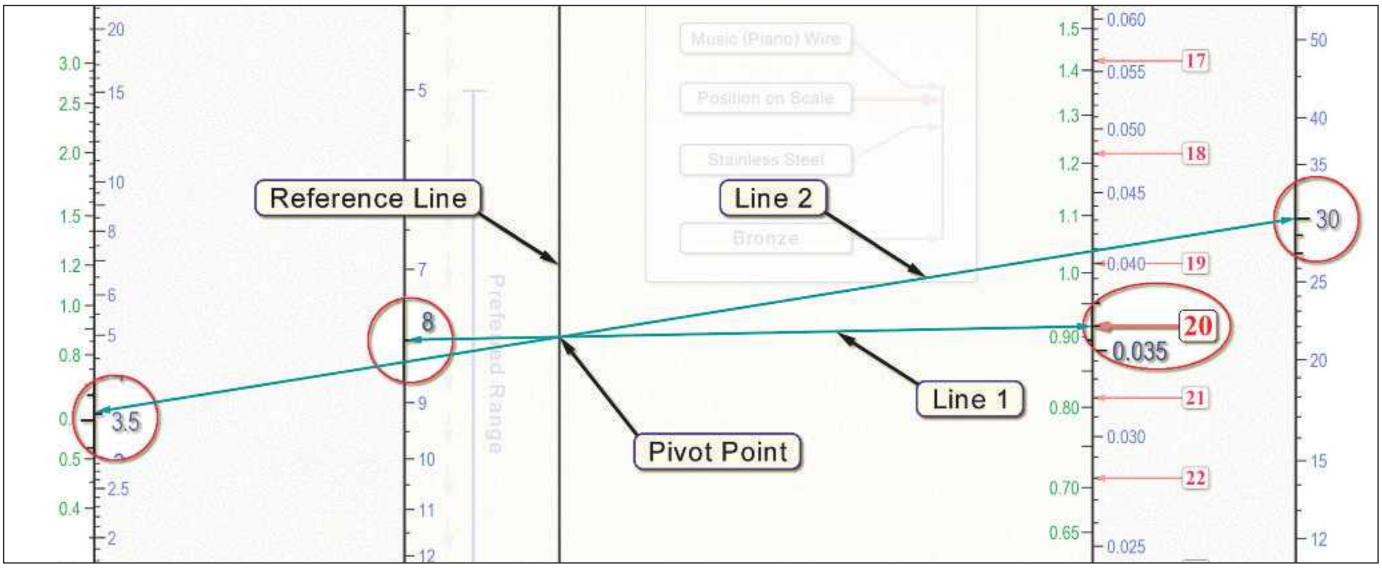
To find the rate for other metals, the supplementary adjustment scale on Chart 4 is used. A copy of this scale can be drawn on a piece of paper, or clear plastic sheet, and only the positioning of the arrow heads is important. Place this scale on Chart 4 so that the red arrowhead points to the 3.5 lbf/inch value on the rate scale (the value that was just found for carbon steel wire). The adjusted rate values for other metals can now be read off from the blue arrowhead positions on the rate scale. The values in lbf/inch should be: piano (music) wire - 3.7, stainless steel - 3.1, and bronze - 1.9.

There is only a five percent difference between the rates for springs made from music wire and carbon steel wire, and therefore the extra adjustment step is usually not worth bothering with for music wire. It could also probably be skipped for stainless steel (rate difference 14 percent) in applications where the rate does not have to be precise. Bronze springs, however, have rate values that are about half those of carbon steel springs with the same specification, so it's usually necessary to make the adjustment for this metal. (Alternatively, since the rate difference for bronze is near enough to one-half, it's easy enough to make this amendment in your head, instead of using the adjustment scale).

A second example

A spring is needed with a rate of 0.3 lbf/inch. What is its mean coil diameter if it is made from 26 SWG bronze wire and has 50 working coils? Also, will these parameters make a practical spring?

Start by putting the supplementary scale next to the rate scale so that the blue arrowhead for bronze points to the 0.3 lbf/inch value. Mark the position on the rate scale pointed to by the red arrow (it should be about 0.56 lbf/inch). This step has adjusted the bronze rate value so that it can be used on the carbon steel rate scale. Put the rule between the marked



point and 50 on the active coils scale, then mark the pivot point where the rule crosses the reference line. Next, put the rule between the pivot point and the 26 SWG arrowhead on the wire diameter scale, and it should cross the coil ratio scale at about 9.8. This coil ratio is within the preferred range, so will make a practical spring. From the wire diameter scale, 26 SWG is 0.018 inches, so, multiplying the coil ratio, 9.8, by 0.018, gives a mean coil diameter of (near enough) 0.18 inches.

A design illustration

To end the article, I'll give a description of using all four of the charts in this series for one design example. This is a slightly modified adaptation of a real design problem, and illustrates the many small steps that are often required to find a suitable spring.

A compression spring with flat ground ends is required for the application that is shown diagrammatically in **fig 11**. In the position shown at [A], the spring should provide a small upward force - say 0.5 lbf. At [B], the top end of the spring is three inches lower than it is at [A], and the force at this point should be 12 lbf. There is a stop which limit's the spring's end movement to four inches, [C]. What is a suitable specification for the spring if it is made from carbon steel wire, and the only constraint is that the spring should be a loose fit around a ½ inch diameter tube? The application is not particularly demanding, and no great precision is needed for the spring parameters.

The following description shows one possible approach to this design problem and, as it's quite long, I'll split it into several steps:

Step 1: The rate
At [A], the spring is at 0.5 lbf compression, and at [B], 12 lbf. The rate is the change in load divided by the deflection difference, which is three inches between [A] and [B]. The rate is therefore (12 - 0.5) / 3, or 3.83 lbf/inch.

Step 2: The maximum load
The spring end can be depressed by four inches, and therefore the maximum load is 12 lbf at three inches depression, plus a further inch at 3.83 lbf/inch, or a total of 15.83 lbf. This will be rounded up to 16 lbf for the next step.

Step 3: The wire and coil diameters
On Chart 1 (part one), a horizontal line from 16 on the maximum working load scale crosses these SWG lines: 18, 17, 16, 15, and 14. The intersection with the 18 SWG line, however, is in the top-left blue region of the graph, and just outside of the generally usable D/d range. 17 and 16 SWG wires can also be eliminated, because at their intersections with the 16 lbf line, they have mean coil diameters of 0.26 and 0.41 inches respectively, and both less than the ½ inch tube diameter. The mean coil diameter for 15 SWG at 16 lbf is 0.59 inches, but subtracting the wire diameter of 0.072 inches (found from either fig 2, or Charts' 3 or 4), gives an inside diameter of 0.518 inches, and only marginally larger than the ½ inch tube diameter. A spring made from 15 SWG wire may therefore fit around the tube - or it may not; the theoretical prediction can't be relied on at this degree of accuracy.

A spring made from 14 SWG wire will easily fit around the tube - at 16 lbf it has a mean diameter of 0.83 inches. This wire size has a diameter of 0.08 inches, and if the coil diameter is rounded to 0.8 inches, this conveniently gives a round coil ratio of 0.8/0.08, or 10 (note: this rounding was downwards, rounding to larger diameters will reduce the maximum load, perhaps by too much).

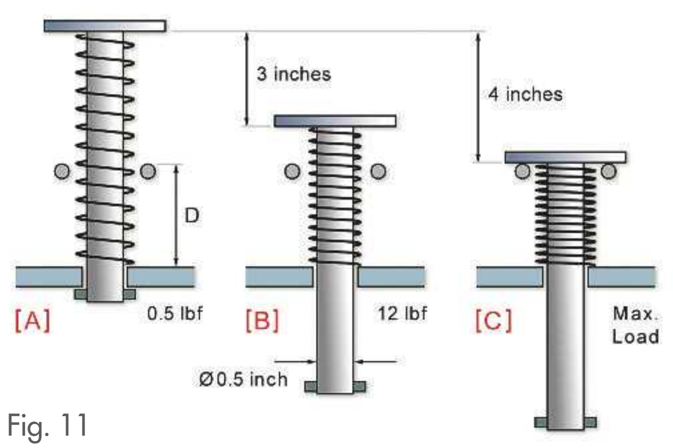


Fig. 11

Step 4: Number of coils
Looking at Chart 2 (part two), follow the 0.8 inch mean coil diameter grid line upwards until the 14 SWG wire line is reached, then looking horizontally to the left-hand scale shows that the rate for one coil is 120 lbf/inch. Place Scale 2 on Chart 2 so that its (normal use) carbon steel arrowhead points to this value on the single coil rate scale. The spring's rate (from step 1) is 3.83 lbf/inch, and Scale 2 shows that the number of active coils required to give this rate value is 31. For a compression spring with flat ground ends, one-and-a-half must be added to this number, to give a total of 32.5 coils.

Step 5: Check the stress
Put a rule on the stress nomogram, Chart 3 (part three), so that it touches the 14 SWG arrowhead on the wire diameter scale, and also 10 on the 'C' scale (values from step 3). Mark the pivot point on the reference line. The maximum load is 16 lbf (from step 2), so connect the rule from this value on the load scale to the marked pivot point. The rule should cross the stress scale at about 73 (x 1000 lbf/sq. inch). This value is less than the 'carbon steel, average duty' range of 75-95 given in Chart 3's stress table, so the required maximum load won't overstress the spring.

Step 6: Check the rate
This article has already described how Chart 4 is used to find a spring's rate, so I won't give these steps. The chart should confirm that a 14 SWG carbon steel spring with 31 working coils, and a coil ratio of 10 should have a rate of 3.8 lbf/inch.

Step 7: Other parameters
The minimum possible compressed length of a spring is the total number of coils plus one, multiplied by the wire diameter. In this example, this is 33.5 x 0.08, or 2.68 inches. This is the smallest size that distance D in fig 11 can be. D can be made larger than this value, and this may help in the application's design. It may be wise not to make D too large, though, because it could result in a spring which can be compressed beyond its designed load limit, and if, unlike this example, there was no stop to limit the deflection of the spring, it would be essential to check the wire stress is within limits at full compression.

To find the uncompressed spring length: when as shown in fig 11 [C], the spring has a load of 15.83 lbf (step 2). The rate is 3.83 lbf/inch (step 1). Dividing 15.83 by 3.83 gives the total deflection, and is 4.13 inches. Added to the minimum compressed length (or distance D, if this is larger), this gives a total spring length of 2.68 + 4.13, or 6.81 inches.

The length, 6.81 inches, divided by the total number of coils, 32.5, results in a coil pitch of 0.21 inches.

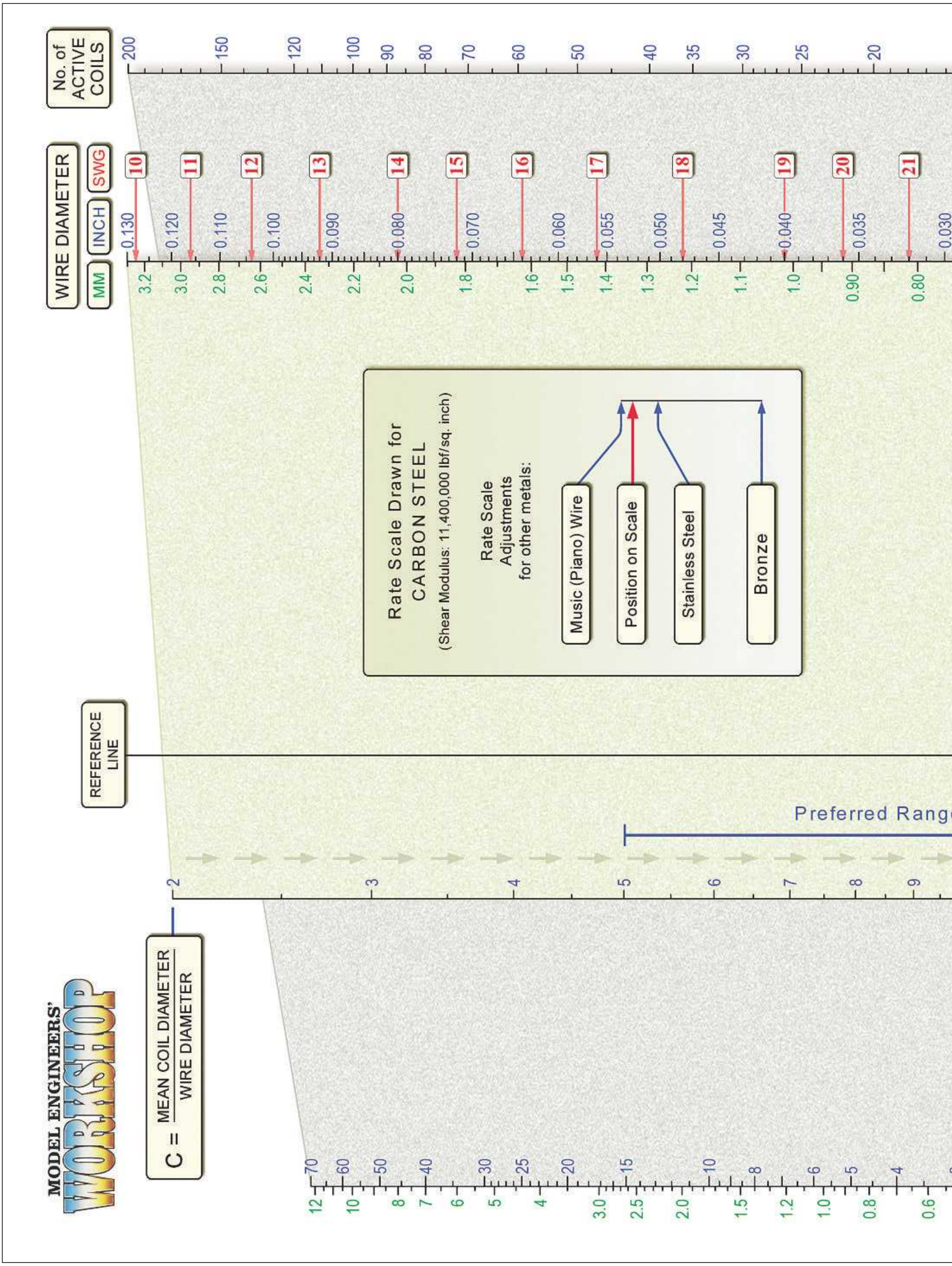
Step 8 (optional): Calculations
The results from the charts can be double-checked by using the equations in part two, or with a website spring calculator. In this example, the difference between the results from the charts and by calculation were: maximum stress = 1.2%, and rate = 0.3%.

Step 9: Make a test spring
With luck, a spring wound so that it is as close as can be practically made to the designed parameters will be good enough for the intended application. If not, the differences between the predicted and actual springs will suggest where adjustments can be made, and this should not entail making any major corrections.

Writing out the procedure for this example has unavoidably produced a lengthy description, but in practice it should take less time to use the charts than it has to read the words! This example was straightforward, and so it may not be representative of a typical spring design problem. Ref 1 has a chapter of worked examples, some of which are more involved than the one shown here, and you may like to try these out (remembering that the charts in this series will give slightly different results to those shown in the book).

Series conclusion

Even though I found that it took some practice to become familiar with graphical methods in spring design work, the effort has certainly been repaid. Choosing springs by intuition alone can give rather hit-and-miss results, and mathematical calculations, even with the help of computers and website spring parameter calculators, can be tedious. I'm very grateful, therefore, to Tom Walshaw for introducing me to this subject. I hope that some readers will, likewise, find the charts described in this series are a useful supplement to Mr. Walshaw's book. From experience, I would never describe spring design work as fun, but with the help of visual aids, it at least becomes more of an interesting challenge, and certainly less of a time consuming chore. ■


MODEL ENGINEERS' WORKSHOP
No. of ACTIVE COILS
WIRE DIAMETER
MM
INCH
SWG
REFERENCE LINE
Rate Scale Drawn for CARBON STEEL
(Shear Modulus: 11,400,000 lbf/sq. inch)
Rate Scale Adjustments for other metals:
Music (Piano) Wire
Position on Scale
Stainless Steel
Bronze
Preferred Rang
C = MEAN COIL DIAMETER / WIRE DIAMETER

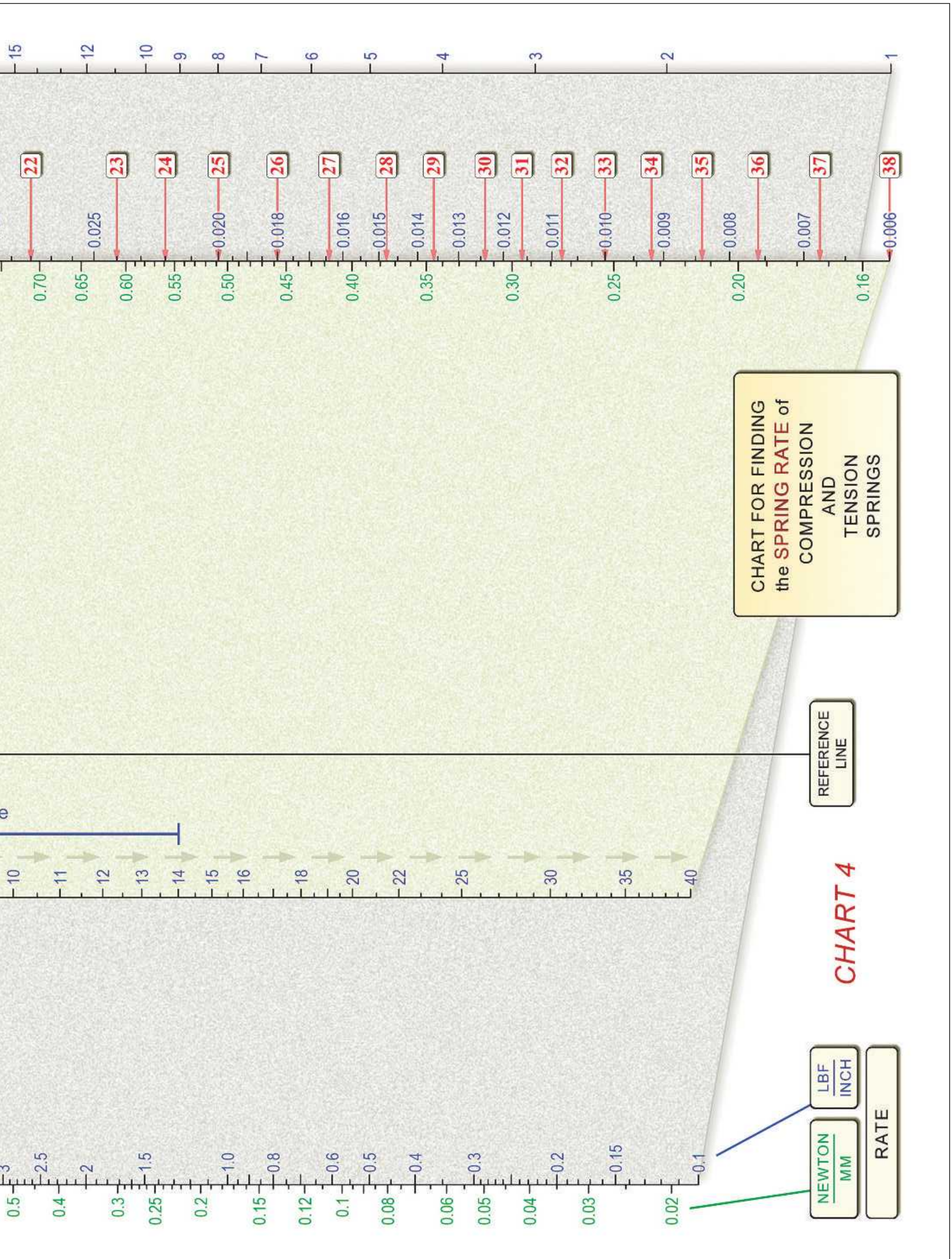


CHART FOR FINDING the SPRING RATE of COMPRESSION AND TENSION SPRINGS
REFERENCE LINE
CHART 4
NEWTON / MM
LBF / INCH
RATE

On the Wire NEWS from the World of Hobby Engineering

This month all the news I have from around the trade is promoting their Christmas offers. As these will be over and done with by the time you get this issue, here's some other news!

From Day into Night: Walking the Ginger

Wednesday 20 January 2016 Time: 19:00 – 20:30

South-east based readers may be interested to join author Iain Sinclair for a talk at London Transport Museum about the day he decided to walk the full circle of the London Overground line, or the 'Ginger line' as it is known. In one single day Sinclair visited 33 stations and walked its 35-mile route from Haggerston via Wapping and Peckham Rye, Willesden Junction and Hampstead Heath to Camden Town.

Shortly after rush-hour and accompanied by a companion, Sinclair begins walking, and along the way encounters strange and familiar places, summoning memories of friends and culture heroes and showing the shifting, changing city from new and surprising angles.

Sinclair traces the circuit of the London Overground just after its final completion in 2012, linking the urban cool of Shoreditch in the east to the more residential Shepherd's Bush in the west. Sinclair and his walking companion encounter football stadiums, prisons and cemeteries – hoping that the new heartbeat of London will be revealed.

Tickets cost £10 for adults and £8 for concessions and London Transport Museum Friends. Visit www.ltmuseum.co.uk/whats-on/events-calendar#sinclair or call +44 (0)20 7565 7298 to make a booking.

Forth Road Bridge

The closure of the Forth Road bridge made big news, but readers may be interested in the proposed solution, which has received less publicity.

In the week since the Forth Road Bridge closed, Amey's team of engineers have been working around the clock to develop a solution to a crack on one of the bridge's truss end links. The detailed plans to fix the problem have now been finalised, checked and verified by two independent specialist engineering firms.

The repair solution involves a plate welded repair to the damaged truss end link and jacking the link into position.

An access platform to allow repair works to get underway is being constructed. The platform will permit teams of welders to work day and night, when weather conditions permit.

Chartered Engineer Mark Arndt, Amey's Account Director responsible for the bridge said: "Progress of the repair work is vulnerable to weather conditions. Wind speeds at times make it unsafe for our people to continue but by having our personnel on standby at the bridge and by monitoring live wind-speed data in our control room we're able to get straight back out to work on the repairs in every available window and our programme remains on schedule for completion in the New Year."

In addition to repairing the defect, Amey is taking preventative action on another seven similar locations on the bridge to prevent any issues from occurring and structural monitoring systems are also being installed at these locations.

One Man and his Lathe

Geoff Walker and his Drummond Type M

The Drummond Type M lathe was produced for around half a century and was a priority item for the forces in WW2, the combination of large numbers and good quality means that a surprising number of these machines are still in everyday use.

1

1948 Myford M type lathe.

I did have some rudimentary experience of using a lathe and had always hankered after owning one. It was only after retirement and the inviting prospect of a mind free from the clutter of everyday work that I finally took the plunge and bought one. I now have two, the Myford M type which is the main feature of this article (**photo 1**) and a Drummond M type long bed. The two lathes are essentially the same machine as I am sure many readers of this article will know.

The Drummond is the older of the two and was made by Drummond Brothers of Guildford around 1929. The Myford was made at Beeston, Nottingham in 1948. The production of this lathe was transferred from Drummond Brothers to Myford during the Second World War, hence two different manufacturers of the same machine. There is a potted history of the M type lathe including the details of the transfer on the now familiar and excellent website lathes.co.uk. This article is essentially a potted history of my 5 year ownership of an M type lathe and how I have used and modified it to meet my needs.

I have to say that before buying I gave the matter very little thought. I knew of Myford, that they had a good reputation and their machines were popular with the home user. The brand was therefore uppermost in my mind. Other than that my principle requirements were a lathe with compact dimensions, a simple design, easy to maintain and would fit the space I had available. A lathe with a 3½ inch centre height seemed about right.

So after little research and a couple of failed bids on eBay I spotted a Myford M type listed by a vendor in Ayrshire, Scotland. I liked that it had the Myford name, its own stand, a motor and countershaft, a 3 jaw chuck, was 'ready to go' and appeared to be a lathe of simple design, suitable for a novice. Also the vendor travelled south with his work and was prepared to deliver. A bid of £215 plus £60 for delivery and it was all mine.

I joined the home lathe users' community late in life. I have always been practically minded and had a home workshop where I've built and made 'stuff' all my life but never owned a lathe. That changed in October of 2009 when I bought a Myford M type through eBay.

They say first impressions mean a lot. On delivery my first cursory inspection was certainly favourable. My previous experience of lathes had revealed how

New and original Norman tool post.

Brass wick feed oilers.

they can be abused, i.e. damage to top slide and cross slide caused by rotating or badly chucked work, marks on the bed from dropped chucks or careless use of a hacksaw. No such issues with this machine it clearly had a history of careful owners (I later discovered that the first owner in Ayrshire had the lathe for nearly 60 years and that I was only the third owner). There were some nice extras which I did not expect, among which was a faceplate, a spare back plate, a fixed steady and a full set of change wheels. My only real disappointment was the rack feed for the saddle. Initially I thought the feed was faulty or damaged in some way as winding the hand wheel towards the headstock moved the saddle towards the tailstock. This to me was just wrong, 'this can't be right', but that's how it was and a quick inspection revealed a direct drive and a single gear engaged with the rack. I could see a way to remedy this arrangement but more about that later.

The lathe arrived attached to the stand and I was immediately taken aback by the sheer mass and weight of it all. My two sons were engaged to move it to its new place in the workshop and after much dragging and scraping, huffing and puffing and numerous unmentionable expletives it found its resting place.

With its heavy cast iron stand and integral countershaft the production costs for this lathe must have been very high and possibly the main reason that Myford discontinued making them in the early 50's. With the demand for the series 7 Myford lathes they must have felt like they had 'hit the jackpot' and as such diverted all their attention towards there production. A shame really as Myford had put some serious development work into upgrading the M type a lot of which appears to have never been seen by the general public.

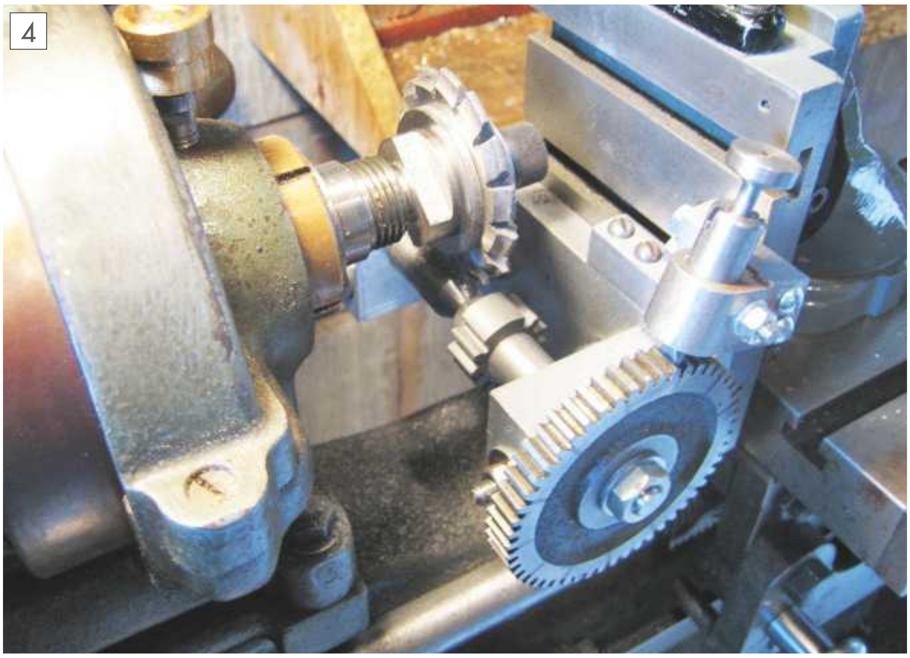
It's a lathe which was I believe designed primarily for home users and as such has many of the features which home machinists seek to give them the versatility which they require. This was more so the case many years ago when the lathe would have to perform many of the functions such as milling, shaping, drilling, grinding etc. which are nowadays increasingly carried out on the now more accessible and dedicated machines. The versatility of this lathe is for me one its most endearing features. I have enjoyed many challenges involving detailed turning and milling set ups using all sorts of brackets and clamps and all exploiting the lathe to its limits. Towards the end of this article I will illustrate typical improvised set ups I have used.

I was now of course very keen to try it out and was certainly well equipped to do so as I had a large stock of engineering tools and equipment. These were all acquired by Dad during the course of his working life and now proudly in my possession.

I liked the original tool post design. This is secured on a 1 ¼ inch diameter boss on the top slide and was introduced by Drummonds when the first M types were made. Known universally as the Norman tool post, tool height setting is simple and easy to achieve. I decided to make some more as I could see it would enable me to set up different tools in each holder and thus be able to change quickly between tools. These include a couple which are angled to provide more reach over the end of the top slide. A lot of machining time was involved but the results and the subsequent use they have had were certainly worth the time spent. The original holder on the right of **photo 2** has no fine adjustment screw. I included one on the other four which makes tool height setting easier. I now also have a popular Dickson type tool post which can be seen in the photo 1. This post is on a second top slide which has the Norman boss removed and a conventional stud fitted.

Another early exercise to give me a feel for lathe were the brass headstock oilers, which can be seen in **photo 3**. Making these wick feed oilers, which replaced the basic oilers, involved some simple but delicate turning and once fitted and in everyday use have proved to be very effective. The caps have clear acrylic domes formed over a turned and polished male plug.

Lathes.co.uk alerted me to the desirable but rare tumbler reverse. This accessory is mounted in the fork at the front of the headstock. I tried to source one of these but eventually gave up and decided to make one instead. This proved to be a real odyssey. The tumbler has two castings the body and the sector. Detailed tumbler drawings were found on the internet and from these I made patterns which I then had cast in cast iron. Machining the castings proved challenging but nevertheless interesting. The other parts were simple enough to make but then a real problem arose. The two small tumbler gears were impossible to find. I soon discovered they were as rare as rocking horse manure. I was faced with two choices, have them made, expensive, or make them myself, still expensive! I chose the latter. I purchased gear cutters and made a purpose built morse taper arbor and a simple direct indexing dividing attachment which are shown in use making the 13t gear in **photo 4**. I did say it was an odyssey! The completed tumbler



Cutting the 13t gear for the Tumbler reverse.

can be seen in place on the machine in **photo 5**.

It was around the time I completed the tumbler that I began to seriously research accessories and design improvements for the M type. The obvious source was a *Model Engineer* magazine index and after identifying issue numbers with Myford/ Drummond articles I acquired them all via eBay. This lathe was rapidly becoming my hobby, I was not really a modeller and therefore had no desire to go down that popular route. I just wanted to improve the lathe, make it better, more versatile.

There have been numerous articles in ME magazine, pre-war and post war but the ones I found of real interest were a series of duplex articles published in the late 40's and early 50's. I suspect and it is only my opinion that many of these articles were the work of one half of that writing duo, the late Mr. Ian Bradley. Through reading his work I became fairly sure that Mr Bradley once owned an M type. His excellent book the *Amateurs Workshop* is littered with accessories and attachments for the M type. This book is a very good buy for any owner of an M type and for me a serious alternative to Sparey's *Amateurs Lathe*.

I have made and fitted to my lathe a small selection of Mr Bradley's designs. These include indicator dials for the top slide and the lead screw, a rear tool post, a cross slide handle, a spring loaded automatic clutch engagement, an arrangement for the popular Potts milling spindle and the superbly designed and extremely useful fine feed which can be seen in **photo 6**. The latter really is a joy to use and a without doubt my favourite addition. The design has a small pulley on

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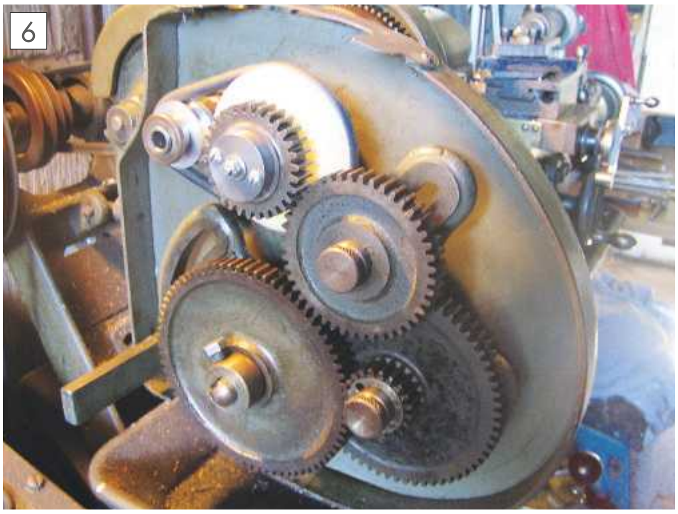
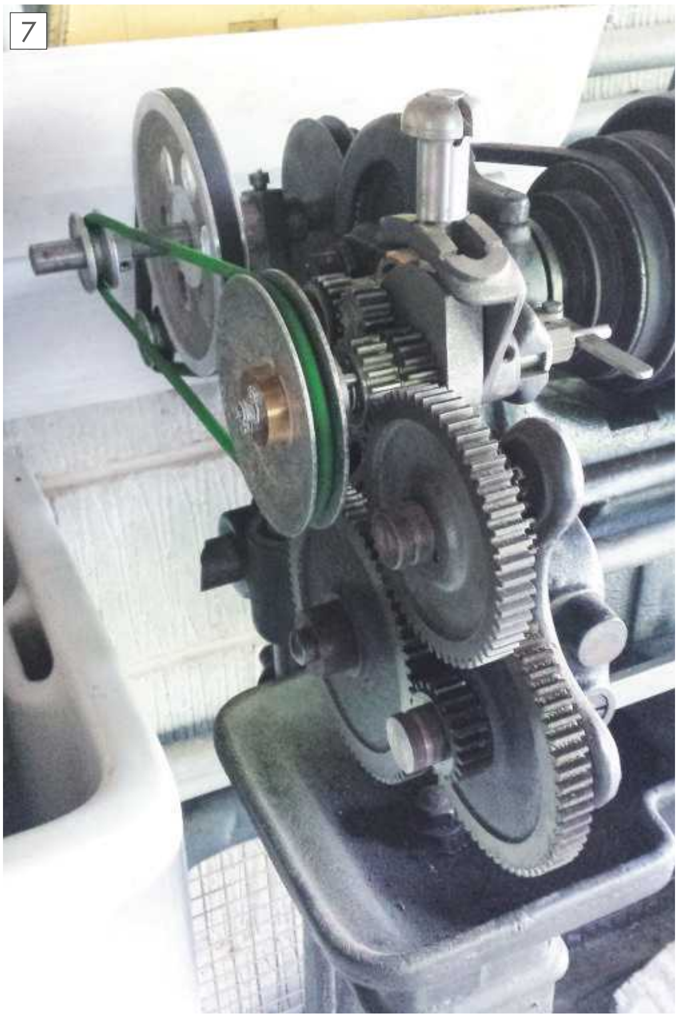
The completed tumbler on the Myford.

6



Fine feed arrangement on the Myford.

7

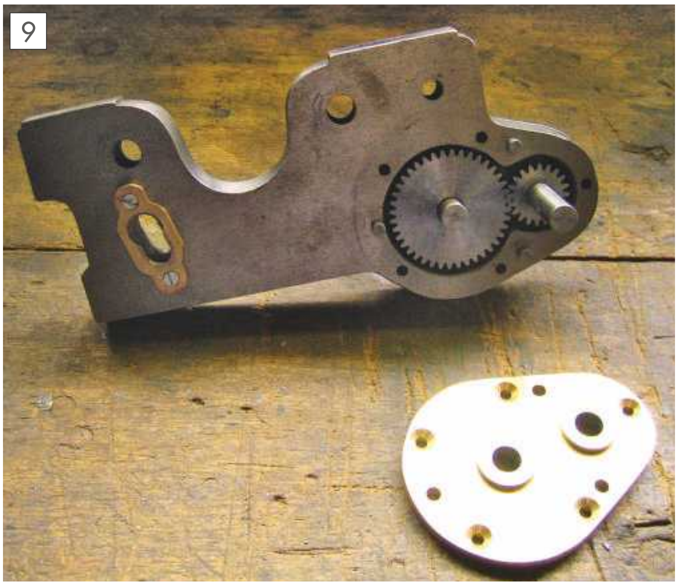


Tumbler Reverse and fine feed on the Drummond.

8

Lever tailstock castings.

9



New apron revealing the aperture for the gears.

the spindle driving another larger pulley. A standard lathe gear is engaged with the larger pulley via a small driving pin and thus transmits the drive through the gear train. A small lever on the other side of the fork is used to engage/disengage the gear via a push/pull rod down the centre of the shaft. As the whole attachment is located on a stud secured in the reversing fork this meant that the tumbler had to be removed. The tumbler which took me ages to make just had to go after less than three months on the machine. Having spent so much time making the tumbler I found I was using it mainly for a power fine feed. With the standard change gears this was around 175 tpi which is not really that fine. The fine feed attachment doubles the tpi to around 350 which is much better. The tumbler was placed in a drawer in the workshop where it remained for around 3 years until being installed on the Drummond M long bed; this can be seen in **photo 7**. In this photo it can be seen that the tumbler is combined with a fine feed. A direct belt drive from a small pulley on the countershaft is taken to a larger one on an extended tumbler shaft. With the tumbler in a neutral position I can engage the larger pulley with the tumbler gears via a driving pin which then transmits the fine feed drive through the gear train to the lead screw. With the larger pulley disengaged I can use the tumbler for its screw cutting function and when applicable the coarser fine feed.

In the main photo it can be seen that I have a lever tailstock attachment. I searched for a lever tailstock design but to no avail. I have no doubt that at some time somewhere this has been done for an M type but I could find no record of such a design. Fortunately it was not too hard to find similar designs and adapt them to my lathe, the ML7 and Super 7 being typical examples. My lever tailstock attachment uses three castings from my own patterns which can be seen in **photo 8**. As can be seen the resultant attachment in photo 1 is much the same as the ones on the series 7 machines. Now I would not be without it, a most useful accessory, great for small drills, fine for larger drills and of course good for quick swarf removal.

The extended bridge which can also be seen in photo 1 is similar to the type used on the series 7 lathes. The standard flat bridge on the M type can in some circumstances be really annoying as it restricts the forward travel of the cross slide and with the slide fully withdrawn there is a long and ugly overhang over the saddle The new extended bridge, cast from another of my patterns, gives an additional 1 ½ inch of forward travel and also evens out the forward and return travel of the slide. The latter has proved to be very useful when using a vertical slide.

Throughout all this time I tolerated the rack feed, in fact I was starting to get used to winding the hand wheel the ‘wrong way’. I do know a number of Myford/ Drummond users who are quite happy with the arrangement but sorry ultimately it was not for me. Another issue with the feed is the small 15t rack gear engaging directly with the rack resulting in a rapid feed and a hand wheel traverse that can sometimes feel very ‘lumpy’.

So two simple problems to resolve, changing the rotation of the hand wheel by adding an extra gear and making the extra gear larger to slow down the feed and remove the lumpy feel. I have seen a many solutions to these problems and all with their different merits. All of them involved adding parts on to the existing apron.

I have added a small gearbox to the front of my Drummond but on the Myford decided to make a complete new apron with integrated gears. This apron can be seen in photo 1. I made a simple flat back pattern, had it cast and then had the front and back surface ground flat. It can be seen in **photo 9** the casting has an aperture to house the reversing/reduction gearing. I’m really pleased with this new apron, it’s a compact design that has slowed the feed rate down and made the traverse smooth and effortless.

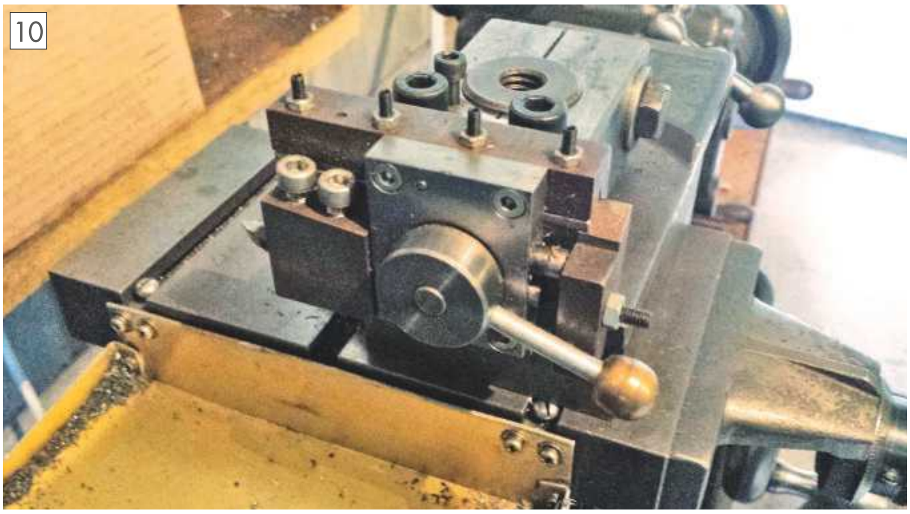
I have some other lathe improvements planned, Ian Bradley’s shaping attachment and more adaptations of his creative use of the Potts milling spindles. Also in the pipeline is a countershaft clutch which I am designing myself. This will incorporate much of principles in Alan Buttolph’s design from an early issue of *MEW*.

On the subject of lathe accessories, I would imagine, at some time, we are all drawn towards the work of the late George H. Thomas. I liked his spring loaded retracting tool holder for screw cutting and decided to make one. This can be seen in **photo 10**. Unlike Mr Thomas who machined the body and slide from mild steel blocks I chose in my now familiar way to make patterns for each and thus have them cast roughly to shape saving a lot of machining time. This accessory is great to use. Cuts are made with the handle in the spring loaded forward position. At the end of a traverse the cut can be relieved by flicking the handle backwards, the spring assisting this action. For successive cuts the tool is easily reset in the last forward position and another cut added via the top slide. I have to say I was quite chuffed when I successfully completed this GHT design. Mr. Thomas set high standards and to go some way towards meeting those standards was rewarding. I occasionally use it for Whitworth and metric threads.

The only real problem I now have with the lathe is the choice of number 1 Morse tapers in the headstock and tailstock. It is difficult to understand why this is the case. Both have substantial castings easily large enough to accommodate larger bearings and therefore a bigger spindle and quill diameter with number 2 Morse tapers. It would be a big task to carry out such a conversion and probably beyond my current capability so I must therefore persevere with things as they are.

The Drummond long bed was in a sorry state when I acquired it two years ago but is now, I’m pleased to say, in general use. This is very often for milling with the Ian Bradley inspired Potts set up using my own home made Potts and an independent overhead drive. Of course having two lathes means I can leave it set up this way for long periods whilst the Myford does all the turning jobs. For light milling operations this has proved to be a stable and easy to use set up. Unlike when I use the vertical slide I don’t have to fight gravity all the time! See **photo 11**.

10

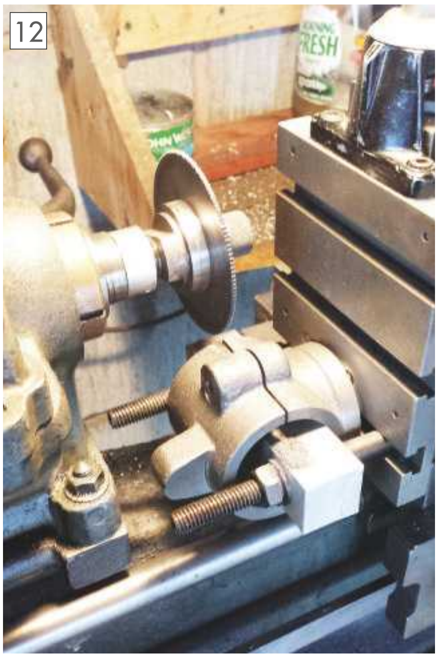


Geo. H. Thomas screw cutting attachment.

11

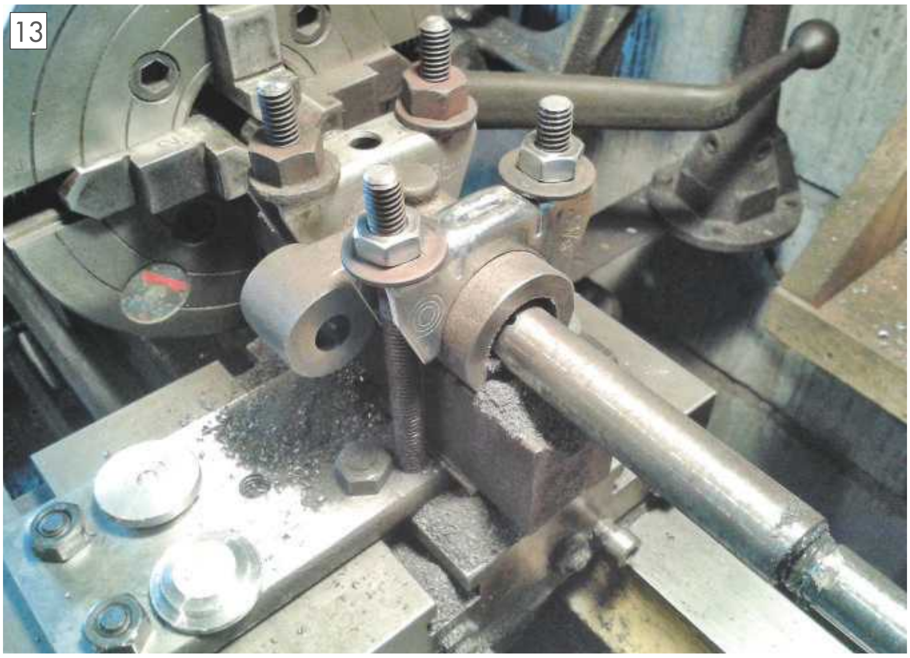
Milling with the Potts on the Drummond lathe.

12



Slitting the Potts trunk casting.

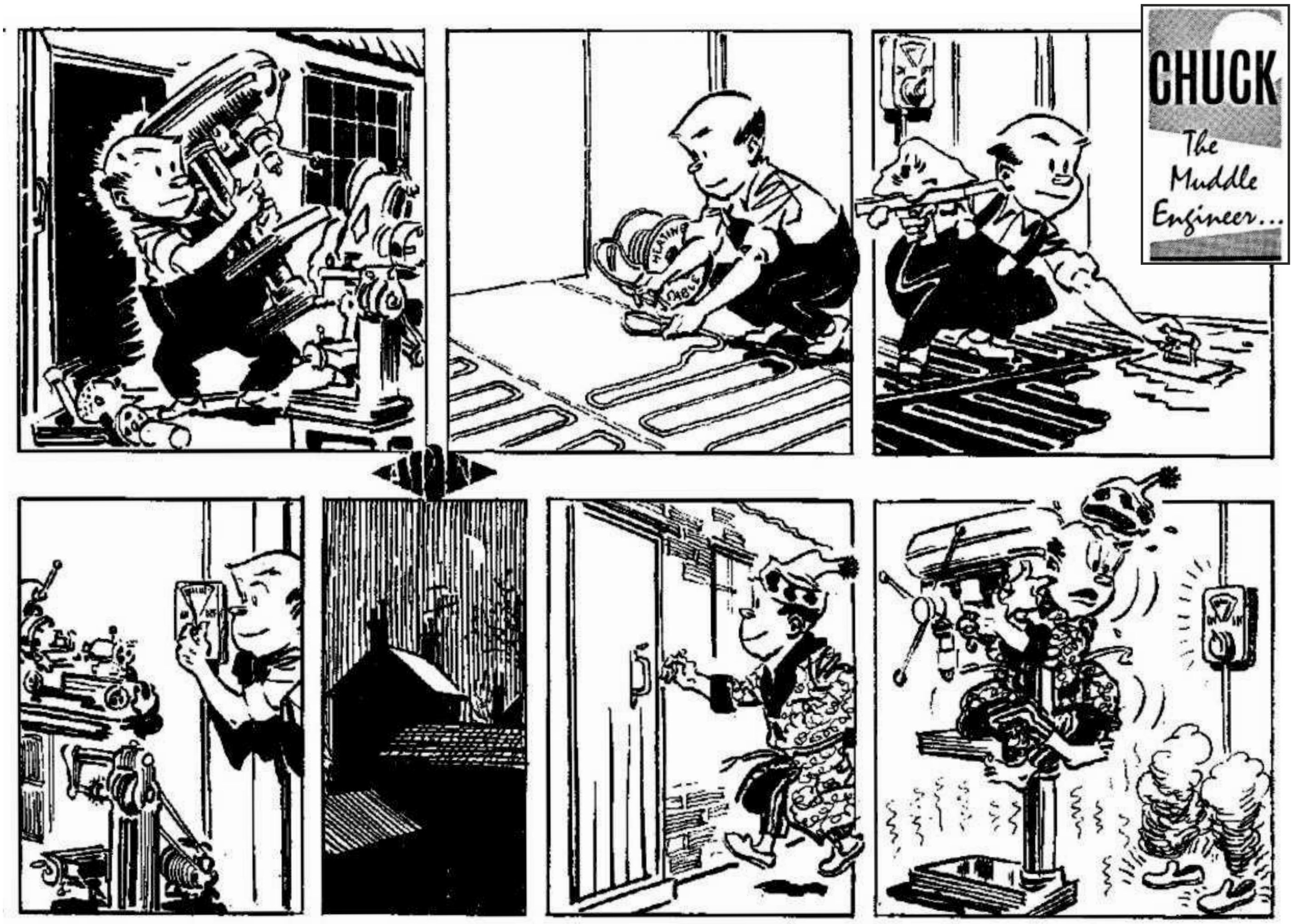
13



Boring a Potts casting – a new use for exhaust brackets!

To extend my use of this arrangement I am currently making an original Potts column milling spindle attachment, with castings again from my own patterns. **Photograph 12** shows the trunk casting held on a vertical slide for a slitting operation and **photo 13** a boring operation on the main casting from the Potts attachment shown in photo 11. This casting is clamped to a vee block on the cross slide using studs, nuts, washers and car exhaust brackets.

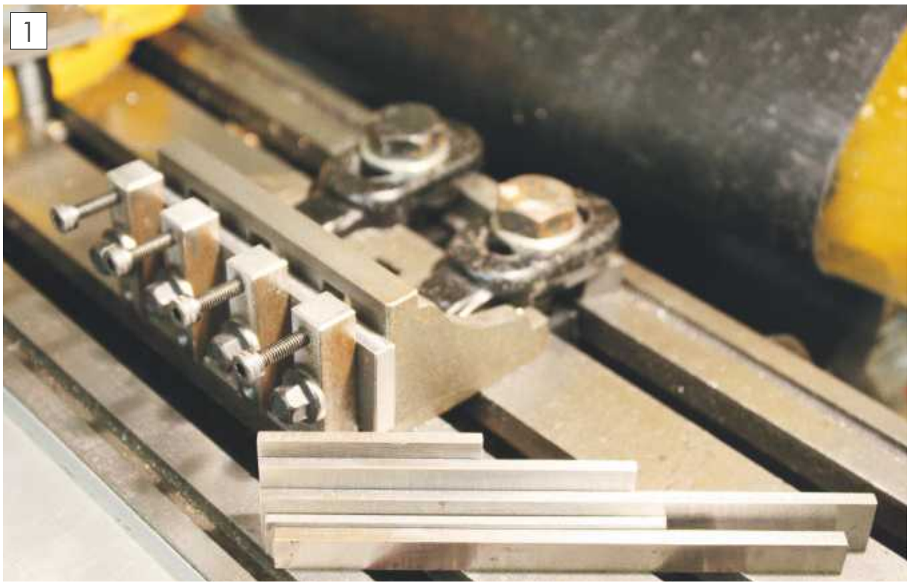
Oh finally! Did I earlier say I'm not a modeller? I am now. The lure of live steam has hooked me in. A Stuart Turner is coming on well even though some of the small fiddly bits are driving me nuts. Also it's nice to work on an excellent set of castings and just for a change I didn't have to make any patterns! ■



Making Parallels

Richard Gordon explains the manufacture of a handy little set of accessories.

Parallels are a necessity for more than very basic work in the mill for spacing parts off the table of vice and general setting up. They are also useful in the lathe, for temporarily placing things parallel before clamping on the faceplate for example. I've always been reluctant to buy a set due to them appearing to be so easy to make. Recently, out of frustration of not having the sizes I needed to hand, I built a simple jig to help with parallel making.



1

The production jig and a few finished parallels.

Methods

The main requirement is clearly to have all sides parallel and square. Not having any grinding equipment, I looked at various methods on the mill. My original thought was to drill holes in the material, bolt to the mill table and cut the sides with the edge of a slot drill. With all the slack taken up in the slideways, this method works well for the larger sizes of parallel. However, I was looking at a range of sizes from 8 to 25mm where this would get a bit tedious.

The next method I considered was to hold the material in a small tool makers vice and use a DTI on the underside of the ends of the material sticking out of the vice and setting true. This would also work but take too long to set up, and I had a few short pieces I wanted to cut for setting parts in the vice, which could not be set up this way.

In the end, I found a small angle plate and arranged a clamping system and a fence, parallel to the mill table, described here. I decided to make this jig on the spot, with no drawings and from scrap around me, so I hope the photos and description will give you the general idea. Sometimes it feels liberating to work in this free spirited way! Photo 1 shows the finished jig and a range of parallels I made with it.

Making the Jig

I started with the angle plate, which had a short side 40mm tall. From this dimension, I determined a 25mm x 6mm bar could be bolted to the angle plate. This could then have four threaded holes to fix four clamping bars to hold the material against the plate. If the top of this bar was machined parallel to the table, and the parallel material tapped down and held firmly against this bar, a perfect parallel could be made, in theory...

Photograph 2 shows the angle plate and the bar and the three marked out holes to clamp the bar to the angle plate, and four additional holes evenly spaced around the mounting holes. These were drilled, countersunk slightly and taped M6 through (**photo 3**).

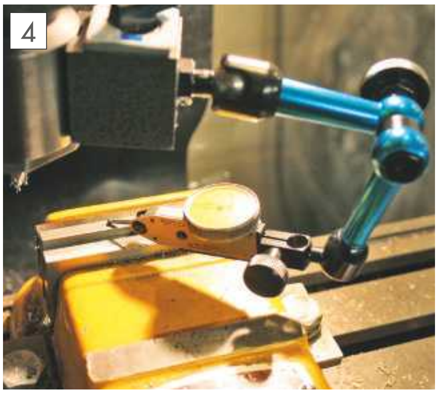
Next, the bar was set up in the machine vice level with the machine (**photo 4**) the top cleaned up and the Z axis dial (or DRO) zeroed. Next, a 1mm step was milled along its length as in **photo 5**. This step allows you to machine the top surface of

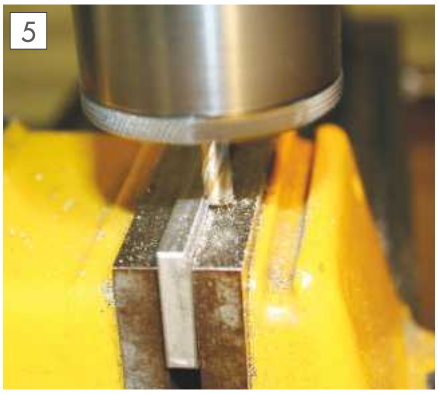
2

Angle plate and marked up clamp bar.

3

Tapping the clamp bar.

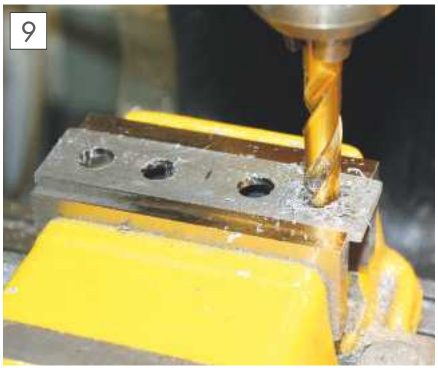

Setting the clamp bar level.


Milling a 1mm step.


Slotting one end of a clamp.


Skimming the clamp bar.


Truing one edge of a parallel.


Drilling holes in a parallel.

this bar once it is bolted to the angle plate without harming the plate.

The clamps were made from 10mm square steel, 40mm long (length same as the angle plate height). A 6mm dia hole was drilled through the middle and a M4 hole drilled and tapped 5mm in from each end for the clamping cap screws. The 6mm hole was then slotted towards one end as per **photo 6** to give some freedom in placing the clamp for clamping a range of work on the jig.

Now, the angle plate was bolted or clamped to the bed, trued up with the x axis and the 25mm bar bolted to the angle plate. I set it about 8mm down from the top of the plate. I also used the DTI to get it reasonable level with the table. Next, the important step, I took a very light cut over the fence face as in **photo 7**. This ensures the parallels come out parallel. Don't touch the set up from now.

The clamping bars are next bolted firmly to the bar. Take care not to bottom out the M6 bolts. Also arrange the bars so they are firmly touching the table as this make the set up a bit more rigid. You are now ready to cut your parallels.

Making Parallels

They should be roughed out before you attach the jig to the mill using the machine vice. Depending on the length you want, you can make in pairs or make longish ones and cut in half at the end of the process. When roughing out, finish one face as carefully and smoothly as you can. Deburr and gently rub on some wet and dry paper on a surface plate to ensure it is quite flat. You can use bright mild steel flat or as I did, some gauge plate off-cuts I was lucky enough to come by a long time ago.

Back to the jig, make sure it is clean and place your first blank in sliding it a bit to feel it is bedding down. Place a scrap of shim steel between it and the M4 cap screws and nip them up. Gently tap the blank down and finally tighten the clamp screws.

I always look out for solid carbide drills at shows as these go through just about anything with ease, and that was certainly the case with this gauge plate.

Mill the surface gently with a sharp end mill (**photo 8**). If you are making in pairs, stop 0.05mm away from the height you want. Swap for the second blank, take that to the final size and remove. Then, not moving the Z axis, put the first one in, checking it is very clean and tapped down, and take the final cut. So far, I made all mine in one length to be cut in two if required, but I will use this method when I make longer ones in future.

Deburr all edges and rub the new faces very gently on wet and dry paper. Clean and check with a micrometer that they are parallel along the whole length. I found that mine had a very slight bow in the middle and that one end was very slightly thicker, that I could just feel in the micrometer. This was quickly corrected by lapping with the wet and dry paper on the surface plate. Clearly my old mill is not quite as perfect as it perhaps once was.

If you have time and the need for really high accuracy, you can blue the edges and compare with the surface plate. Lap any high spots to make a ‘reference’ face and check the other face is parallel to it with the micrometer.

The final step was to true up the ends by setting the parallel with its side face upwards in the machine vice and then take a cross cut with an end mill along the end of the parallel. If the vice is clocked in accurately this should be exactly 90 degrees to the parallel face. Also in that position, drill some holes at a logical spacing as per **photo 9**. I always look out for solid carbide drills at shows as these go through just about anything with ease, and that was certainly the case with this gauge plate. There is a fair amount of debate on the internet as to what the holes are for in larger parallels, ranging from weight saving, stopping warping during heat treatment, for clamping and for gripping with oily hands. If anyone has a definitive answer, I'd really like to know!

It took about four hours to make this jig and set it up and about another three hours to make the range of parallels in **photo 10**, and lap them to a good level of accuracy level. These parallels will certainly come in handy and I hope you can also find other uses for the jig too. ■


A finished set of parallels.

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An Engineer's Tee-square

Mark Frampton introduces a neat square to complement his adjustable 'parallels'.

This tee-square was made to complement my spring parallels (*MEW* 229) which were designed to facilitate the setting up of workpieces in the machine vice. The spring parallels are simple and effective, but since they do not show when the desired set-up has been achieved, separate tests must be carried out as part of the adjustment process. While it is possible to obtain good results by using a surface gauge or sticky pin to pick up a line scribed horizontally across the job, a positive mechanical indication is to be preferred, and this means setting the side of the job vertical. Almost immediately, however, a snag is encountered, for it is found that the most obvious tool for the task – the engineer's try-square – cannot be used, owing to a lack of space. Meeting with this very difficulty 30 or more years ago, George Thomas conceived the idea of making his own special tee-square, the blade of which was mounted on, rather than in, the stock, so that when the stock, which was narrow, rested upon the top edge of the fixed jaw-plate, the blade passed down between the jaws and could be brought into contact with the side of the job.

Design

As I have described elsewhere, my own version of the tee-square differs from the original because it is used in conjunction with a pull-down vice.

The vice in question is a Charles Taylor, an interesting design, which seeks to overcome the bugbear of jaw-lift by means of floating jaws of triangular cross-section. The sloping backs of the jaws are able to slide against matching registers in the castings – visible in **photo 1** – so that when the clamping pressure is applied, a wedging action occurs, with the result that the jaws do not simply move together – they also move downwards, pulling the job firmly onto the parallels. The pull-down action is very effective and tapping down with a mallet is usually unnecessary, provided the job is square.

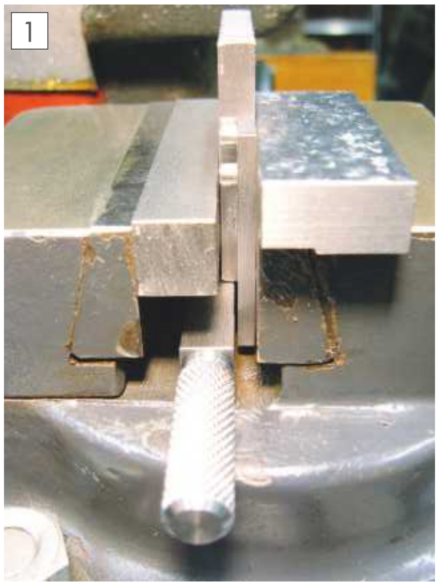
However, with such a vice, it cannot be assumed that the upper surfaces of the jaw-plates will be parallel to the bottom of the vice. The tee-square was therefore redesigned with a much larger stock which could rest on the ground surface of the main casting behind the fixed jaw-plate. A step in the stock provides clearance over the jaw-plate. This is necessary because the jaw-plate is supported from beneath by a spring and is sometimes pushed just proud of the surface of the main casting.

Construction

In his original description, published in *The Model Engineer's Workshop Manual*, George Thomas suggested that both stock and blade would be best made from ground flat stock, but I didn't have any in the necessary sizes, so I used mild steel and planed up what I needed on the shaper.

The stock was made from a piece of 10mm bright mild plate. This was first squared up and brought to size. Then the step was cut on the underside and the remainder of that surface scraped to the surface plate. The upper surface was scraped for appearance' sake.

The blade was planed from a piece of 3mm bright mild plate. Now, the shaping machine used is probably more than 50 years old, and work produced on it usually exhibits a slight taper. To correct for this whenever a really accurate job must be done, a shim can be introduced beneath the outer end of the workpiece. In the present case, a single thickness of cigarette paper sufficed. Checking the blade afterwards with a 'tenths' mic', I found that the difference in width along the length of the blade was just 0.0001 inches (2.5 microns), which shows that the use of shims is not as haphazard as it sounds – as long as you know your machine – and should not be despised.



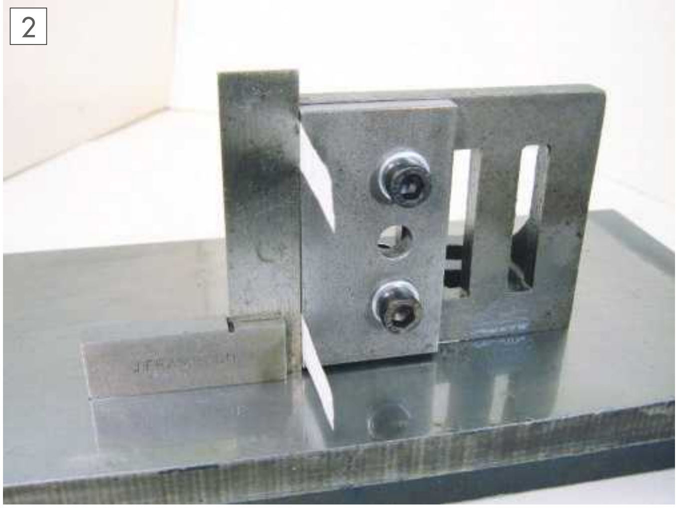
Charles Taylor vice, showing the wedge-shaped jaw-plates and recesses.

To join the blade to the stock, George Thomas suggested lightly riveting the parts together and then, when satisfied as to squareness, fixing the joint with soft solder. I did not fancy this approach, because I thought that the heat required might cause the parts to move relative to each other. I decided instead to screw and pin the blade into place.

The next step was therefore to drill and tap the stock for the screws, and drill the clearance holes in the blade. These operations were carried out in the lathe with the parts mounted in a small vice on the vertical slide. I did not bother to mark out the hole positions, but worked by jig-boring methods, picking up the edges of each part using a piece of silver steel as an edge-finder, together with a cigarette paper as a feeler.

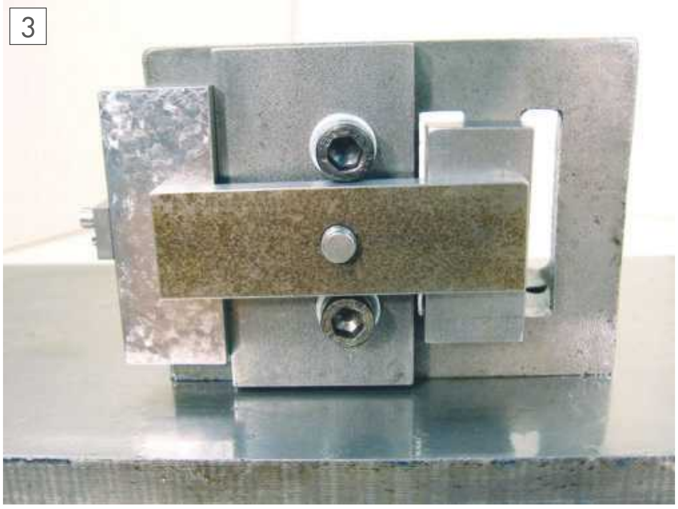
Before the pin holes could be drilled, the blade had, of course, to be set square with the stock. No guidance was offered in the book as to how this might be done, but suffice to say, an ordinary try-square cannot be used! The method I adopted was to screw the parts together lightly and then mount them on an angle plate on the surface plate. I then checked that the blade was parallel to the surface plate by sliding the whole ensemble to and fro beneath the leg of a test indicator (**photos 2** to **5**). The purpose of the squared-up fence was to ensure that the edge of the blade was horizontal, viewed across its width; any tilt here would have compromised the indicator readings. Gentle finger pressure was all that was necessary to adjust the angle of the blade until, in traversing its entire length beneath the clock, the needle showed only the faintest flicker of

2



Setting a fence square to the surface plate.

3



The tee-square clamped in position.

4

Clocking the upper edge of the blade.

5

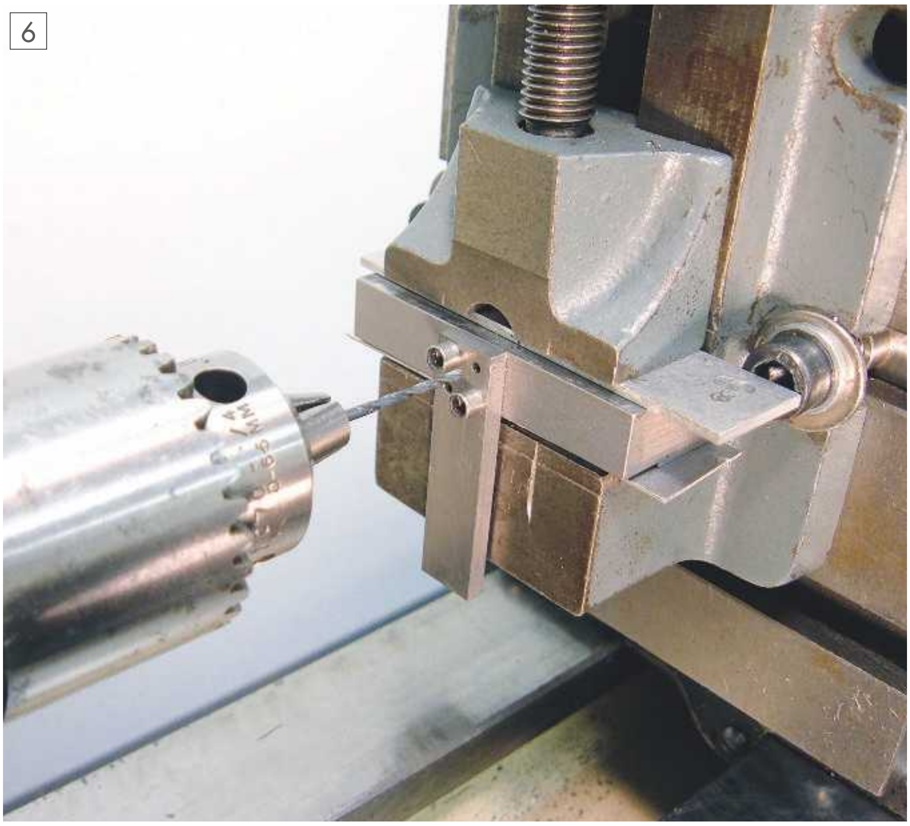
Double checking the setting by clocking the lower edge of the blade.

movement. The screws were then pulled up very firmly, and a final check of squareness made, before drilling the pin holes, which was again done by co-ordinate methods with the square held in the vice on the vertical slide (**photo 6**).

During the setting process, slotted cheesehead screws were at first tried, but proved tricky to set to the right tension, neither too tight nor too loose. Hexagon socket cap-head screws were therefore substituted, a hexagon wrench offering the possibility of greater control compared with a screwdriver. The cap-heads of these screws were rather too large and of a somewhat tapered shape, so I held them in a screwed bush in the lathe and skimmed them down parallel to a diameter of 0.150 in. (3.8mm), the same as the cheeseheads they replaced. A couple of small, sacrificial washers placed under the screw heads allowed the tool to run beyond the head and trim off any ragged skirt which might otherwise have remained.

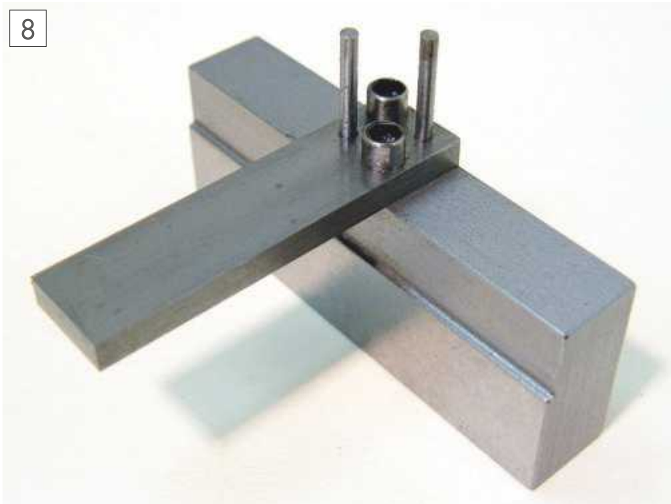
For pins, I used pieces of 1⁄16 in. silver steel about 15mm long. Working on the assumption that a small drill, even if new, can be reckoned to cut about 0.002 in. (0.05mm) oversize, I drilled my holes 1.5mm (0.059 in.) and polished down the pins to suit. Rather than using emery cloth for polishing, I prefer to use an old Swiss file, the first inch of which has long since worn shiny. In fact, to obtain an even less aggressive cut, I have flattened the teeth

6



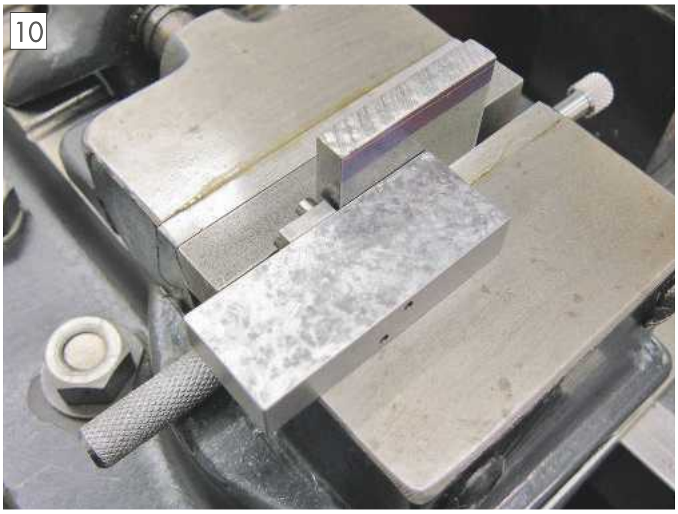
The tee-square set up on the vertical slide and the pin holes drilled.

Test pinnings.



Pins inserted, ready for pressing home.

Pins pressed home and flushed off. The completed tee-square.



Using the square. A piece of plate to be squared up.

Keeping the file lubricated with light oil, it is possible to work to a few tenths of a thou, and there is little danger of the pins becoming scored.

still further by rubbing them with an India stone and thin oil. Keeping the file lubricated with light oil, it is possible to work to a few tenths of a thou, and there is little danger of the pins becoming scored. There is, however, a certain amount of trial-and-error in the fitting of pins, so first of all, I drilled a few 1.5mm holes in a piece of scrap 6mm plate, and made test pinnings to establish the ideal size of the pins (**photo 7**). These tests showed that a diameter of between 0.0612 in. and 0.0615 in. would serve, so the pins were made to this tolerance. To enable a good start in the hole, the first few millimetres were polished still further so as to taper down to 0.060 in. or less, and the extreme end of each pin was well rounded. Incidentally, it is not necessary for the work contemplated here to possess a micrometer which reads to one ten-thousandth of an inch; estimating to the nearest half or quarter of a thou with an ordinary micrometer will be plenty accurate enough. A 'tenths' mic' is, in any case, something of a blessing in disguise and requires in use a fairly careful touch if repeatable results are to be obtained. A view of the square with the pins inserted, ready for pressing home, is shown in **photo 8**.

As it turned out, 0.0615 in. was too optimistic and one of my pins, which was fully up to this size, jammed during the pressing operation. The pins were pressed in over a length of 9mm and I think perhaps the problem might have been revealed earlier had I made my test pinnings in 10mm thick material, as opposed to the 6mm thick material which I actually used. When I tried to remove the jammed pin, it snapped off below the surface and had to be drilled out. This did not take long, using first a 1.4mm and then a 1.5mm drill, but it was a nuisance. A spare pin of about 0.0612 in. diameter was tried next, and this was pressed home without a hitch. The pressing was done in the bench vice, and when the pins were right home, about 5mm of their length remained above the surface so that their ends were just proud of the cap-heads.

The workpiece set up ready for machining.

The square was then returned to the vertical slide and the protruding stumps of the pins were milled away to within a few thous of the blade. These operations completed the tool (**photo 9**) and it has already proved a most useful addition to the workshop (**photos 10** and **11**). ■

Filing Buttons

Stub Mandrel buttons up.

Filing buttons are a simple, yet astoundingly useful aid to hand shaping components. They are just round discs of metal fitted either side of a hole to guide hand filing and the production of a neat, round end. For a rough and ready result, just using a cap screw or cheesehead screw might be sufficient, see **photo 1**, but it is very easy to get excellent results with a little more care.

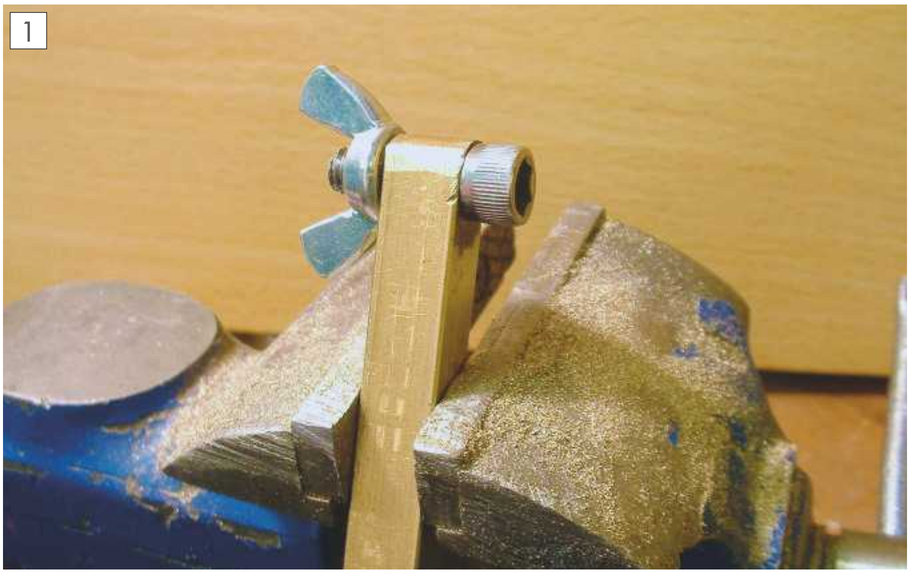
Obviously to get a really good result the button should be exactly the same width as the bar, and the bolt that holds buttons and bar together must be a good fit in all three parts. This is not hard to achieve, even if using a plain screw to hold the parts – but do measure the screw first. Many screws (especially metric ones) are significantly smaller than their nominal top diameter. I prefer to make filing buttons from silver steel, hardened but not tempered. Glass-hard, the file skids off them without damage, and they don't need to be left free to rotate. You can use softer materials, but if you do they need to be able to rotate so the file doesn't wear them away; this means a sloppy fit at the expense of a little accuracy. If you don't have material of the correct diameter just turn some down, the surface finish is not critical. Drill through a good snug fit for the securing screw, and part off two slices. These should not be too thin, like washers, instead aim for similar proportions to a full nut. Use the same drill on the component to be shaped – you can enlarge the hole to a larger size later if required.

Using the buttons is simplicity itself. Fit hardened buttons securely in place, or leave softer ones a running fit. Hold the part securely in a vice and file away, guided by the buttons. Interestingly the buttons control the cut taken by the file, so getting a good finish is usually easy, even with a coarser file than usual.

Normally you would use a flat file, but you can use more than one button to create more complex shapes with other types of file. The balanced crank pictured was made using three pairs of buttons in two sizes (**photo 2**) and the concave sections between each pair of buttons was finished with a half-round file. The second photograph of this crank shows it with its edges profiled, then treated with a sanding drum followed by a felt mop with polishing compound. But where is the hole for fixing the buttons to the balance weight? It has been plugged by a piece of similar steel turned to a driving fit. The plug is invisible after polishing (**photo 3**).

Finally, keep your buttons paired up on their matching screw. You will soon build up a neat little collection of useful sizes, and if properly hardened they should last a lifetime. ■

1

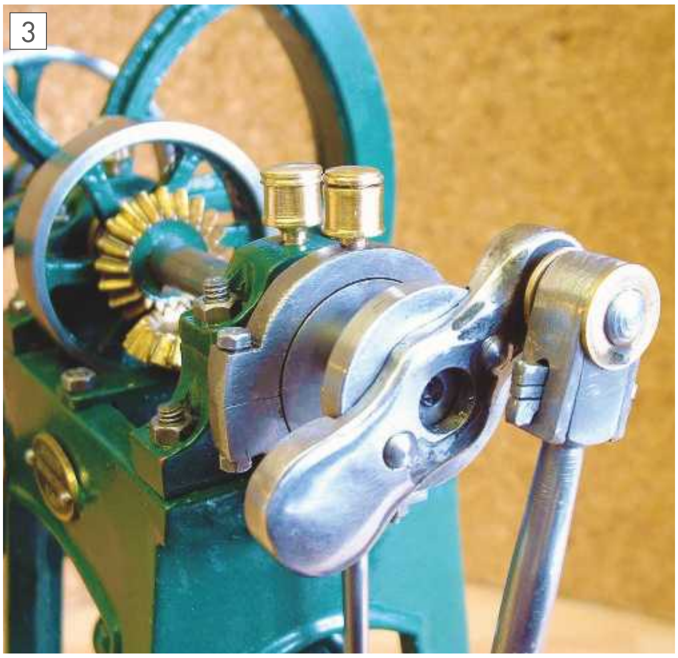


Using a cap screw as a crude filing button.

2

Three pairs of filing buttons screwed to an embryo crank.

3



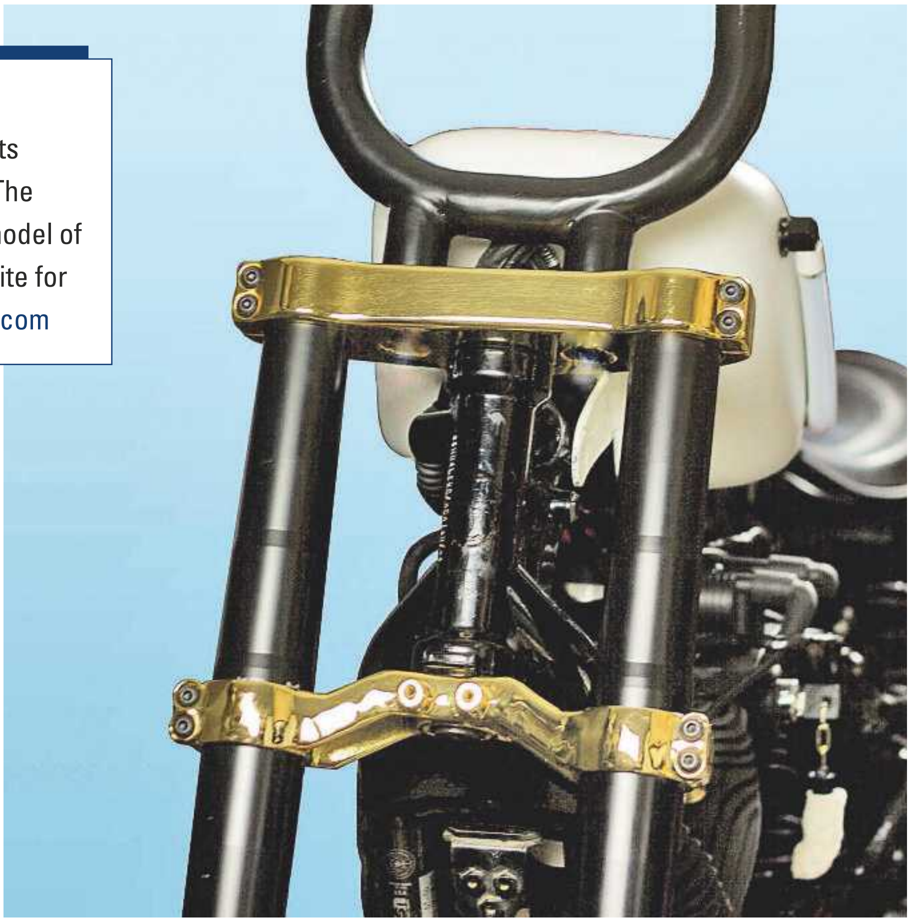
The finished crank polished up nicely.

CNC in the (Model Engineers') Workshop

Part 19

In this instalment, Marcus Bowman tackles a more ambitious 3-dimensional part.

This series of articles started from fundamentals and covers many aspects of CNC programming and machining. The series is not specific to one make or model of machine tool. There is a support website for the series at www.cncintheworkshop.com



Custom fork yoke

Harley Davidson motorcycles may be iconic and much sought-after, but their nickname 'The Milwaukee tractor' confirms the general impression that their handling and ride characteristics are not perhaps the most highly developed.

One popular remedy amongst custom bike builders is to mount Yamaha forks which allow a better front suspension action and provide for finer control of ride height and damper action. This is an established modification, but it is best accomplished by buying or, as in this case, making a new top yoke to hold the forks. **Figure 100** shows the drawing of the yoke, and **photo 106a** shows the end result, the rest of this article deals with the challenge of holding the workpiece, and CNC aspects of the manufacturing process.

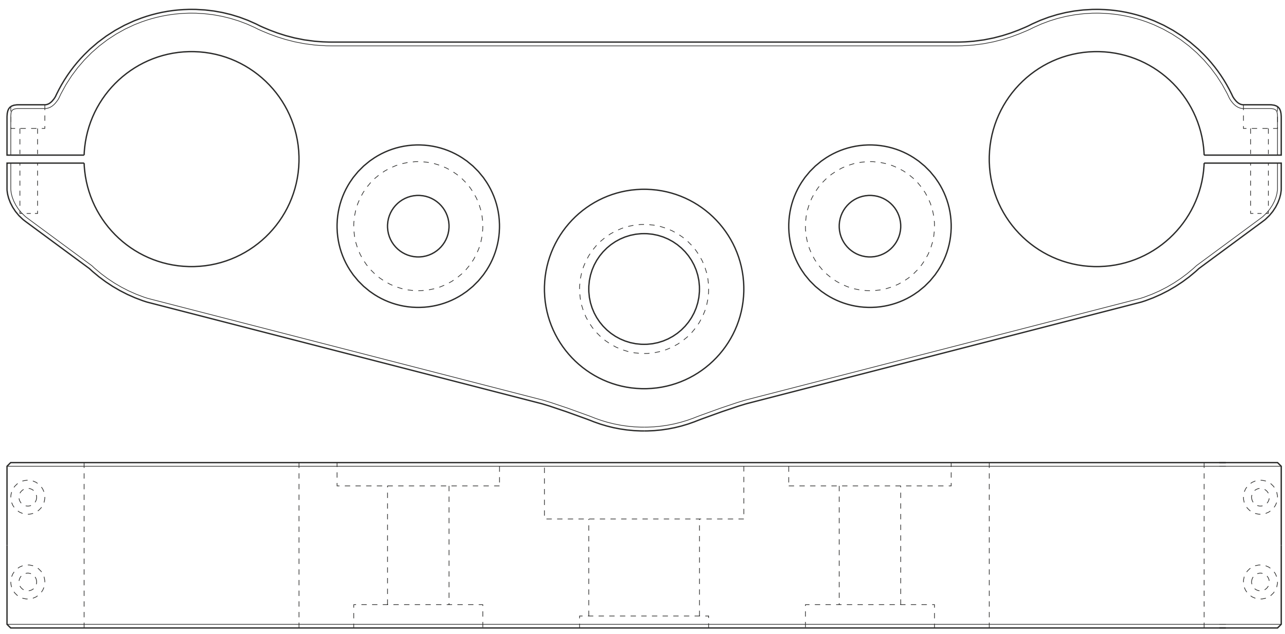
106a

Finished front fork yoke to mount Yamaha forks on a Harley Davidson motorcycle.

Design factors

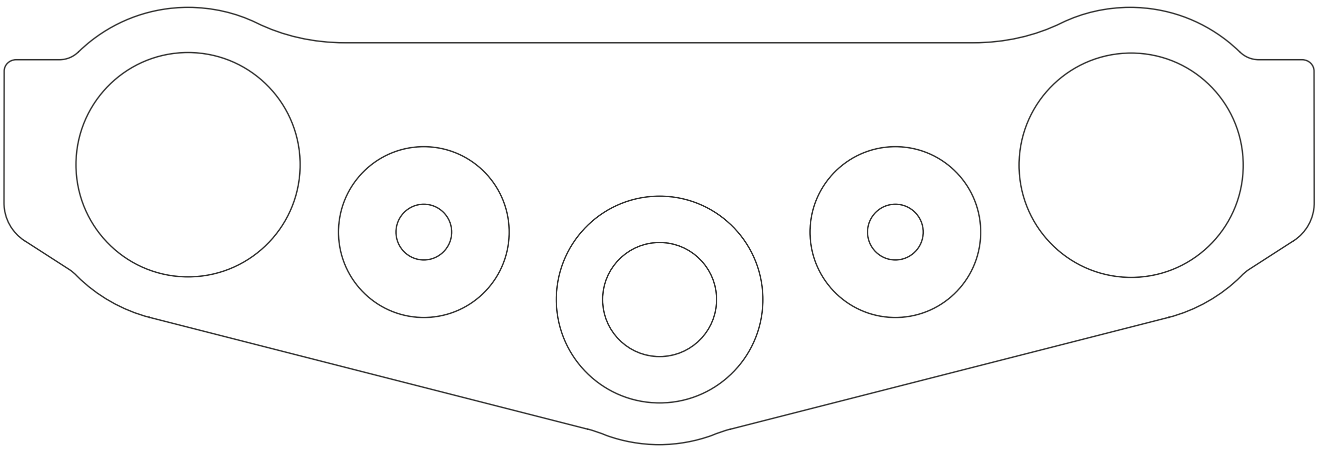
The existing lower yoke is an aluminium casting and is easily modified to take the Harley stem by fitting a thin 'top hat' sleeve to reduce the diameter of the stem hole. The lower fork legs are also aluminium, so it makes aesthetic sense to make a new top yoke out of aluminium. The most appealing option is to balance the visual 'weight' of the lower and upper yokes by making them of the same thickness. Creating a recess in the top surface of the yoke to take the stem securing bolt allows this to happen, so the thickness of the yoke was chosen as 37mm. The length of the yoke is determined largely by the spacing of the fork legs, and the breadth by the offset between the legs and the stem. Some accurate sketches showed that the whole yoke could be created from a block of 38 x 100 x 300mm aluminium. Rectangular bar 38.1mm x 102mm is available as 1½ x 4 inches in old

Fig. 100



A drawing of the yoke, prepared in a vector drawing package.

Fig. 101



A modified drawing omitting the slits and providing a single continuous periphery. This drawing is ready to be saved as a DXF file then imported into a CAM program.

money, so that's what was used.

The minimum radius of curve used for the periphery of the workpiece will determine the maximum diameter of the cutter (so that the cutter can reach into all the curves), and the minimum radius was set to 6mm, so that a 10mm diameter cutter could be used. Yes; a 12mm cutter could theoretically be used, but it is a good idea to avoid 'crowding' a cutter in a recess, so I prefer to use the next smaller size of cutter.

The grade of aluminium is important because we need a balance of strength and sufficiently good machining qualities to allow a good machined finish without too much difficulty, especially because the yoke was to be gold plated (no; really).

Grade 6082 (or the old HE30) will do the job quite nicely, while being readily available. There are some other, much more expensive, grades which have better machining characteristics, and there are several stronger grades which have poor machining characteristics, so 6082 was chosen as a good compromise.

Tooling

Choice of tool is a significant factor, in this job. The material will be 38mm thick, and the tool must be capable not only of reaching the lowest part of the job, but of taking a finishing cut along that 38mm face. The material is aluminium, and we know that really demands a tool with appropriate cutting angles, especially for a job of this size which requires a good surface finish. I chose a 2-flute carbide end mill with a 55 degree helix angle, capable of cutting across a face 40mm deep. The cost was some £20. The geometry of these tools is interesting because the 55 degree helix angle and the polished flutes give it a slicing action more suited to aluminium. The cutting angle (i.e. the angle between the periphery of the cutter and the inner face of the flutes, at the cutting edge) is designed specifically for aluminium, and the tool is capable of a significant material removal rate. With a 55 degree helix angle, the tips of the flutes are a little fragile, and some manufacturers use a variable geometry so that the helix angle at the tips is reduced to provide more strength at the tips. As the flute twists upwards, the helix angle changes to 55 degrees. Of course, those are more expensive cutters.

I did some research on these carbide cutters, because I was worried about the strength of such a long cutter, but the consensus seems to be that you will run out of spindle power long before you break the cutter. My tests suggest that is true, although your nerve may not hold that long.

To test the cutter and set some overall parameters for speed and feed, I clamped the 38 x 100mm material to the bed of the mill and took some cuts across the end face. Running the cutter at 3000rpm and cutting across the whole 38mm face of the block, a climb cut of 0.2mm at F200 mm/min resulted in a very good finish, with just a trace of vibration. Taking a cut 0.5mm deep at F500 was exciting and produced a good finish but with some thin hairy slivers stuck to the surface, presumably as a result of local welding. They brushed off reasonably easily, but did indicate a practical upper feed rate. A cut 1mm deep was a little more than my nerves could stand. Impressive, but stressful for cutter, motor and me. Keep a bucket and shovel handy for the swarf.

Work holding

The CAM program really needs the whole yoke periphery to be continuous, so the slits (visible in photo 106a) were produced later. That posed some work holding challenges, so I prepared a small fixture sub-plate for general-purpose use, with some accessories prompted by this job. The sub-plate (or sub-table, if you prefer) is a mild steel plate 320 long x 150 broad, with a selection of M8, M6 and M5 tapped holes, as well as 6mm and 3mm reamed holes, all laid out at known distances referenced from the central 6mm hole (**photo 107**).

The tapped holes are all counterbored, and the top and bottom faces of the plate were ground parallel (although flycutting or finishing the faces using multiple passes with a large diameter multi-tip cutter would be a viable alternative). The two long sides at front and rear are finely finished to act as reference faces. There are four securing holes, one of which is for a ‘fitted’ 8mm bolt (i.e. it is a reamed hole and the unthreaded portion of the shank of the bolt is a close fit) and the other three are 8.3mm diameter drilled clearance holes. The plate sits on 3 spacer blocks made from 38mm square section mild steel. These are ground or machined parallel on top and bottom surfaces, and are all finished to the same thickness. The blocks carry through holes to allow the plate securing bolts to pass through and reach the tee nuts in the mill table. The blocks also carry two M8 tapped holes running parallel to the mill table and the tee slots, for accessories. The ends of these blocks are finished square to the side faces. I actually made four identical blocks, and the fourth will come into play later.

In use, the front edge of the plate is set parallel to the X axis. With the bolts just finger tight, it is relatively easy to clock the front edge parallel, using the fitted bolt to act as a pivot point. In fact, I used a laser edge-finder initially, for speed (**photo 108**), holding it out over the edge of the plate using rods and clamps from a DTI set, then made a final adjustment using a lever-style DTI (**photo 109**) which has a very small total range of travel, but is graduated in 0.002mm and 0.0001inch increments. With a gauge as sensitive as this, you have to be realistic about the extent to which you can actually achieve zero deflection over the length of the plate. A total deflection of 1 graduation over 300mm represents just 0.004 degrees out of parallel. Double check after tightening the bolts carefully.

107

A sub-table with a selection of tapped and reamed holes.

108

Using a laser edge-finder to help set the front edge of the sub-plate parallel to the X axis.

109

Using a lever-style DTI for final adjustments.

The plate can be supported on only two of the support blocks, but placing the third block under the centre of the plate adds rigidity. It is not necessary to bolt through that central support block; and you may find it needs to be a little off-centre anyway, especially if you are using bolts or pins through the holes in the plate.

At the time of making the yoke the plate was secured using hex head machine screws, and those are visible in many of the photos. I intended that these be countersunk screws, but ran out of the appropriate size, and put that job on the 'To Do' list.

The workpiece can now be clamped to the plate, but taking the cutter lower than the full depth of the work will cut into the plate, so we need some spacers between work and plate. I made 5 spacers by parting them off from a 19mm bar in the lathe, then finished them all to exactly the same thickness. This is most important, especially when we come to the fine little chamfer running around the edges of the finished workpiece. Use a surface grinder if you have one, or carefully face to a finished size, probably by using the lathe and a chuck backstop, and/or lap to a fine finish or carefully finish on a large whetstone. Make the spacers a little thicker than the height of the washers and bolts used to secure the plate, so that a cutter machining just a little lower than the bottom of the work (i.e. cutting across the full depth of the vertical face of the work) clears the tops of the bolts. I made my spacers 16mm thick.

As it happens, this particular job is rather large for the sub-table, so we will need some other plates when we try to face the work.

Facing the block

The yoke needs a finely finished flat surface, top and bottom, with those surfaces parallel to one another. I first ran a ball-ended DTI along the top surface

End plates were added to the sub-table, to allow the material to be gripped from the side.

The workpiece was faced using a flycutter bolted to a lathe faceplate.

of the sub-plate, parallel to X, then again parallel to Y, to check the plate was sitting parallel to the mill table. Then I sat the block on the spacers. This is about the maximum width of block + cutter my mill can cope with, so the block needs to be positioned with some care. The problem is that it is difficult to arrange clamps so that the whole of the top surface can be skimmed. I could have drilled some recessed holes roughly where the larger holes would eventually be, and clamped through those using countersunk or recessed bolts, but I decided to use two end plates attached to the spacer blocks beneath the sub-plate. **Photograph 110** shows the arrangement. There are large washers trapped between the end plates and the spacers under the sub-table, to hold the end plates clear of the ends of the sub-table. The end plates carry tapped holes so that M8 bolts can be used to press against the ends of the workpiece, like a large vice. This is a general-purpose fitting for the sub-table, and is likely to be used on other jobs, so the extra work making the plates will not be wasted.

The choice of tool for facing is dictated by the finish required, and the area the tool can cut. Multiple passes with an end mill or a facing cutter would produce an accurately finished face, but there would be a visible pattern of parallel tracks across the face, which would be unacceptable for this job. Instead, I elected to use a flycutter which would sweep across the whole width of the face at each pass, and **photos** 110 and **111** show the arrangement. A flycutter is bolted to a lathe faceplate, and an adaptor is mounted in the mill spindle to provide a replica lathe spindle thread. I took the time to make a suitable securing arbor to lock the adapter into the spindle. Note that photo 111 appears to show more than one flycutter protruding from the faceplate. This is an illusion, as the faceplate carries one flycutter block, and three other blocks, used for another purpose, which do not protrude as far as the flycutter. Those additional blocks play no part in this project.

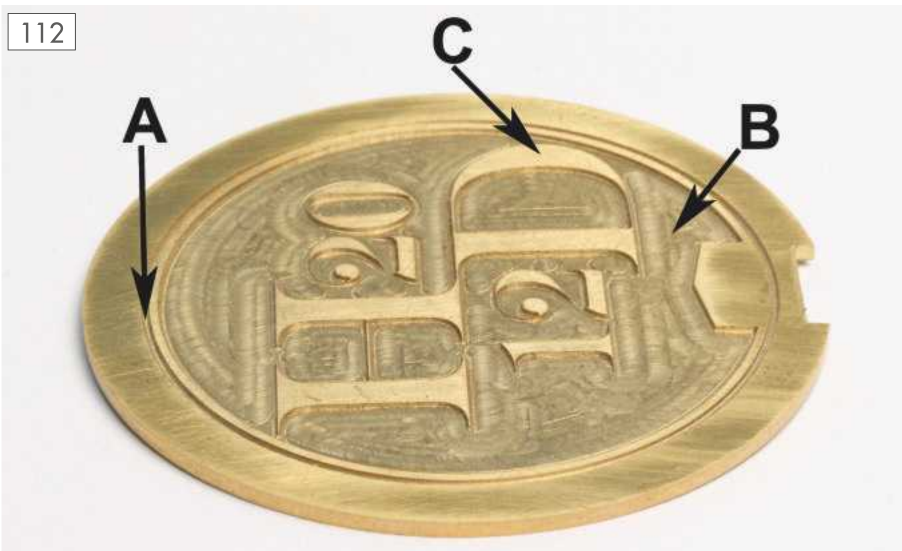
Running the mill at its lowest speed provided a suitable cutting speed for the flycutter, but does highlight the significant limitations of an electronically variable speed drive to the mill motor. With a belt-driven motor, altering the pulley ratios to slow the spindle increases the torque available, so that maximum torque is provided at the slowest speed, and the speed of the spindle will not vary noticeably between cutting the work and cutting air. With a typical variable speed drive, the specification may say that full power is available throughout the speed range. True; but that it not the same as saying there will be enough torque for a job like this. The result is that the cutter runs at one speed through air, slows very noticeably as it enters the work, then speeds up again as the electronics try to maintain the speed selected by software or by a potentiometer knob. For CNC work, I would not wish to be without electronically variable speed control, but it does have significant practical imitations even when there is 1500W (2HP) available.

The required spindle speed is calculated in the usual way, using the radius of sweep of the flycutter in the formula. The slower the feed for the final shallow cut, the finer the finish, but do keep the cutter and work lubricated to avoid pickup. I used Castrol Ilocut 486; a thin, neat, cutting fluid which works well on steel and aluminium.

This first face establishes a datum, so bring the work to thickness by turning the block over and facing the other side. Take a moment to admire the finish. If your flycutter bit has a generous radius, and the linear feed for the final pass is low (50mm/min or less; 0.02mm depth of cut) you will need your sunglasses.

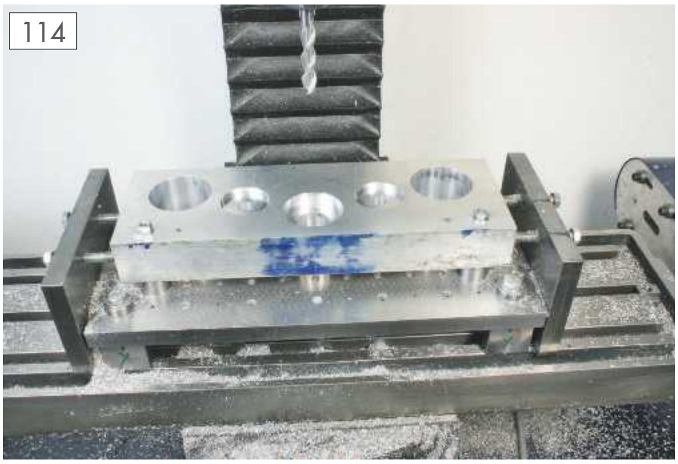
Profile and pocket cuts

Holes pass right through the work, while a pocket is a hole which stops part-way through the work. A pocket has a profile (i.e. the shape of the boundary, in plan view) and the area inside the profile may be entirely cleared of waste material or may contain some 'islands' of material deliberately left proud of the bottom of the pocket. **Photograph 112** shows a single line (A) created by an engraving cutter cutting ON a path, a pocket (B) formed by a cutter machining away the waste material inside a profile, and several islands standing proud inside the pocket (C). Those islands are each defined by their own profile and are not treated as waste, so all islands are left unmachined. The pockets in the top yoke differ in their depths, but contain no islands. They do contain holes in their centres, though, but those are created separately. Using a CAM program, if the diameter of the cutter is more than half the diameter of the hole a profile cut with the cutter running inside the profile will ensure the internal waste is automatically machined away. If the cutter is less than half the diameter, the hole could be treated as a pocket with a depth slightly greater than the thickness of the workpiece. The cutter would then perform overlapping passes to remove all the waste.



Objects may contain a single path (A), a pocket (B) and protruding 'islands' (C).

A paper template gives an approximate visual indication of the position of the main features of the work.



The block was clamped using bolts through holes drilled in areas of waste.

I made 5 spacers by parting them off from a 19mm bar in the lathe, then finished them all to exactly the same thickness. This is most important, especially when we come to the fine little chamfer running around the edges of the finished workpiece.

Setting out for the internal holes

Bearing in mind the cost of the aluminium block (approximately £38), and taking a belt-and-braces approach, **photo 113** shows that I used a paper template as an approximate indication that the finished yoke would fit into the block (and yes, I did this before I cut the block from the whole length of bar). You will see I have scribed a centre line down the front face of the workpiece, as a check. Notice the two 6mm holes drilled through the block in areas of waste. **Photograph 114** shows that these were used to clamp the block. If the side plates were the belt, the securing holes were the braces.

Set the work origin X0 Y0 at the centre of the middle hole which will be cut in the yoke. I set X0 Y0 at the front left corner; moved to the right half the length of the block, and set X0. Then I moved to Y1 (to give an allowance for finishing the front of the block) and set Y0. Then I moved to the Y co-ordinate of the centre of the hole, and set Y0 there, to give me the origin.

Creating the through holes

In thin sheet, it is easy enough to create a hole whose diameter is large in comparison to the diameter of the cutter. Just machine around the inside of the hole to create the inner edge, and the waste in the centre will be detached. In a thick workpiece, that won't work. Machining a deep groove to create the outer surface of the hole risks the cutter being crowded or jammed by the chips, while the central waste 'plug' remains a solid barrier. At best, the surface finish will be poor; at worst, the cutter will jam and the work will be ruined. The central waste needs to be cleared as we go along. At shallow depths, that can be done using a vacuum to suck the chips out or a stream of compressed air to blow the chips away. For deeper work a better plan is to create a through hole and to machine away the internal waste material. There are two approaches. The first is to set the cutter to a Z depth, and cut a spiral or a series of concentric circles at that height, to clear the waste and finish out to the edge of the hole. The second is to create a central hole, of smaller diameter, right through the material, then to machine a series of overlapping concentric holes, each to full depth, until the last forms the outer edge of the hole. In either case, the chips need to be removed, but using the second method means much of the swarf falls through the central hole and because the work sits up on spacers, the swarf can be removed from underneath the work.

I chose to drill a 13mm hole through the centre of each hole. For the two outer holes, I used the second method (concentric circles, each milled to full depth), using climb cutting throughout, and took a fine finishing cut to bring the holes to final size. The scuff marks inside the largest right hand hole are from a trial fitting of the fork leg in the hole.

Positioning the holes

A hole is, in essence, a simple shape to program. It is at its simplest when the centre of the hole is at X0 Y0. Unfortunately, only one of the fork holes is at that position, so moving to another hole position means the co-ordinates used in the commands for the circular paths are different even for similarly-sized holes. The yoke has two pairs of identical holes, but the commands will be different for each, because they are centred on different points.

The G92 command applies a global offset to the co-ordinate system, and it can be used to make the current CP position be treated temporarily as X0 Y0, or any other chosen values, so the same commands can then be used for identical circles or other paths, no matter where their centres actually lie. G92.1 cancels the offset.

The form of the command is G92 X~ Y~ Z~ where the ~ values are the new temporary co-ordinate values. So moving the CP to X60 Y30 and using G92 X0 Y0 will create an offset (which Mach3 calculates automatically) to make the current point X0 Y0. Z can be set to a new value as well, but if Z is not mentioned (as in this case) its new value will be the same as the existing value. Note that the current point can be given any co-ordinates, so that G92 X5 Y10 would treat the current point as X5 Y10 temporarily. Usually, making the current point X0 Y0 is most useful.

Here's a program snippet showing how you would use this:

Beginning with X0 Y0 at the centre of the middle hole of the yoke,
G0 X60 Y30 (centre of the right hand large circle)
G92 X0 Y0 (so that now becomes X0 Y0)
… insert commands to create a circular hole centred on X0 Y0
G92.1 (restore original co-ordinates)
G0 X-60 Y30 (centre of the left hand large circle)
G92 X0 Y0 (so that now becomes X0 Y0)
… insert commands to create a circular hole centred on X0 Y0
G92.1 (restore original co-ordinates)
and on each occasion, machining the circular hole centred on X0 Y0 is most efficiently done by using a single subroutine.

The same method can be used to deal with the two identical smaller shallow holes.

A sizeable problem

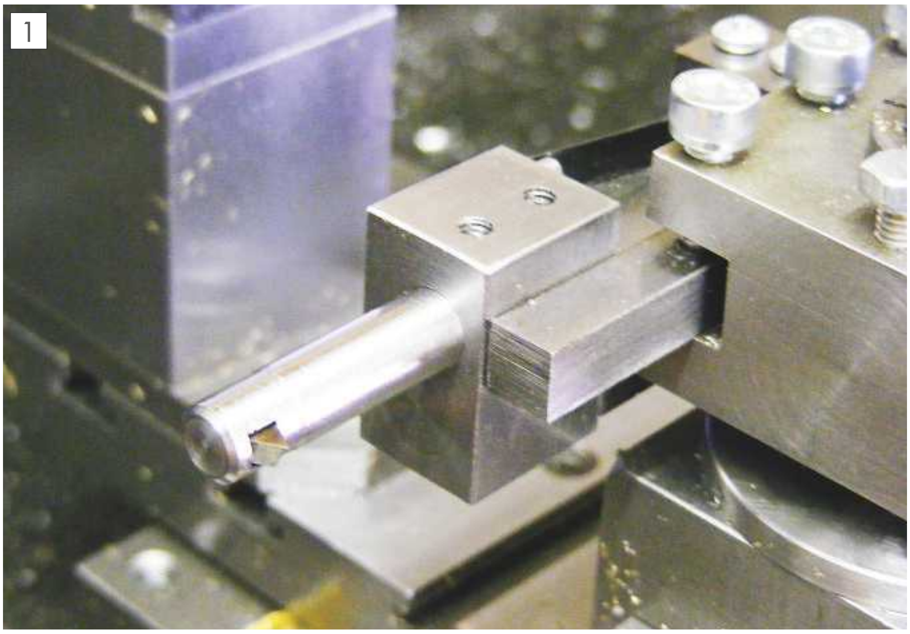
One unexpected problem was that the diameter of the cutter turned out not to be the stated 10mm, but a few tenths less than that, so that each hole was slightly too small. There are sophisticated methods of dealing with this, but in my case it meant altering my subroutines to compensate, then running the cutter around the inside face of each hole for a second time, to bring them to final size. I made a note of the actual size of the cutter, for future reference. Maybe, at only £20 for the cutter, you get a little less than what you pay for…

To be continued...

A swing tool holder for internal threading

This excellent accessory for small lathes from Mike Cox makes a great short project.

Swing up tool holders for external threading greatly simplify thread cutting in the lathe. An article on such a tool was published in *MEW* 178. Feed back from others that have built swing up tool holders has been very positive and all agree that the thread cutting procedure is both easier and less prone to error compared to conventional thread cutting procedures.



The completed tool mounted on the lathe.

Fig. 1

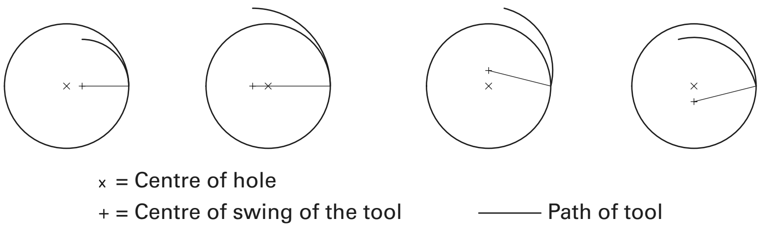
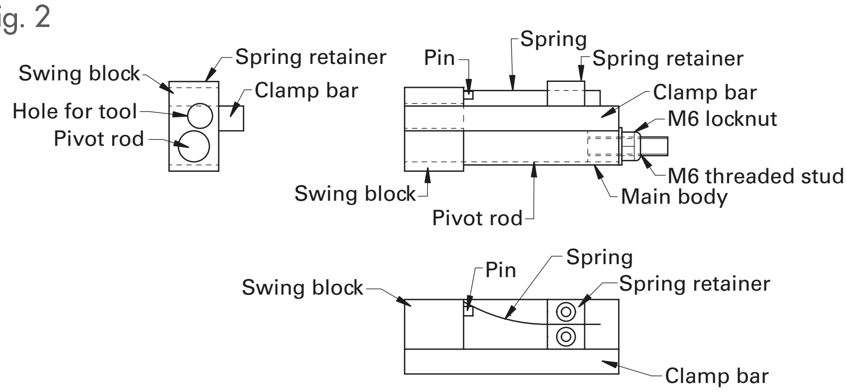


Diagram Showing Possible Geometries Of Swinging Tool

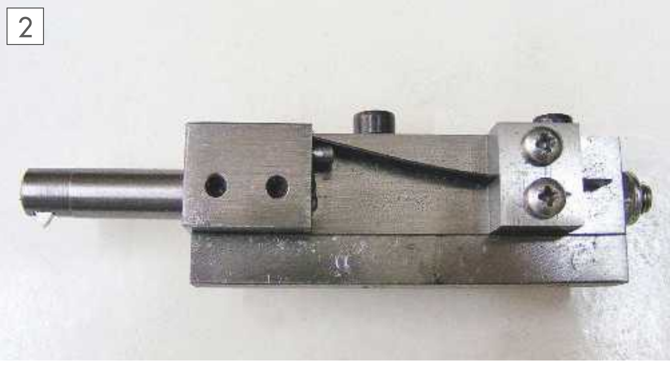
Fig. 2



General Assembly - Minor Details Omitted For Clarity

Having used and tested the swing up concept over the last year I started to ponder whether it was possible to design a similar tool holder for internal thread cutting. The design of such a tool is, however, more complex than for external threading. Consider the diagram **fig. 1**: In this diagram the solid circle represents the hole being threaded and the swing of the tool is represented by the dotted line. In the left hand diagram the radius of swing of the tool is less than the hole radius. In this situation the tool can swing up and away from the internal surface of the hole. Unfortunately, this situation is more theoretical than practical since it could only arise with using small threading tools in large holes. The second diagram shows what happens if the radius of swing of the tool is greater than the radius of the hole. Here there is no clearance for the tool to swing up at all. The same problem arises if the centre of swing is above the centre of the hole. In the right hand diagram the centre of swing has been drawn below the hole centre. Here the tool moves progressively away from the inner surface of the hole as it swings and this provides plenty of clearance. The swing threading tool holder described here is based on having the centre of swing located well below the centre of the hole being threaded.

The completed tool holder is shown mounted on the lathe in **photo 1**.



The swing tool holder viewed from above.

Showing the individual components of the tool holder.

Photograph 2 shows the tool holder, viewed from above, in more detail and the individual parts can be identified.

To the left is the 60 degree threading tool cutter. This is mounted in the 8mm diameter rod that projects from the swing block. It is secured in the swinging block by the two grub screws in the top of the block. To the right of the swinging block is the main body of the tool holder. This is bored through for the pivot rod. Below the main block is an 8mm clamp bar for securing the tool holder to the tool post block. This runs the full length of the tool holder and also serves as a stop for the swinging block. The swinging block is held against the stop by the leaf spring on the top of the main body. The leaf spring is anchored to the top by the block on the left hand side. Axial movement of the pivot block is prevented by the lock nut that can be seen on the left hand side.

The individual components of the tool holder are shown in **photo 3**.

The centre row shows the swing block with the 10mm pivot rod ending in an M6 threaded rod. To the right is the body of the tool and the washer and lock nut that retain the pivot rod in the body. Above are shown the leaf spring and its retainer block. Below are the cutter mounted in the 8mm rod and the stop/clamp bar.

Construction

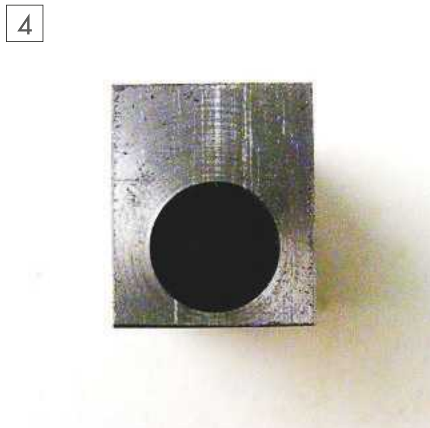
The general assembly drawing is shown in **fig. 2**.

The body (**fig. 3**) is made from a 50mm length of 16 x 19mm steel bar. This was set up exactly vertical on the mill table (I used a Keats angle plate for this) and drilled out and reamed to 10mm. It was then positioned in the mill vice and the two 4mm holes drilled. **Photograph 4** shows an end view of the body.

The swing block/pivot rod assembly (**fig. 4**) is made from four parts. The swing block (**photo 5**) is made from a 27mm length of 16 x 19mm bar. This was faced off both ends in the mill and then drilled through for the 10mm diameter pivot rod, for the 8mm cutter holder rod and for the spring pin. It was also cross drilled and tapped for the M3 grub screws that clamp the cutter holder rod into the swing block.

The pivot rod is just a length of 10mm steel rod 59mm long. This must be a close sliding fit in the body. Both ends were faced and one end drilled out to 5mm for a depth of 10mm. This was then tapped M6.

The spring pin is a 9mm length steel rod. This was machined from machined from a 3mm OD rod to be a tight fit in the 2.5mm hole.



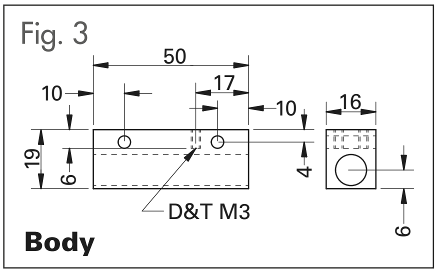
End view of body.

The swing block.

The final part is just a 36mm length of M6 studding.

All the parts were degreased with white spirit and dried. The non threaded end of the pivot rod and the inside of the 10mm hole in the swing block were coated with epoxy resin and the two parts pushed together and any excess adhesive was wiped off. When the adhesive had set the end of the studding was given a smear of Loctite and screwed into the end of the pivot rod.

The swing block/pivot rod assembly was then chucked in the lathe and the front and rear faces of the swing block faced off to a good finish. The spring pin was then pressed into the 2.5mm hole in the swing block. The assembly (**photo 6**) can then be fitted into the body and secured using a thick washer and a nyloc nut. The nut was



The swing block/pivot rod assembly.

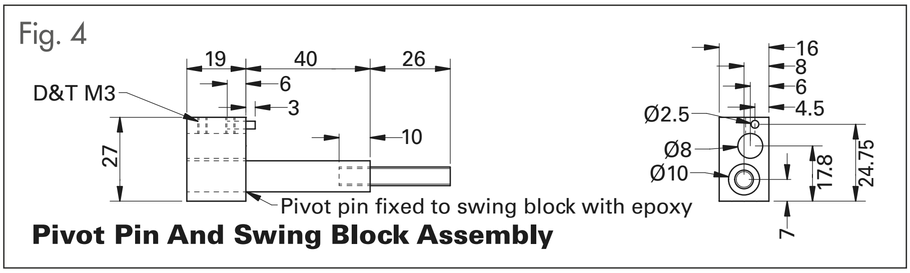
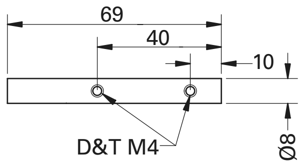
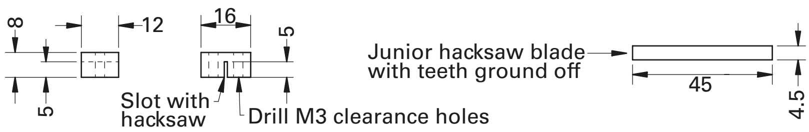


Fig. 5



Clamp Bar
Mat'l: 8mm sq. bar

Fig. 6



Spring Retainer Block And Spring

adjusted so that the swing block rotates easily in the body but with little axial movement possible.

The clamp bar (**fig. 5**) is made from a piece of 8mm square bar. This was drilled and tapped as shown. This was then fixed to the body using M4 socket screws.

The spring retainer block (**fig. 6** and **photo 7**) is made from a piece of 8 x 12mm bar 16mm long. The ends were trued up with a file and the two holes for the M3 retaining screws drilled. The slot was cut 5mm deep using a junior hacksaw. This was positioned on the body and the position of the holes for the retaining screws was marked using a 3mm transfer punch. The body was then drilled out 2.5mm for a depth of 8mm and the holes tapped M3. The retaining block is then screwed to the body using 12mm pan head M3 screws.

The leaf spring was made by grinding the teeth of an old junior hacksaw blade (Eclipse) and the snapping the blade to a length of about 48mm. The ends were then cleaned up on the grinder to give a final length of about 45mm. The spring was slid through the retaining block and then bent to locate behind the pin as shown in the general assembly drawing. The tension of the spring is sufficient to prevent movement in the slot and no other means of securing it are necessary.

The cutter holder

The cutter holder (**fig. 7**) is made from a 48mm length of 8mm rod. This was faced both ends in the lathe and a 3.2mm hole was cross drilled 3.6mm from the end. The hole was then broached to a 3.2mm square hole. This was done by carefully tapping a piece of ⅛ inch square section HSS into the hole with repeated removal and filing to remove the internal burrs created. Once the hole had been broached through the piece was chucked in the lathe with the broached hole inside the chuck. The other end was drilled out with a 3.3mm drill until the drill broke through into the broached hole. The end was then tapped with an M4 tap to a depth of 10mm.

The push rod was made from a 37mm length of 3mm round steel.

The cutter itself was made from ⅛ inch square HSS which was ground to a 60 degree point with a 7 degree clearance on each side. Once ground the cutter was cut off to a length of about 10mm using a Dremel type tool.

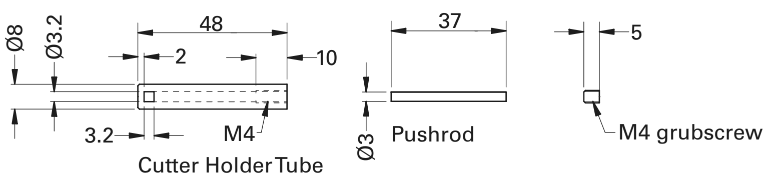
The cutter was pushed into the broached hole of the cutter holder, the push rod inserted and then the grub screw tightened to hold the cutter in place. The completed cutter holder is shown in **photo 8**.

The cutter holder fits into the 8mm hole in the swing block and locked into position by the two M3 grub screws.

In use

The swing tool holder has been used to cut internal threads in both steel and aluminium. **Photograph 9** shows a 1mm pitch internal thread cut in EN3 steel using the tool holder.

Fig. 7

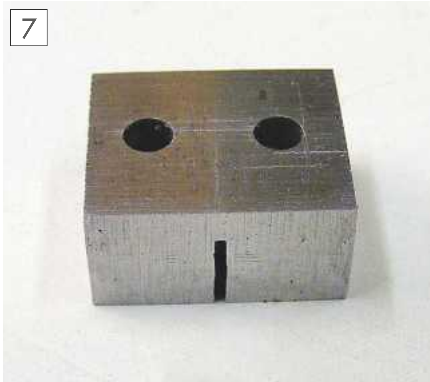


Cutter Holder

8

The cutter holder.

7



The spring retainer block.

The tool holder is simply clamped to the tool post in the usual way and the height adjusted to bring the cutter on centre. With the lathe gears set to give the appropriate pitch the cutter is brought up to the hole to be threaded. The lathe is started and the cutter is wound slightly into the hole and the cross slide retracted until the cutter just starts to cut metal. Now withdraw the cutter from the hole and set the cross slide dial to zero. Engage the half nuts and make the first pass. At the end of the pass stop the lathe select reverse and restart the lathe. This will withdraw the cutter. When clear of the hole then stop the lathe retract the tool a little more and select forward to make a second pass. This sequence is repeated over and over until the full thread depth is reached. At no point must the half nuts be disengaged.

Cutting takes place on the forward passes into the headstock. On the return pass the cutter swings back and rides on the flanks of the previously cut thread. This procedure eliminates the need to keep winding the cross slide back between cutting passes resulting in greater speed of threading and far less possibility of making errors. ■

9

A 1mm pitch thread in steel.

A Parallel Stub Mandrel, with a difference

Harold Hall's HINTS

Harold Hall describes a useful aid to concentricity.

There are two common types of shop made mandrels used for workpiece holding in the metalworking workshop, a parallel mandrel with a threaded hole in the end allowing the workpiece to be securely held with a screw, and a mandrel with a very slight taper where the workpiece is held purely by friction by being pressed onto the taper. The benefit of both is that if the mandrel remains in the chuck after machining it to be a close fit in the workpiece's bore then any subsequent machining of the workpiece will be concentric with the bore.

The parallel mandrel however benefits from having a much more secure hold of the workpiece, particularly important if large diameters are being machined or intermittent cuts are taking place, as in the example that follows. Access to the sides of the part is limited though, due to the mandrel on one side and the securing screw on the other.

With the taper mandrel, the grip may be less secure and if working with intermittent cuts being taken, or at large diameters, these will have to be very light. It does though have the advantage that both sides of the workpiece are fully available for machining. However, care will have to be taken if machining on the chuck side as the pressure on the workpiece will be attempting to force it off the mandrel.

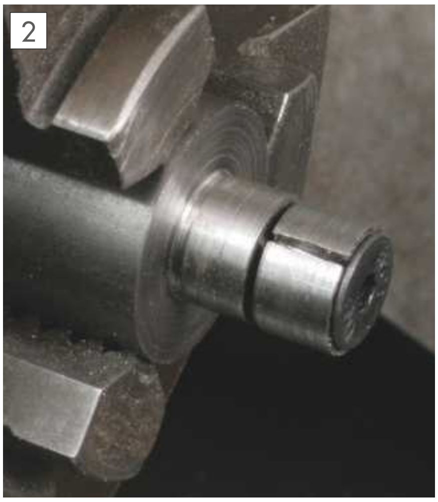
As will be seen, the modified parallel mandrel in this article overcomes the problem of machining the sides, though it may be required to remove the part and refit the other way round to machine the second side, depending on the amount of machining required.

See **ref. 1** for more details regarding using stub mandrels should their use be a new subject to you.

How the idea came about

I was in the process of making a Stuart Half Beam Engine and machining the two Main Bearing to support the Crankshaft, the material for which was supplied as two pieces cut from a brass extrusion. This, providing part of the eventual shape. The first task was therefore to machine the bore and one side which included producing a boss. Being an irregular shape the only options for most will be to hold this in the four jaw or mount it onto the faceplate. I would myself use the faceplate, but that is beyond the purpose of this article. (Neil, I remember that you mentioned an interest in articles that showed workshop setups. If you would like a very brief item on using the faceplate for the purpose do let me know and I will machine the second bearing using the method. No hurry as I am unlikely to resume progress on the engine before the autumn.)

The initial machining of the bearing block with the part held in my alternative to a Four Jaw Chuck.



The Parallel Stub Mandrel with separate expanding part for gripping the inside of the workpiece's bore.

I chose to use my alternative to a four jaw chuck (**ref. 2**) as one jaw would provide a much more accurate surface for the base to locate on being much wider than a conventional four jaw chuck jaw. The benefit being that it would then be much easier to get the bore parallel to the base, also the second bore in the same place as the first when machining it. This ensuring that the bore would be at the same height in both bearings.

Photograph 1 shows the arrangement with the first side and bore already machined. It can be seen that two jaws have a blue mark on them, the purpose of which is to remind me that these are not to be moved, the two unmarked ones being used for removing and fitting the second bearing. This should ensure that the second bearing would be placed identically, to an acceptable degree of precision at least.

As the bore was now parallel to the base, machining the second side was much less critical, in fact, only critical from a visual point of view. With the body of the bearing block requiring to be only $\frac{3}{8}$ inch wide, and needing to give a little to avoid the cutter contacting the chuck jaws, only about $\frac{5}{16}$ inch would be in contact with the jaw. I was not confident therefore that the bearing would not reliably sit accurately on the two fixed jaws resulting in the two sides not being parallel. The error then may even be sufficient for it to be visually apparent and decided therefore to mount it onto a parallel stub mandrel.

The problem with the approach then being that it would be impossible to machine the outer face of the boss which needed quite a lot removed. This, as the original piece of extruded brass was unnecessarily long. My first thought was to make a taper stub mandrel for holding the part, followed by, could I make the end of a parallel mandrel expand to grip the inside of the bearings bore? Whilst this would work I would need to remove the mandrel for adding some slots to give the flexibility required, as a result, loosing the high degree of concentricity present if made and used whilst still in the chuck. It was with the idea still uppermost in my mind that I came up with the idea for making the expanding portion separate from the main part of the mandrel.

The idea is shown in **fig 1** and the finished mandrel in **photo 2**.

Making the Mandrel

The process starts with making a conventional parallel mandrel roughly as long as the workpiece and drilling a tapping size hole for the eventual securing screw to be used. Follow this by opening up with a clearance size hole, say 8mm deep and countersink the end to take the head of the countersunk screw being used. Finally, on the lathe, part off a piece 8mm long. Of course, I have only used 8mm to simplify the explanation, the length would

The Parallel Stub Mandrel being used conventionally, that is with a securing screw on the end.

be chosen to suit the task in hand, could be longer of even shorter, perhaps only 3mm for a narrow workpiece.

The part can now be slit, once fully to the centre hole and at three other places part way to the hole, as the drawing for part B shows. No need to make a posh job of it, just hold it in the bench vice and use a hack saw for the task.

Finalising the bearing block

I then used the mandrel, without the expanding piece to carry out most of the machining on the second side (**photo 3**) and then, with the expanding piece in use, reduced the length of the boss as seen in **photo 4**.

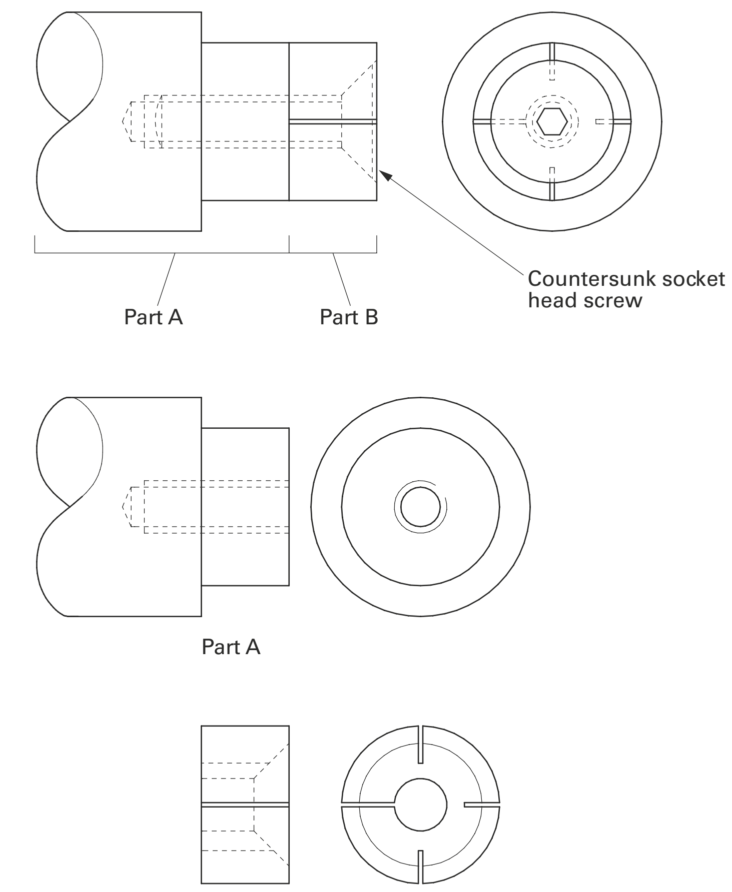
Before starting the machining process I applied a moderate turning force to the workpiece by hand without it moving and decided therefore that it was more than adequate for the task in hand. Possibly, though I cannot be sure, it may even have coped with the intermittent cuts for fully machining the part.

To increase the grip the part could have just been centre drilled and used with a socket cap screw with the head machined to match the centre drill angle. I think then, the 60 degree internal angle, compared to 90 degree for the countersunk screw, would definitely have coped with machining the face completely.

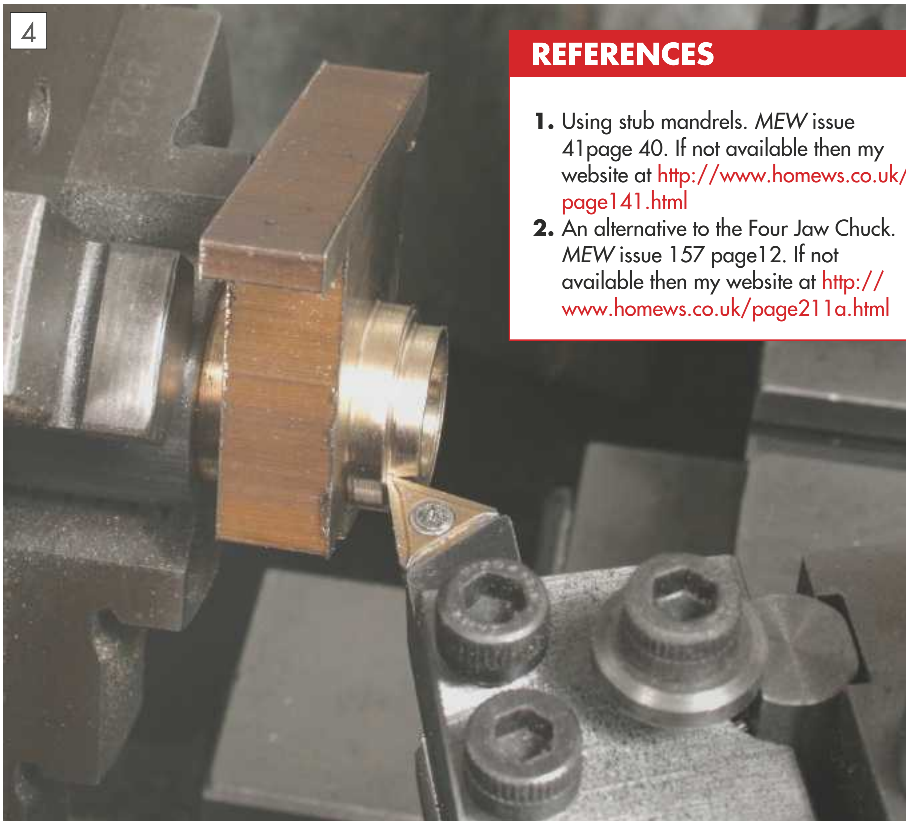
Incidentally, I mentioned earlier that I was concerned that the two sides of the bearing would not likely be parallel if other methods were attempted and was very pleased with results I found with the method used. Across the long width of the base the difference in thickness was just 0.001 inch with the top of the bearing being just a little less accurate with a difference between the base and the top of 0.0025 inch.

I cannot recall having seen the idea published in any way before so perhaps the idea is unique. However, most methods have been tried at some time so if that is the case perhaps someone will enlighten me. Even so, I am sure there are many for whom the method is new and will benefit from this short article. ■

Fig. 1



Parallel Stub Mandrel With A Difference



The Parallel Stub Mandrel being used with the additional expanding portion enabling the end of the bearing block to be fully machined.

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1. Using stub mandrels. *MEW* issue 41page 40. If not available then my website at http://www.homews.co.uk/page141.html
2. An alternative to the Four Jaw Chuck. *MEW* issue 157 page12. If not available then my website at http://www.homews.co.uk/page211a.html

Three Jaw Chuck Mount

What to do to fit an unusual 3-jaw chuck to a watchmaker's lathe with a non-standard taper? Henry Hicks found a way.

Due to the break-up and sale of a friend's workshop I was able to purchase a miniature 3 jaw chuck. **Photographs 1** and **2**. The lathe I wish to use it on is a 6mm watchmaker's lathe, made in Germany with an unreadable name. The chuck has the name Wolf Jahn.

The chuck works, it's a little stiff, but has no mount to attach it to the headstock. However, there are three tapped holes which are there for just such a purpose. These holes are obviously set at some PCD allowing a mount to be made and screwed to the chuck back plate. Clearly some method of measuring the PCD of these holes is required. I started with three silver steel screwed plugs, oddly enough 5 BA, which fitted nicely in the holes and left an unthreaded section proud of the backplate (**photo 3**).

The distance between the plugs was then measured using a vernier gauge as in **photo 4** giving a distance of **0.71** inches. If we now subtract the diameter of one plug, **0.125**, from this reading we will have the distance between the centres of the plugs, giving **0.586**. Armed with this information we can draw an isosceles triangle of side equal to this distance.

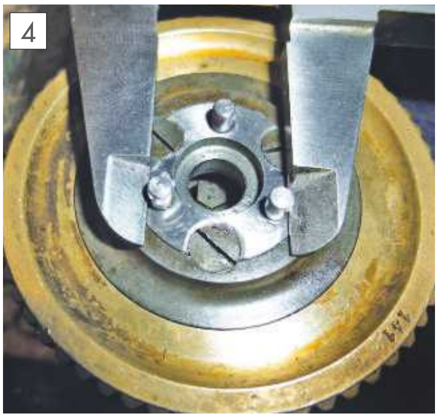
There are now two ways we can proceed. The first is to use a drawing package and draw this triangle. Start with one line of length equal to the distance found above. Now add on to the end of this line another line which is at 120° to it. Then draw the third line of the same length and at an angle of 120° to the second. This third line should, of course, close the triangle (**fig. 1**). Finally draw the circle which joins the three points together (**fig. 2**). Measure the diameter of this circle, and this is the PCD of the holes, namely **0.677** inches.

The second method is to use old-fashioned trigonometry. First draw an isoscles triangle to represent the real one. This triangle has angles labelled **A**, **B** and **C**. Now draw the circle linking the three points as in **fig. 3**. Now draw a line from one of the triangle's apeces (plural of apex) through the middle of the line opposite (point **D**) as far as the circle (**fig. 4**). Finally draw a line from the apex to the

The neat miniature chuck.

Mounting face of the chuck.

Silver steel plugs in the mounting holes.



Measuring across the plugs.

Fig. 1

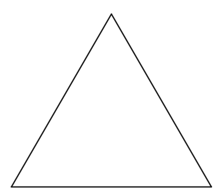


Fig. 2

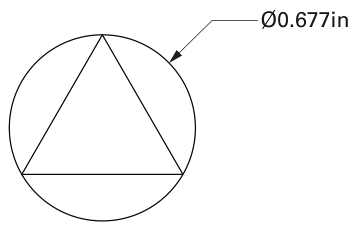


Fig. 3

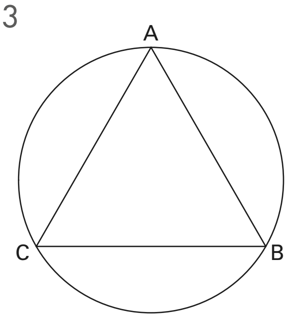


Fig. 4

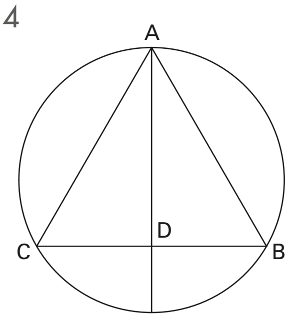


Fig. 5

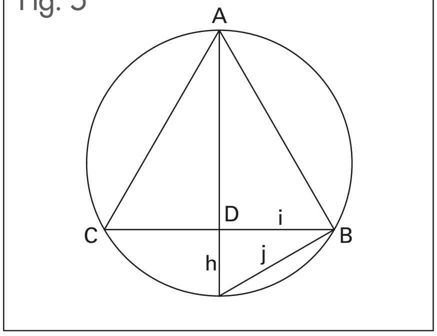
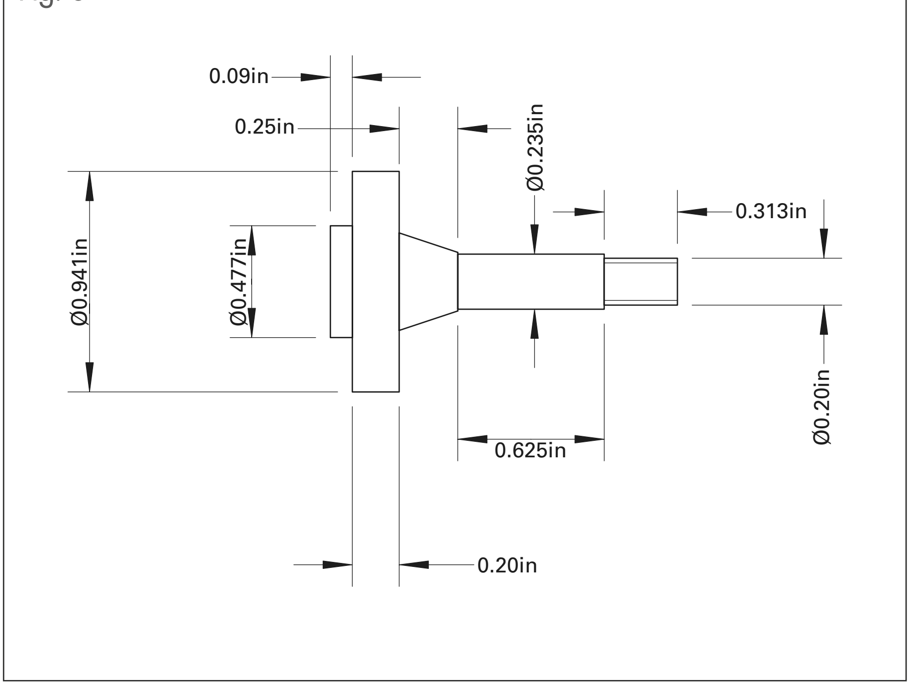


Fig. 6



right of this line, (**B**), to the point where the diameter hits the circle (**fig. 5**).

Since the triangle is isosceles, all sides same length, the three angles formed must all be the same, namely **60º**. Consider the triangle labelled **hij** in fig. 5. This has half of one side of the original triangle as side i, a bit of the diameter as side **h** and the hypotenuse as side **j**. This has to be a right-angled triangle because the diameter we drew from the apex goes through the middle of the line forming the original triangle. Therefore we can say

Tan(30) = h/i.

We know this angle must be **30º** because any two lines joining the ends of a diameter and a point on the circumference of a circle always form a right angle, **90º**. And the angle **CBA** is 60º since it is part of the original triangle and **90 – 60 = 30**.

From 4-figure tables or from your calculator **Tan(30)** is **0.5774**, and we know **i** is **0.586/2** or **0.293**. Therefore

h = i*Tan (30) or = 0.169

Now consider the triangle **ABD**. This is another right-angled triangle, the right-angle being at point **D**. We know the length of i and the length of the side **AB**. We can calculate the length of the line **AD** because it is the third line of the triangle. Thus :

$i2 + AD^2 = AB^2$

and the only bit we do not know is AD. Putting in the numbers we know gives:

0.2932 + AD2 = 0.5862

or

$0.0858 + AD^2 = 0.343$

and hence

$AD^2 = 0.257$

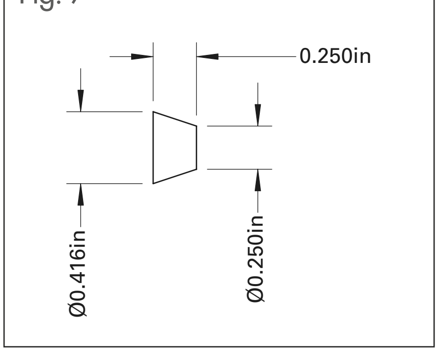
and finally

AD = 0.507

To this figure we must add the line **h** (**0.169** from above) giving a total for the pitch circle diameter as **0.676** which agrees very closely with the value obtained painlessly using a drawing package.

As luck would have it, I already had a 3 jaw chuck of this size on a mount, but the mere fact of ownership did not give me any dimensions, but it did give me a mount to copy. I was able to measure all the diameters needed, the size and pitch of the thread at the rear and an example of the chamfer. The result is shown in **fig. 6** with the chamfer drawn separately in **fig. 7**. In order to machine this chamfer I

Fig. 7



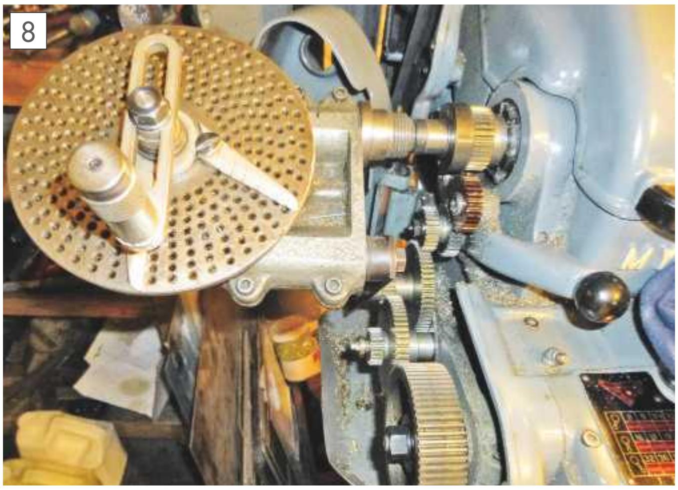
ground a tool to cut the necessary angle using the existing mount as a template, and this seemed to work very well.

To finally make the piece I first machined the 'tail', that is the 0.625 x 0.235 inch section and the bit on the end to take the 0.2x36 tpi thread. I do not have a die for this thread, so I machined it using a single point tool at 55º (**photo 5**). Since the thread was 36 tpi I decided to treat it as

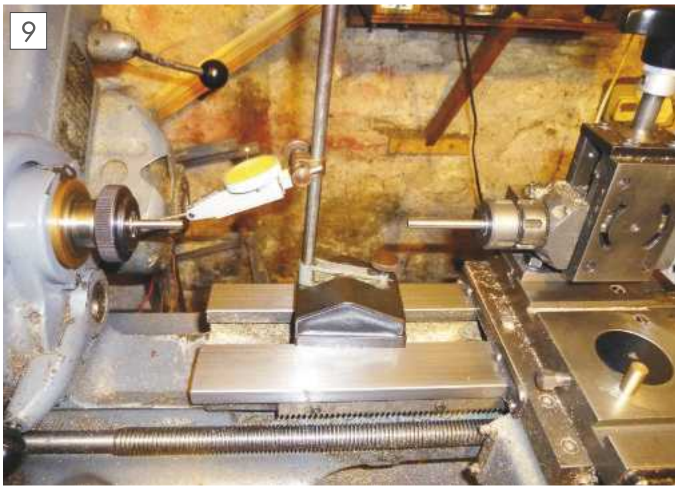
Threading the 'tail'.

Using a form tool to form the chamfer.

Drilling mounting holes, the small size of the backplate is apparent!



Dividing head on rear of spindle.



Procedure for setting the milling attachment at centre height.

Finished mounting arbour fitted to the chuck.

Imperial rather than metric and it is the case that the drawbar matches the thread very well. Note that I drilled the mount with a centre drill first so that I could use a running centre to prevent any distortion of the workpiece.

I then moved on to the chamfer, which was machined using the form tool ground as above (**photo 6**). Then the embryonic mount was parted off from the stock, reversed and held in a collet to finish off the front. Finally the three holes were drilled at a PCD of 0.676 (**photo 7**). This exercise is made easy by mounting the dividing head on the lathe headstock (**photo 8**) and setting it to divide by 3. **Photograph 9** shows how the milling attachment was set to lathe centre height. A ¼ inch ground blank is mounted in the lathe headstock and another in the milling attachment collet. The height of the milling machine blank was set to the same height as the headstock blank using the dial gauge. It was then set to lathe centre by adjusting the position of the mill until the blanks just touched and then advancing another ¼ inch. From this position the mill is advanced 0.676/2 inch to give a PCR of 0.338 inch. Now the blank is replaced by a centre drill, the headstock blank replace by the mount in a collet and the holes started. Each hole is drilled using the centre drill, the work rotated 20 turns of the dividing head, the next hole started, and so on. The centre drill is then removed and the holes drilled full size. They are then counter-bored on the drilling machine using a drill of appropriate size, the screws are made chamfered because I do not have a counter-bore of the right size. The finished result is shown in **photo 10**.

Note that there is a small groove machined in the 0.625x0.235 inch section into which a small stud fits to stop the mount rotating relative to the headstock. This was machined using a small slitting saw held in the milling attachment.

This sort of task would be very much more difficult without a milling attachment of some kind. Also a mount which allows the attachment to be set up with its axis coincident with that of the lathe. This is illustrated in photo 9. A second method of mounting it is to treat it as a tool to me mounted in the quick set tool holder where it can be used to mill gears, drill cross holes and mill grooves parallel to the lathe's centre line. ■

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