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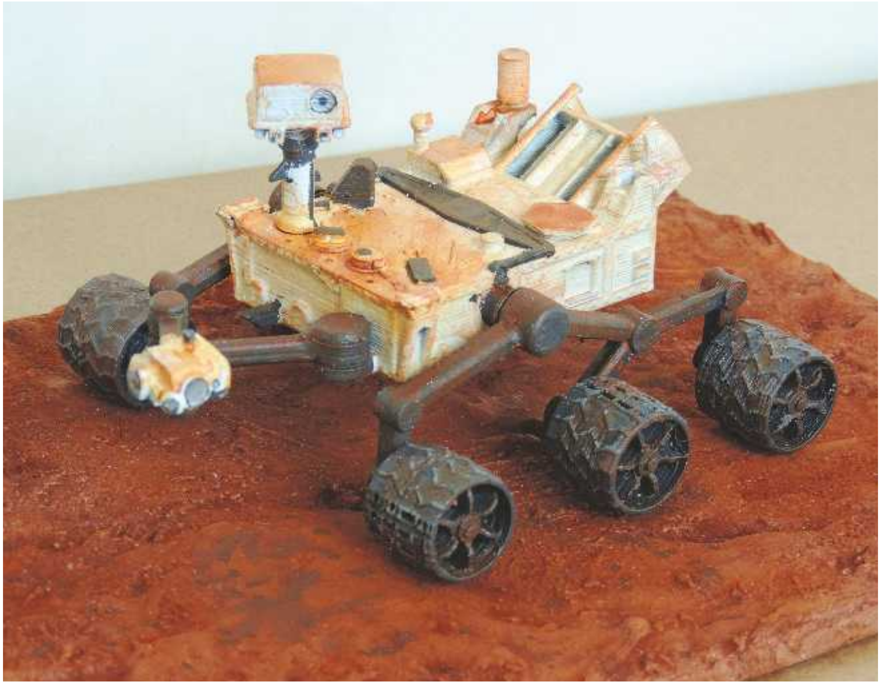
print & digital media publishers

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



Adventures in 3D printing

Following my experiences with the Dremel 3D40 printer, I was in no doubt whatsoever that a 3D printer of my own belonged in my workshop. I had been offered a generous discount on the review machine, but though I was very impressed by it I wanted something with the capability of printing in a wider range of materials. Also, like many readers I thought why buy one ready made when I can make one! That said, I chose a Prusa i3 kit from Factory3D, a Tyneside-based company, rather than gamble on one of the cheaper kits direct from China. This meant I benefited for a design which incorporated an aluminium frame, uprated stepper motors and an improved 'hot end' – and a very good build manual. I was also able to get support by email which helped me get the printer set up and printing excellent prints very quickly, and I also know where I can get spares and upgrades quickly and at reasonable cost. In many ways, the same benefits you get when you buy workshop machines and tooling from a reputable supplier.

It took me about ten hours to get the printer together, then the frustration of one of the stepper boards being u/s, so I had to wait for a replacement. It took less than a day of experimentation to get good prints. I had to ignore most of the changes I had made to software settings and revert to the defaults, as most of my 'issues' turned out to be not having set the print nozzle close enough to the bed.

Now I have the printer 'dialled in', I am getting prints which are the equal of those from the ready-made printer, and I am looking forward to experimenting with some other materials, especially flexible filament for tyres and similar parts.

Most of my prints have been parts and items I have designed myself, but for a bit of fun I printed out a model of the Curiosity Mars Rover – one of a large collection of models, from radio-telescopes and spacecraft to asteroids and lunar terrain, that can be downloaded from the NASA website. The photo shows a 'simplified' version, on a bit of Martian terrain and liberally weathered with Mars dust.

Neil Wyatt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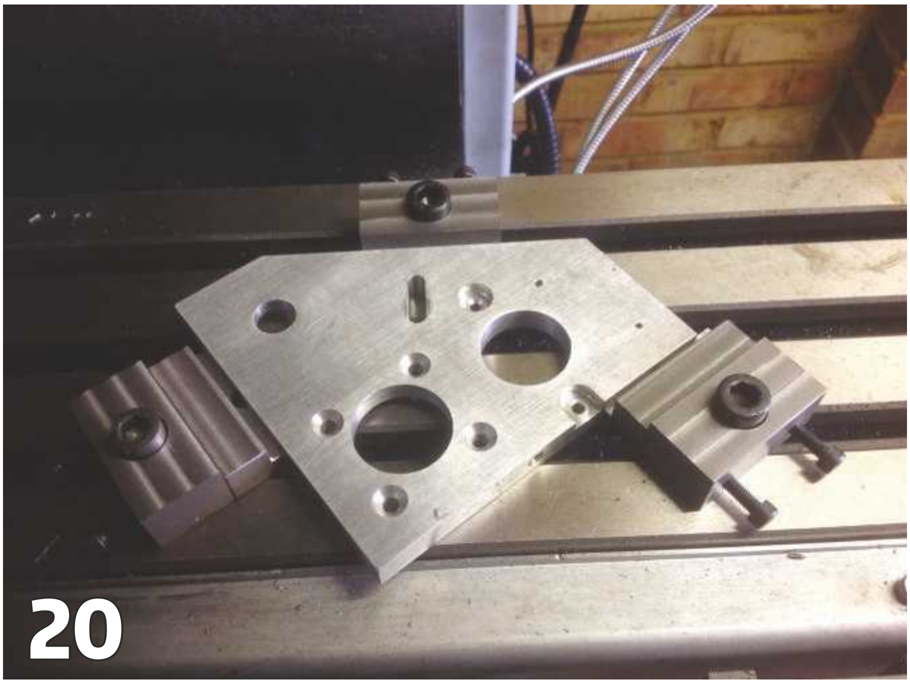
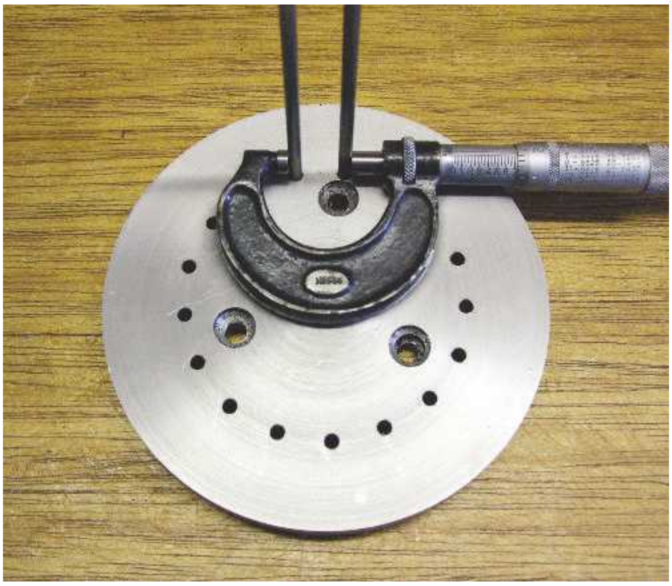


See page 32 for details.

Coming up...

in the July issue

Coming up in our next issue, MEW 256 will be another rewarding read.



Regulars

ON THE COVER »»

This month's cover shows David Graves' 'up and over' ball-turning technique, as featured on page 48, in a must-read article for anyone contemplating building a Quorn grinder!

HOME FEATURES WORKSHOP EVENTS FORUMS ALBUMS

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THIS MONTH'S BONUS CONTENT

You can also visit our website for extra content and join in our online forum

SillyOldDuffer's Arduino Dynamometer Code

Launch your favourite browser and enter www.model-engineer.co.uk/dynamometer in the address bar to download the source code for SillyOldDuffer's Torsion Dynamometer. Then pay a visit to the forum at http://www.model-engineer.co.uk/forums/latest_posts.asp to join in what promises to be an interesting discussion of the project.

Come and join the forum and let us know what you've been making in your workshop!

Can a low-pressure boiler be soft-soldered
- Would you use a soft-soldered boiler?

Making a Small Plastic Fan
- The challenge – restore a 1970s Black and Decker drill. The solution – might be a surprise!

P-Power Hacksaw
- A fascinating project to build a 3D printed power hacksaw, using a car windscreen wiper motor.

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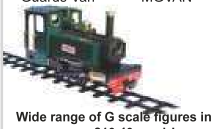

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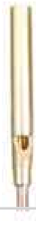

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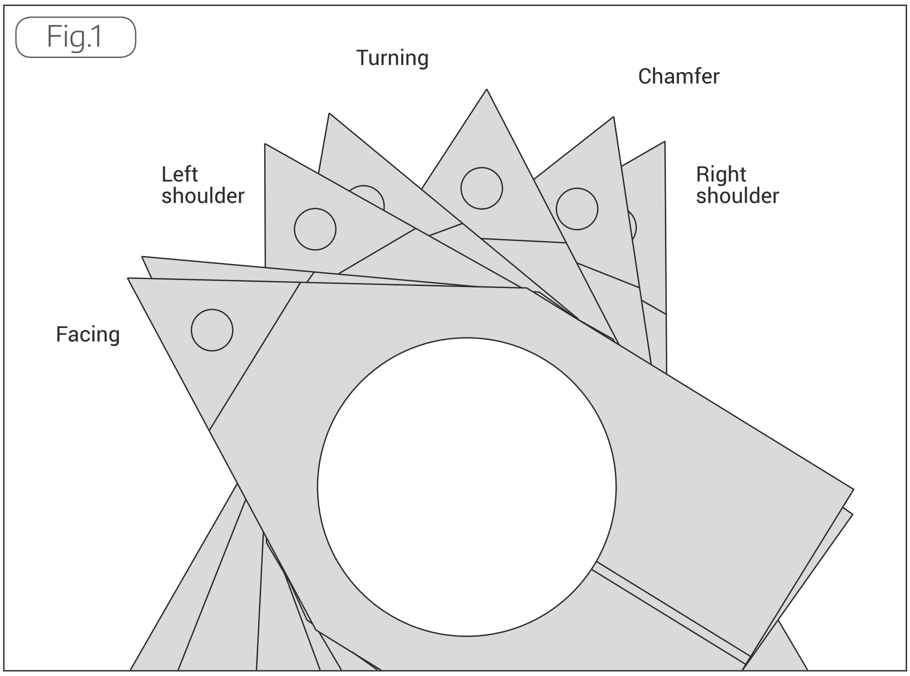
Prototype Tooling Manufacture

Richard Smith's tooling system, featured in MEW 248, raised a great deal of interest among readers. In this article, he gives further details of making the tooling.

I have previously described my prototype tooling system which is based on carbide inserts. This article is about how I actually made it.

To recap, the starting point was I wondered if I could use just one insert in a single mounting to replace my 5 indexable toolset and 4 way toolpost. I sketched an insert mounted symmetrically on a holder rotating about a central hole. This arrangement gives all the five tool insert positions – and more. Tools are normally mounted so that the tips are close to the top left topslide corner, minimising the overhang and maximising the access to the work. Locating the pivot point close to this corner with only a small radius to the tip will do the same thing. The basic operations are all just a rotation away from each other – no tool changing, **fig 1**.



Carbide inserts are made to close tolerances and I wondered whether the insert holders could also be made to close tolerances and whether there was any real need to provide individual vertical adjustment. In the end, I felt this was going to be too demanding an approach – and I'd probably end up with packing! My next thought was to thread the hole in the holder and screw it onto a cylindrical pillar which in turn drops over a toolpost with some form of clamping. To lock the adjustment split the non-tip end of the carrier and provide a locking bolt. This seemed quite an attractive idea and the bigger the pillar diameter the better supported the holder would be. But this involved a lot of threading which needed to be a good fit. In the end, I decided to use a plain hole in the holder with a split end clamping to a cylindrical pillar – much easier to make and less critical. To clamp the pillar the simplest way would be to put a nut and washer on the toolpost – great for rigidity but hardly quick change with multiple turns! I realised that a quarter to one third turn on an M10 x 1.5 threaded post would be enough to go from loose to tightly clamped and the problem then becomes how to allow the unclamped pillar

Raw materials

Thicknessing plate

to be lifted off the post. The solution I came up with is to use a cylindrical nut that the pillar goes over, and to apply the clamping force with a removable bar (handle) through a crossdrilled hole in the nut which overlaps the top of the pillar on each side. To spread the load the bar has a flat machined on it and a washer is put on top of the pillar. If the same washer is used with each tool and the pillar height is kept the same the clamping position will also stay the same. To adjust the actual clamped position of the handle either adjust the washer thickness or make provision to rotate toolpost. The cylindrical nut, handle, and washer are the parts most likely to wear and are easy to make.

My lathe centre height is 37.5 mm above the top of the topslide and the usual tool shank height is 16 mm. The ground surface on the topslide is 76.8 mm wide and there is a central tee slot. This appears to be a common arrangement with this size of lathe. To get a pivot point (toolpost) where I wanted it I decided to mount an adaptor plate on the topslide and attach it using the tee slot, and then provide the new toolpost. Based on my sketches the pivot point would be 16 mm in from both top left corner edges, with a 30 mm diameter pillar centred on a 20 mm diameter locking nut. The actual insert tip was to be 40 mm from the pivot point. The 37.5 mm height available had to be divided between this base plate, a small adjustment clearance, and the insert carrier. I looked to see what materials I had around and found some rusty 20 mm thick steel and a piece of cast iron bar, **photo 1**. I decided on a nominal 19 mm thickness for the insert carrier (20 mm cleaned up), and 16 mm thickness for the base plate.

I started by turning from the cast iron bar two 25 mm high by 30 mm diameter pillars with 20 mm diameter bores, plus a matching 5 mm thick MS washer (from some other steel bar). To cleanup the material for the baseplate I drilled and tapped two M10 holes in opposite corners and bolted it to the faceplate using caphead screws that didn't reach the working surface. I had previously made stepped washers to use M10 capheads in the faceplate slots. Having cleaned up one side of the piece I reversed it and reduced it to 16 mm thick, **photo 2**. As the faceplate was on the lathe I decided to cleanup the material for the insert carrier using the same mounting technique, and bored a 30 mm diameter central hole using a pillar as a gauge. This was a bit wasteful but I was sure I'd find a use for the cutoff pieces, **photo 3**.

3

Preparing insert carrier

4

Sawing baseplate

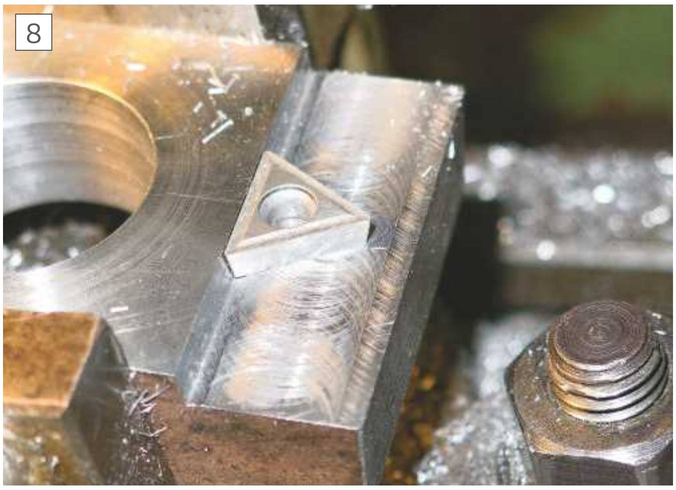
5

Trial fit of baseplate

6

Testing QR action

Setting a blank at an angle



Using an insert to gauge hole position

Facing with a cutter with only one insert fitted.

Back to the bandsaw!

The baseplate was sawn out of the thicknessed piece, **photo 4**, and the edges milled to size. The clamp piece to sit in the topslide tee slot was milled and drilled and tapped with a central M10 for the actual clamping and two loose M6 for two guides to align it. For the toolpost I used an M10 caphead in a counterbored hole in the bottom of the baseplate. To stop the head rotating I cross drilled for a brass plunger with an M8 screw behind it. To allow me to adjust the locked position I filed two flats on the M10 caphead (toolpost) to take an 8 mm spanner just above the baseplate. I found a piece of 1 inch stainless steel from which I turned and drilled the nut and then turned the handle and milled the flat on the end. I made sure the nut didn't cover the flats on the caphead when at the operating height, **photo 5**.

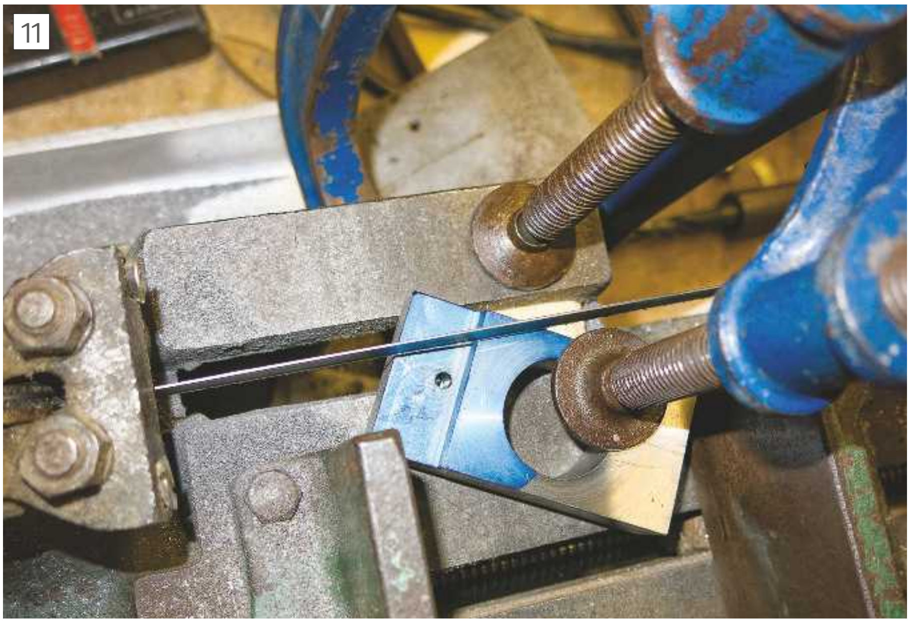
Now I could try out the quick release clamping action and see if it actually worked, **photo 6**!

About a quarter turn of the handle locks the pillar or releases it. Release, pull out the handle, lift off the washer and the pillar, change the pillar, drop on the washer, replace the handle and lock. Using the 8 mm spanner I adjusted the locking position and locked it with the M8 caphead. The pillar was really solid so it was worth carrying on and making an insert holder.

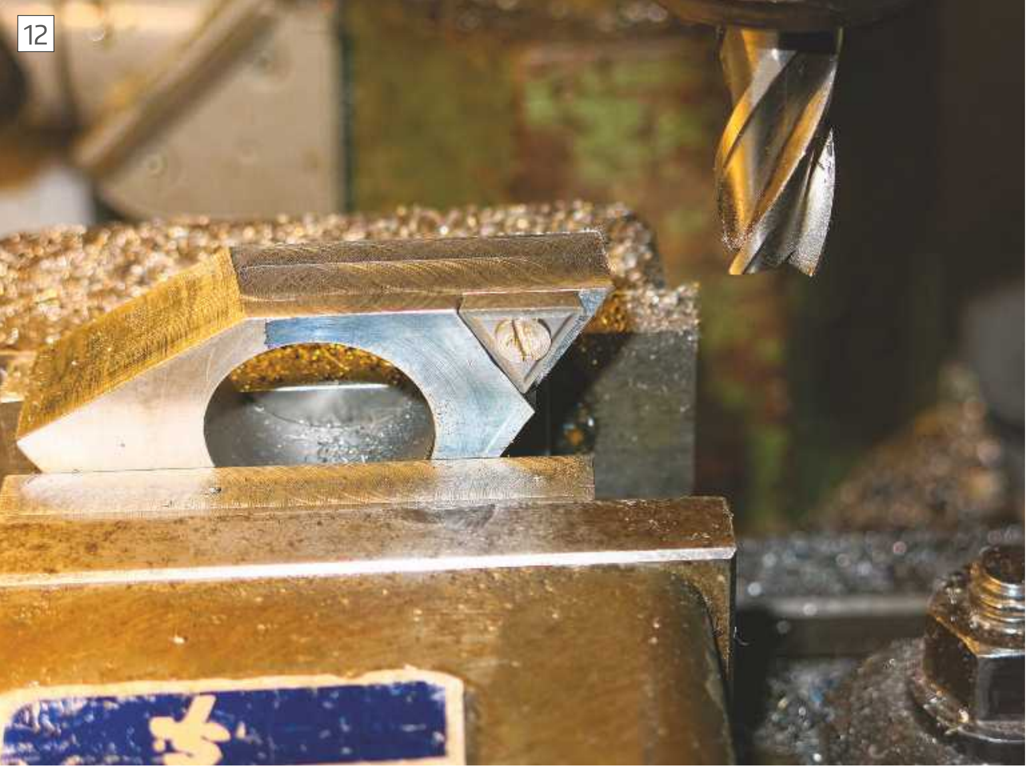
The first insert holder

I planned on a 40 mm radius from the centre of the hole to the tip so cut off one end to slightly over. I milled a step 5 mm deep to suit my existing inserts and then mounted in the vice at 7 degrees and cut the slope of the back edge to match the insert, **photo 7**. To make sure the insert would not foul on the corner I cut a little deep, **photo 8**. Incidentally, I looked for cutters with a 7-degree angle and you can get them – at a price.

Using the insert as a guide for position and biasing slightly towards the shoulder



Cutting the point angle



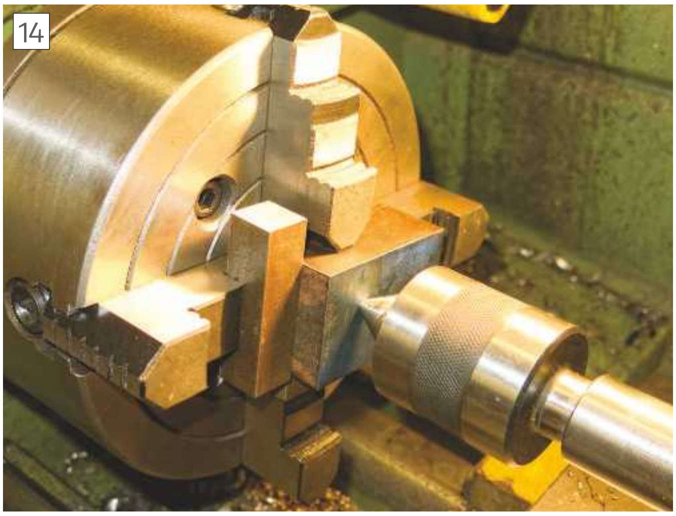
Cleaning up the cut edge

Ready for a trial cut

I drilled and tapped for the M4 Torx screw from my existing tooling. I made an error here and drilled oversize producing a useless but fortunately only shallow thread. I was able to drill deeper with the right size and produce a good thread at the bottom. Now I hadn't got a long enough Torx screw and wound up using a chromed brass screw as it was the only countersunk headed M4 I could find. I was worried whether it would be strong enough but in fact rather to my surprise it works fine.

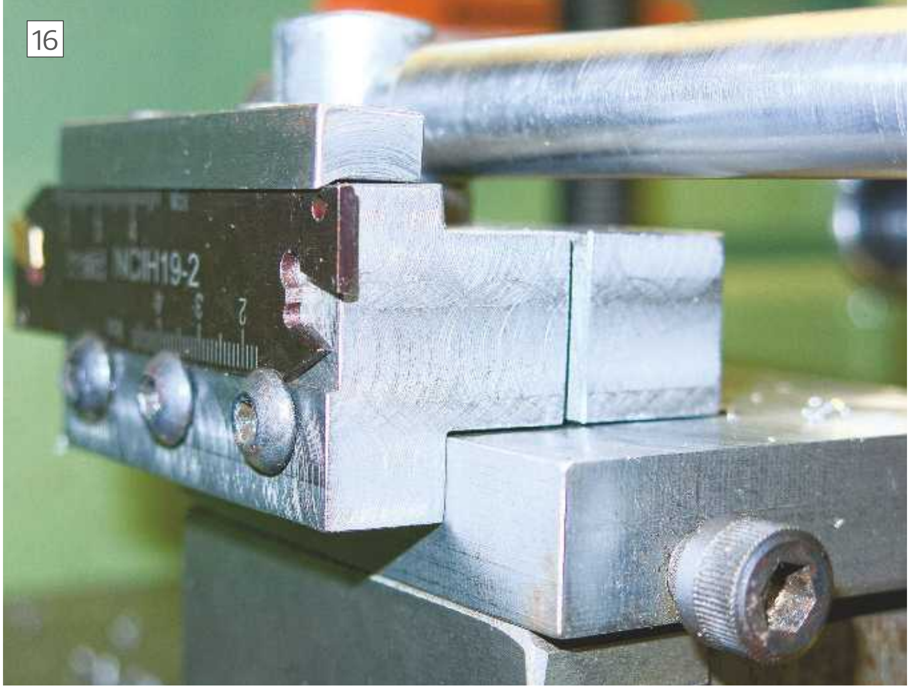
I then sawed the surplus metal off the other end. The sides of the insert end are also inclined at 7 degrees and I decided to use two wedges in the vice to set this angle between the jaws, and then I could set the point angle along the direction of the vice jaws. An immediate use for one of the offcuts! Machined it to a 7 degree wedge using an old face cutter with just one insert as a fly cutter, **photo 9**, and cut it in half, **photo 10**. The width of the holder was reduced from the original 50 mm to 40 mm symmetrically about the centre hole by sawing and machining. Next I marked the pointed end and sawed most of the waste off, **photo 11**. The saw has been used a lot in this project. It was the second machine I ever bought – after hand sawing ONE piece of 50 x 50 BMS. Life is too short.

It could then be mounted in the vice with one wedge each side to tip it at 7 degrees forward. The point angle was set using the digital angle gauge on the machined surface and the sawn edge machined, **photo 12**. Repeated for the other sawn edge. I removed the insert for the final cuts! The other end was cleaned up and drilled and tapped and counterbored for an M10 caphead screw and finally a slot was sawn to provide a clamp. Then the carrier was put on a pillar and mounted on the lathe, **photo 13**. After fitting an insert, I set the tip to approximately centre height and faced a scrap of bar. Then reset the height to eliminate the pip. This is easy to do in practice. Incidentally, I have changed the insert since and have not had to change the height.



Blank for parting tool holder held in 4-jaw

Side view of parting holder



End view of parting holder

Parting off tool

The next carrier to make was for the parting-off tool. I started with an offcut of 50 x 50 (left over I think from the job that caused me to buy the saw) which I sawed down nearer the thickness and length I needed. This then had a centre hole drilled where I wanted the mounting hole to be and was mounted in the four-jaw chuck using the tailstock centre to locate it, **photo 14**.

I had been using a tool from Chronos and planned to use the insert carrying blade from it. The blade is held between a fixed and a clamping dovetail. I don't have a suitable dovetail cutter - how often there seems to be a problem for which I don't have the right thing and don't want to buy it! My solution was to use the Chronos tool top clamp piece, and to mill a step to a depth just less than the blade thickness and add three M6 button head screws overlapping the blade to act as sideways clamps. I subsequently bent both ends of the blade and have replaced it with one from Arc which is shown in the photos. **Photograph 15** shows the side view and **photo 16** shows the end view and you can see how the blade is held. Because of the depth of the blade it had to overhang the baseplate and I had to mill a step in the base of the tool to get the tip height in range. I positioned this step to align with the edge of the baseplate. If the baseplate edge is set (by rotating the topslide) at right angles to the lathe axis the parting tool can be set square simply by pushing the step against the edge before clamping. There is a little freedom with the clamping action.

Boring parting holder

This end mill was securely held.

Boring bar

The big problem with boring bars is vibration. The cutting edge is on the end of a bar whose diameter is limited by the size of the hole being bored. This in turn is clamped into a tool holder which has to have provision to adjust the height so that the cutting edge is on the centre height. Conventionally the bar or bar holder is clamped in a tool holder by two or three screws making point contacts onto packing – not exactly a vibration deadening arrangement. With a quick change toolholder the packing is eliminated but the toolholder is not directly clamped to the topslide but hangs off the central post relying on the clamping action and adding another potential source of vibration – the edge is further from solid support.

I could choose to position the boring bar either side of the clamp i.e. inwards towards the centre of the lathe and overhanging the topslide, or outwards and directly above the topslide and really well supported. It also occurred to me that if I clamped the block in position I could drill and ream it exactly at centre height so no height adjustment need be provided. The combination of a solid block (good for damping vibrations) and mounted over the topslide with the downward forces from the boring action being supported directly by the topslide seemed a good idea!

I have a 10 mm tipped boring bar from Chronos which is round with flats top and bottom. As no height adjustment is needed I needed a block the same height as the pillars (30 mm) so I sawed down the last of the 50 x 50 to about 35 thick. To be sure that the 20 mm dia. mounting hole was exactly at right angles to the base I decided to drill and bore then face the bottom before turning over and facing down to the 30 mm height. The mounting hole is near the top edge when viewed from the base so I centre drilled the location and used the centre in the tailstock to locate it against the chuck. To help balance the setup I included another piece of steel then drilled, bored, and faced it, **photo 17**. Then I sawed the surplus length and turned it over and faced it to height, **photo 18**.

To be continued

Making the Most of an Old Chuck

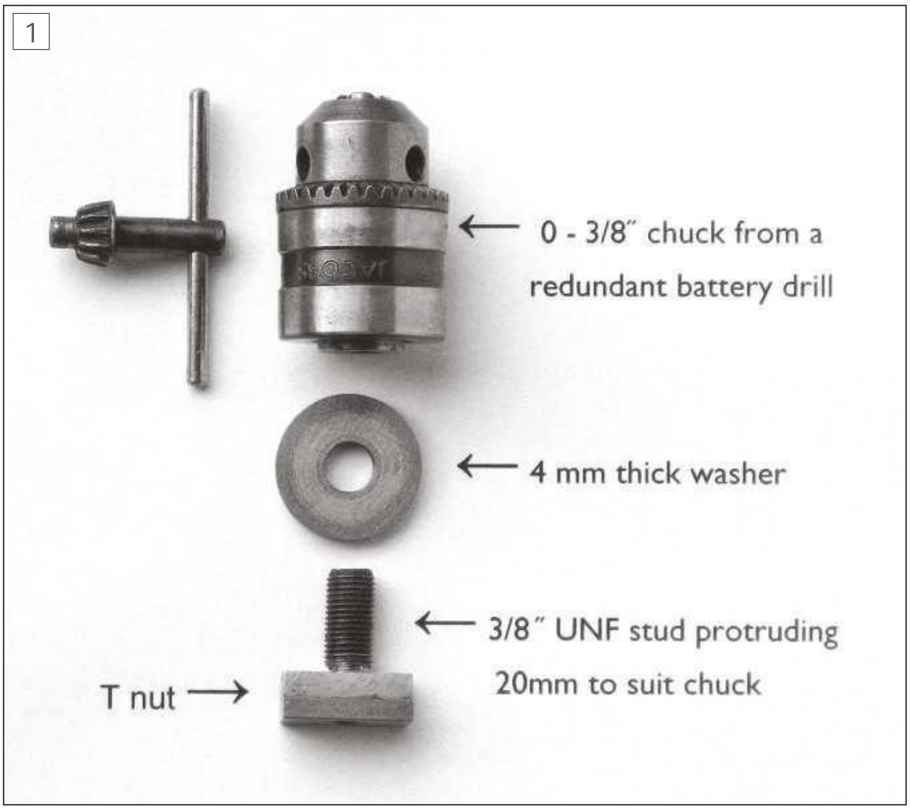
Eric Clarke finds redundant drill chuck makes a versatile dti base.

I have both standard size and mini type magnetic bases for supporting DTIs used on the lathe or other machines. They are not always very convenient to use however as they often take up space in the immediate work area and can sometimes be inadvertently displaced without this being apparent. This short article describes a simply made alternative to normal magnetic bases that takes up less space and cannot be accidently moved during use. It has the attraction of being very quick and cheap to make in fact I found most parts in my scrap box. It is also ideal for a beginner who may not yet have a magnetic base.

This article includes a mixture of imperial and metric measurements as some of the components Chuck and T nut have existing imperial threads, however where I have made new items normal metric dimensions have been used.

Making the drill chuck base.

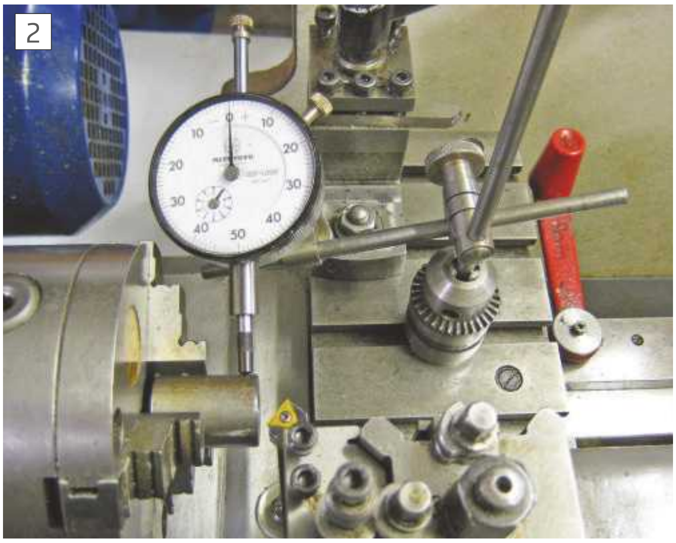
Searching for different means of support I hit on the notion of using a drill chuck mounted vertically on the lathe cross slide utilising one of the T slots. My scrap box yielded a very nice USA made Jacobs 0-3/8 capacity drill chuck salvaged from a first generation battery drill that I scrapped many years ago when its integral battery failed (the inescapable end for all battery drills). This chuck has a 3/8 x 24 UNF female thread which is pretty well standard on similar drill chucks



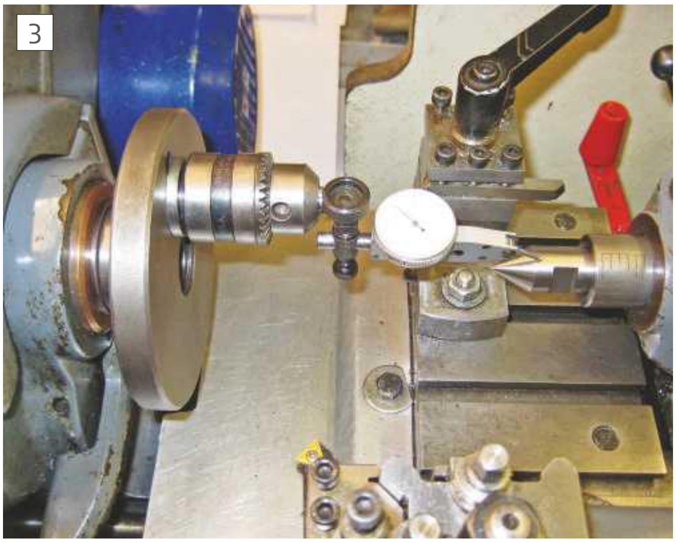
The components laid out.

- despite the UNF system being long out of general use in England.

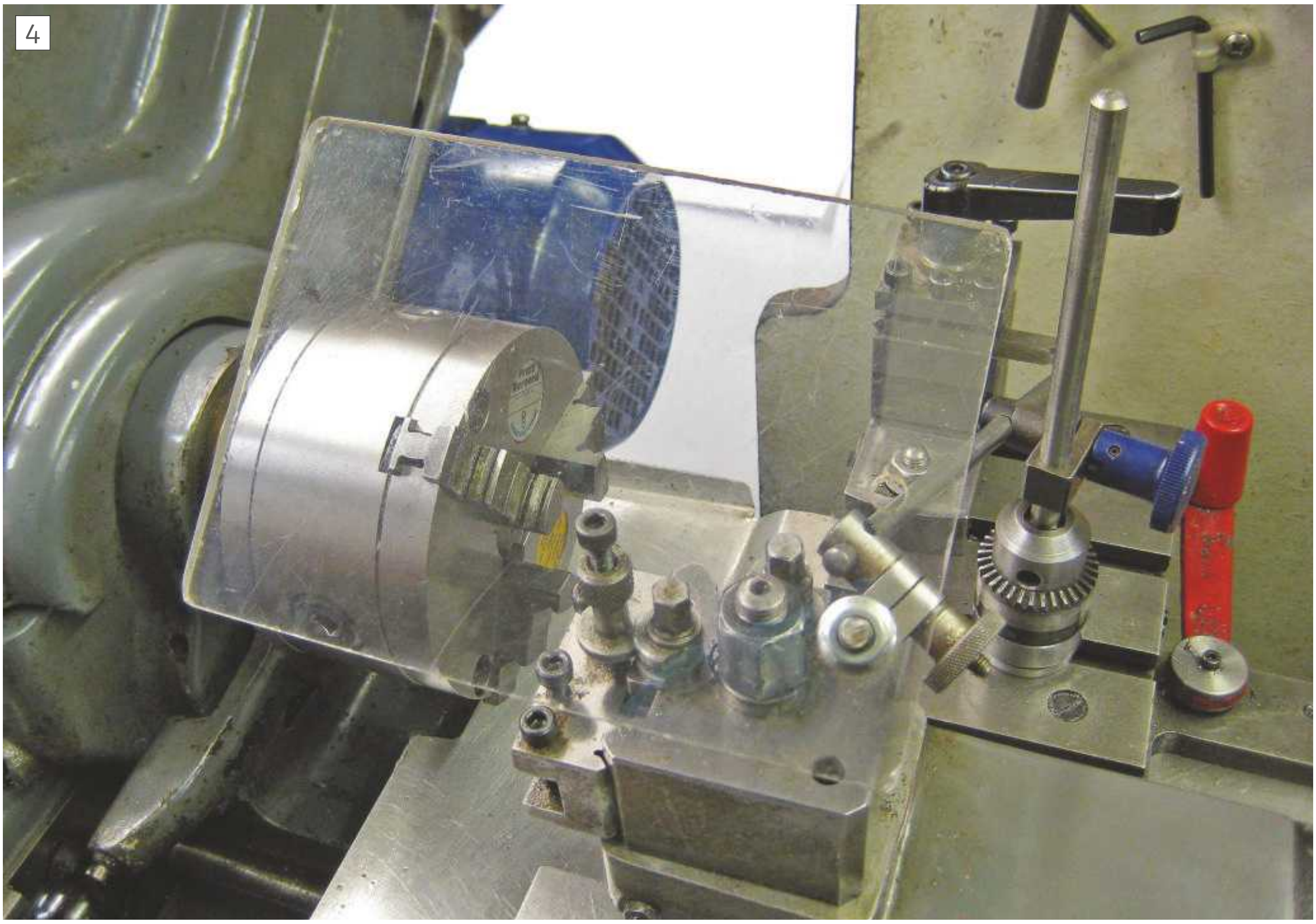
I had a few old 3/8 UNF bolts left from my 1970s vintage tractor days so one was made into a double ended stud with a short length of 5/16 BSW thread on one end



A typical application



Checking tailstock alignment



A small guard

to suit an existing Myford T nut leaving 20mm of 3/8 UNF thread for the chuck on the other end. (UNF screws are still freely available on eBay).

As the rear face of the drill chuck was only about 16mm diameter I made a 28mm diameter x 4mm thick washer to spread the clamping load over a wider area above the T slot so the chuck could be clamped down firmly without risk to the cast iron cross slide.

The chuck is easily and quickly mounted on the cross slide by engaging the T nut in its slot and turning the chuck by hand until it is as tight as possible finishing off with a final nip using the key to turn it a bit further. This provides a very firm support for vertical rods up to 8mm diameter, **photo 1**.

Photograph 2 shows the chuck and DTI firmly mounted on the cross slide of my Super 7

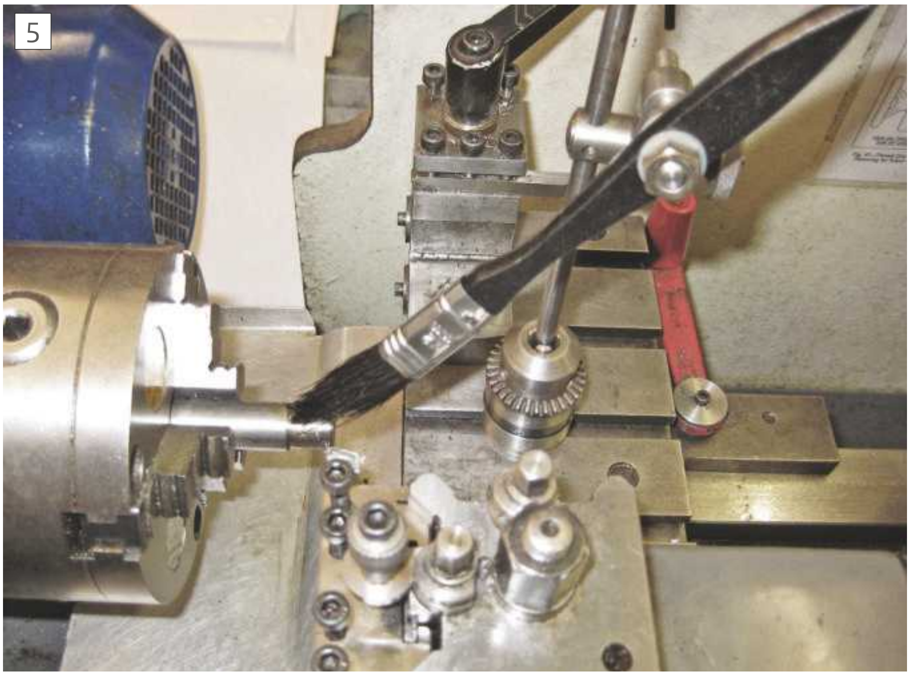
Photograph 3 shows the chuck mounted on the catch plate to check the alignment of the tailstock. A small mirror is needed to see the DTI when it is round the back. A small polycarbonate guard that can be positioned close to the work is in **photo 4**.

A small paintbrush can be used to apply cutting fluid such as Rocol to the work, **photo 5**. This has the benefit of using the minimum of fluid and the bristles of the brush follow the tool tip along.

The brush is a "use and throw" type from Tool Station that cost 23 pence each for ½" or 27 pence each for 1" sizes. They are not much use for painting as you might imagine at the price as they shed bristles easily but they are ideal for this application and for general machine cleaning.

I find this adapted drill chuck very useful, secure, easy and pleasant to use.

Although all the above applications could be achieved using a magnetic base the drill chuck base is much more user friendly and cost me virtually nothing to make! ■



Using a paintbrush to apply cutting fluid

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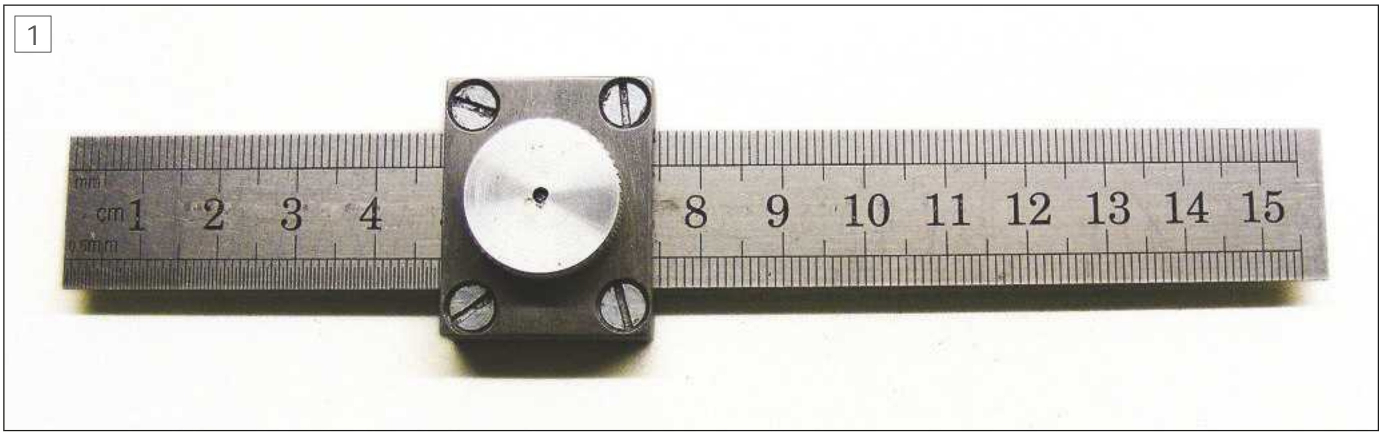
Mike's WORKSHOP

Making a Marking gauge

Mike Cox describes a handy accessory that makes an ideal beginner's project.



The Marking Gauge

Marking gauges are familiar items to woodworkers and they are used to scribe lines parallel to the edge of the work piece. Typically, they are used to mark out tenons. Similar gauges are not so common for marking metal. Metal workers tend to use Jenny callipers (also known as odd leg callipers) or a scribing block to mark lines parallel to the edge of a piece being worked on.

Jenny callipers can be quite tricky to use especially when marking out distances a long way from the edge. They are also time consuming to use because the callipers must first be set up by reference to a steel rule.

The tool described here is very simple to make and it converts a steel rule into a versatile marking gauge that can be used to accurately mark off distances from an edge and draw lines parallel to an edge. It is one of the most used tools in my workshop.

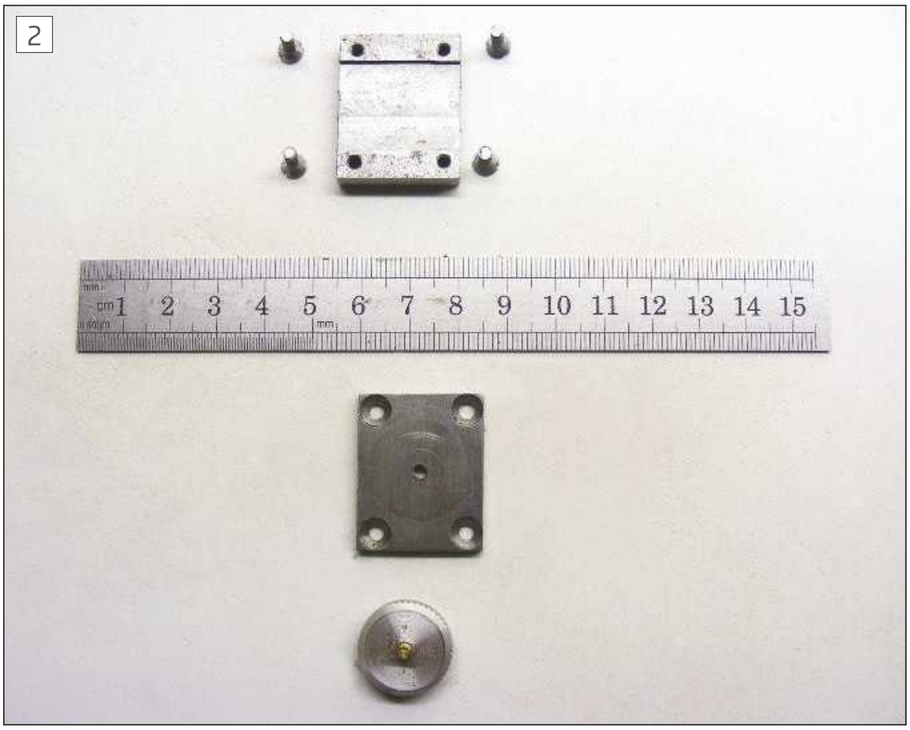
Photograph 1 shows the finished marking gauge. It consists of two components: a steel rule and slider that can be clamped at any point along the rule by turning the knurled knob at the centre of the rule. Thus the slider can be set at a distance along the rule and then the slider can be aligned with the edge of a work piece at that distance marked off. The point of a scriber can be held at the tip of the rule and the gauge then slid along the edge of the work piece to scribe a line parallel to and a set distance from an edge.

Construction.

The rule that I used for the gauge was 19 mm wide and 0.95 mm thick and the measurements shown on the drawing relate to this. However, it would be simple to modify the dimensions to suit other sizes of rule.

Photograph 2 shows the parts of the marking gauge. From top to bottom are the base plate, the rule, the cover plate and the knob

The base of the slider was made from a piece 6 x 25 mm steel. It was cut to a length



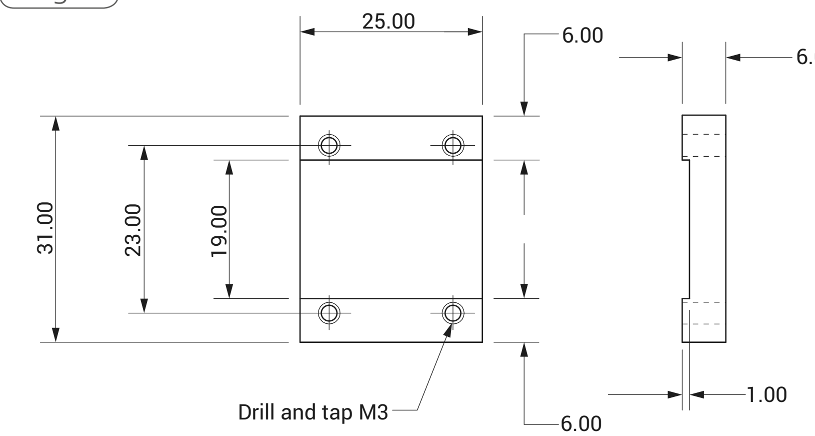
An 'exploded view'!

of 31 mm. This was mounted in the milling vice on parallels and a wide groove 1 mm deep 19 mm wide was cut centrally in the piece, **see fig. 1**.

If necessary enlarge the depth and width a little so that the rule will slide easily in the groove but with very little side play.

The cover plate was made from a piece of 3 x 25 mm steel 31 mm long. This was marked up for drilling the holes as shown in **fig. 2**. The hole positions were centre punched and the plate drilled with 2.5 mm holes at all positions. The holes were then carefully deburred. The top and bottom plate were then clamped together with a small toolmaker's clamp and the assembly clamped in the milling vice with the 31 mm edges parallel to the vice jaws. This ensures that the edge of the base plate and the cover plate are aligned. The corner holes in the cover plate were then spotted through to the base plate and drilled out 2.5 mm.

Fig.1

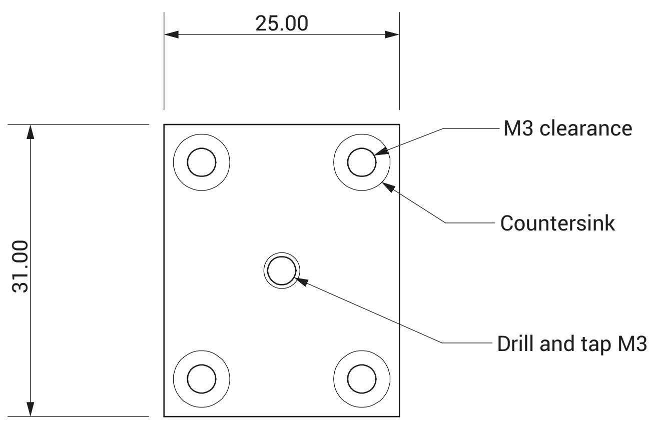


The Base

3

A closeup of the clamping knob

Fig.2



Cover Plate
Mat'l: 3 mm thick MS

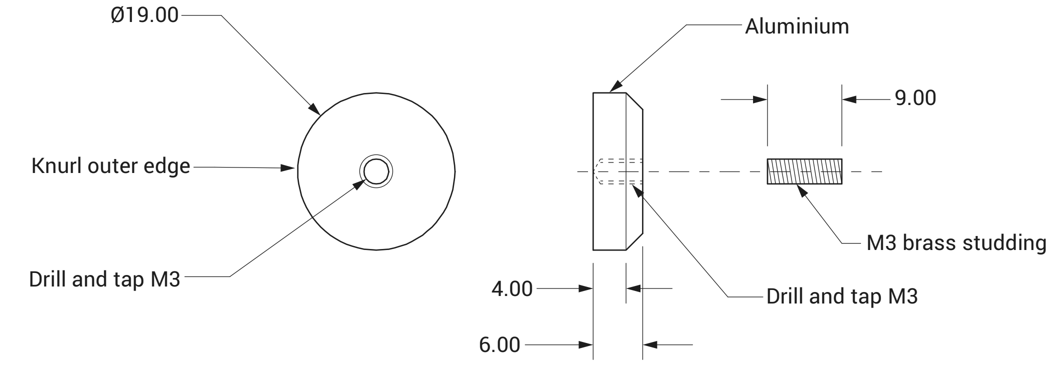
The assembly was dismantled and the corner holes in the base plate were tapped M3. The centre hole of the cover plate was also tapped M3. The corner holes in the cover were drilled out 3.5 mm and countersunk.

The slider was assembled using four countersink M3 screws. After assembly, the rule was slipped into the slider and checked to see that it moved freely. The cut ends on the assembly were cleaned up and all the corner and edges chamfered with a file.

The final part is to make the clamping screw. I made this from 19 mm round aluminium bar. The end was faced in the lathe and knurled for a distance of 7 mm. It was heavily chamfered, see **fig. 3**. It was drilled 1.5 mm for a depth of 7 mm and then 2.5 mm for a depth of 5 mm. Whilst in the lathe an M3 tap was started in the 2.5 mm hole. The knob with the tap was parted off at 6mm from the end. The 2.5 mm hole was tapped M3 to full depth and finished with a plug tap. The knob was degreased along with a length of M3 brass studding. The hole and end of the stud were smeared with epoxy adhesive and screwed together. Excess epoxy was cleaned off and the assembly chucked lightly in the lathe chuck by the 3 mm brass stud. Pressure was applied to the knob using the end of the tailstock chuck. Doing this ensures that the stud is accurately at right angles to the knob. Once the adhesive had set the pressure from the tailstock chuck was removed. The lathe chuck was tightened a little and the front face of the knob lightly skimmed with very fine cuts until flat. The final operation on the knob is to lightly chamfer the front face to remove any sharp knurling at the edge. The brass screw thread was cleaned up by running a M3 die along the stud.

The stud was cut off leaving about 5 mm protruding. The end of the protruding stud was cleaned up with a file and then the knob was screwed into the cover

Fig.3



Clamp Screw
Brass stud secured to the aluminium knob with epoxy adhesive

plate. **Photograph 3** shows the finished clamping knob.

Tightening the knob should clamp the rule in the slider. Check the gap between the knob and the cover plate and if necessary shorten the stud using a file.

Usage.

I find this very simple gauge extremely useful in the workshop. It is much quicker than using jenny callipers because the required distance is just measured off on the rule and clamped. It is also more accurate than jenny callipers because the rule is always maintained accurately at right angles to the edge of the work piece. ■

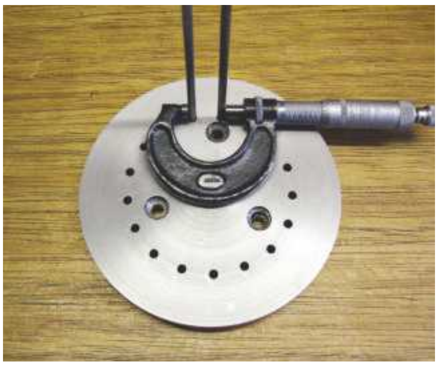
In our Next Issue

Coming up in issue 256
On Sale 16th June 2017

In the June issue, 256, of Model Engineers' Workshop, you can look forward to another great read:

Trevor Winter and his lovely Zyto Lathe.

David Addison fits DROs to his Warco mill.



Paul Murray makes custom division plates.

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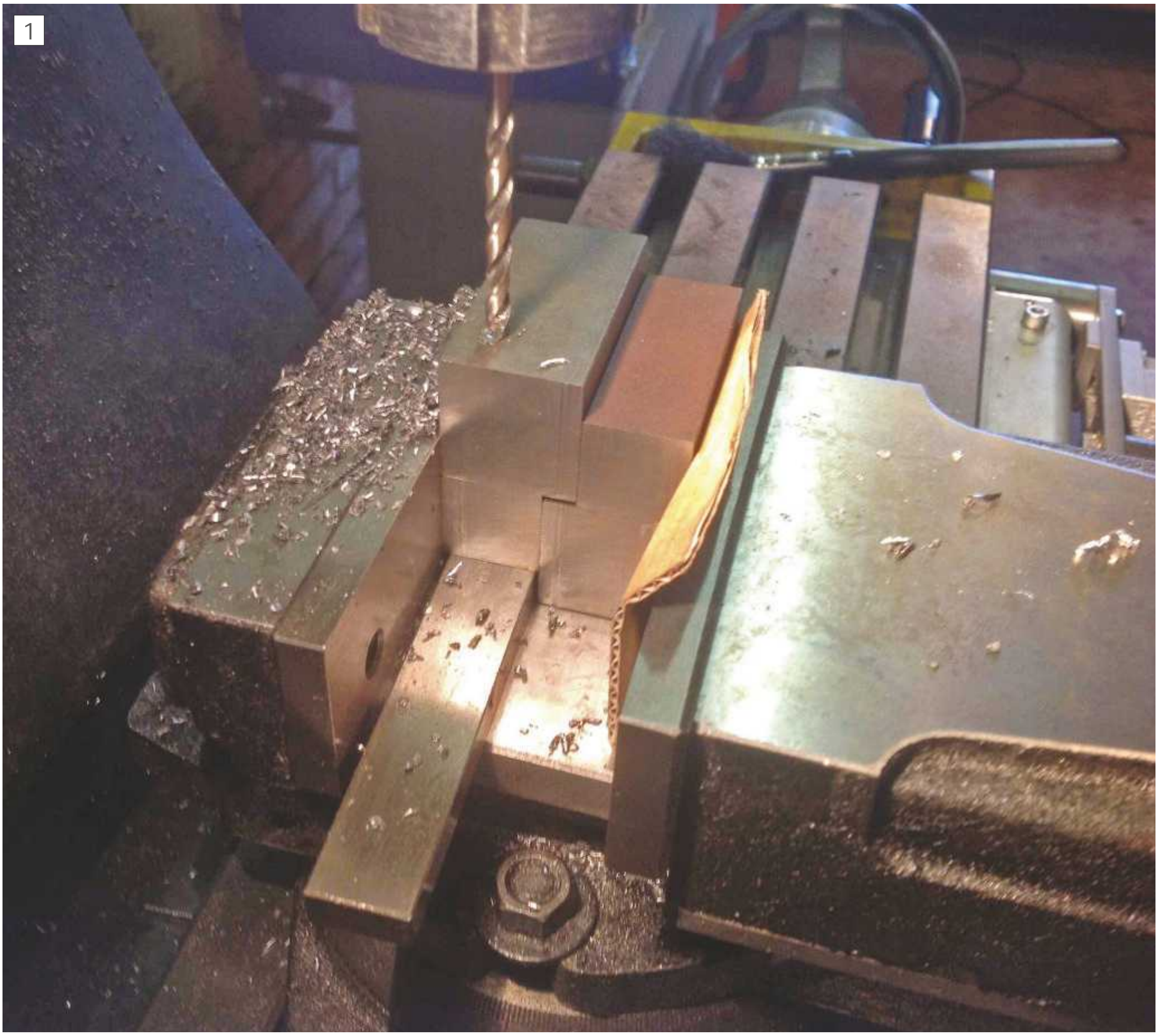
Low profile mill clamps

John Hinkley describes a project to help with machining thin work.



Setup for drilling the clamps.

This is a weekend project to construct a set of milling machine low profile clamps for use with material as thin as 5mm, as well as irregularly shaped objects. They can also be utilised as a longitudinal vice for small pieces where low cutting forces are involved.

The design was configured to use steel stock which I had in my scrap box, hence the use of 1x1" and ¾x¾" square material. (I have converted these sizes to the metric equivalents in the drawing as I normally work using that measurement system.) The actual dimensions are not in any way critical, although one should endeavour to keep the overall dimensions as small as possible, in order to achieve the tool's objective whilst maintaining its strength. As always, it is a matter of compromise.

First make the twelve dowels from 8mm diameter silver steel. A simple face - chamfer - part off - face to length - chamfer process. Then cut the 1 inch square and ¾ inch square mild steel into slightly over 50mm in length (to allow for cleaning up). Accurately shorten these in pairs to 500mm overall length. At this point, I stamped the pairs at one end with identification numbers in order that they could be kept as discrete pairs. The 'handed' sliding clamps are used with a single fixed clamp, so you will end up with four fixed clamps and eight sliding clamps altogether.

Using the method shown in **photo 1**, hold the respective pairs in the mill vice and align on end with the vice jaws (or adjustable stop, if you have such a device) to maintain position. Zero one end with a wiggler or end-finder and measure 10mm from one end, 7.5mm in from the edge which both pieces share. Spot drill and open the hole to 4.2mm (5mm tapping drill size) to a total depth of 35mm. Repeat the process with the other pairs and re-use each pair of fixed clamps with the second pair of handed sliding clamps to position the holes in the latter.

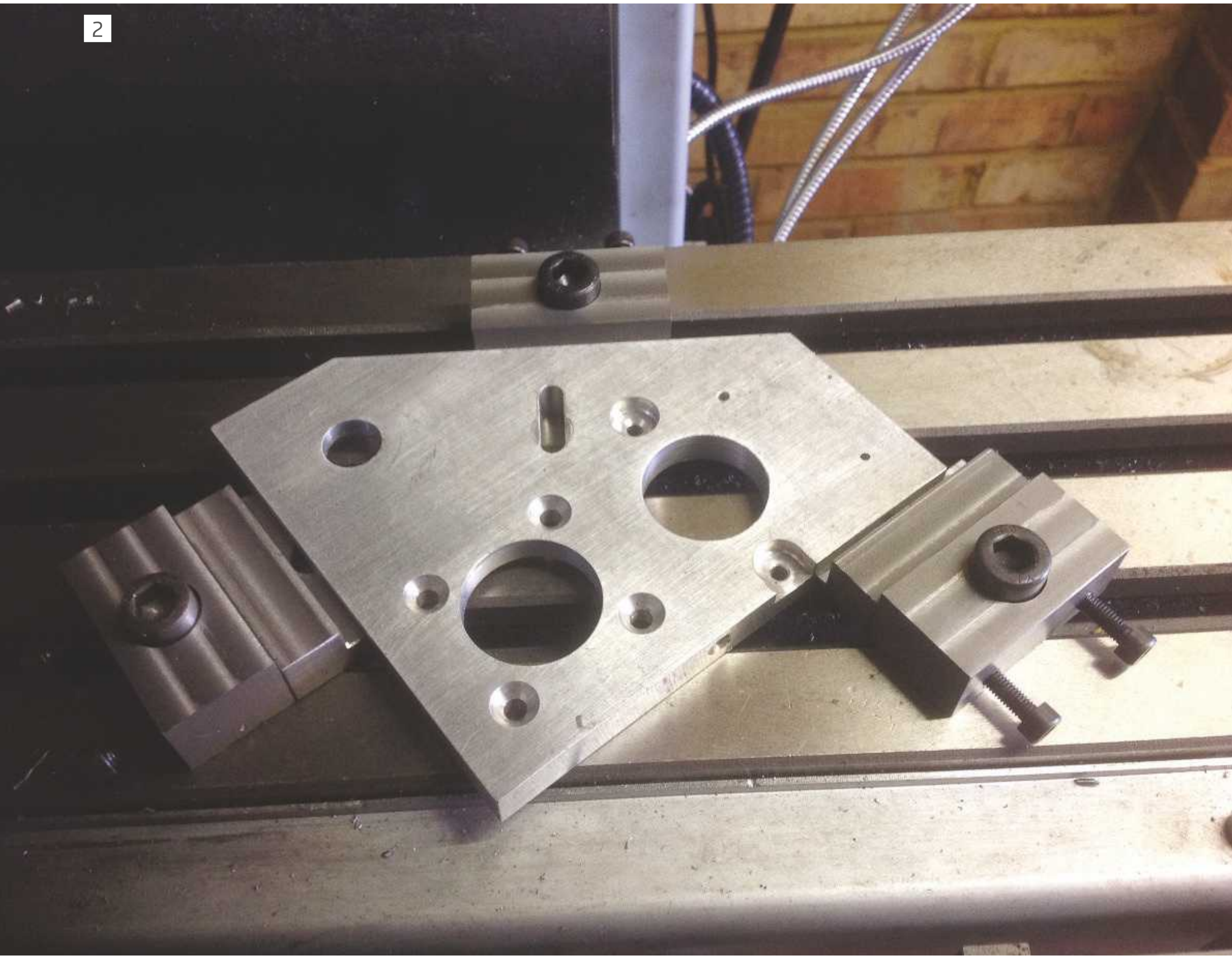
Next, clamp the individual sliding clamps in the mill vice and, without moving the Y-axis, align the drilled hole with the spindle. I used the 4.2mm drill and the DRO to achieve all the correct alignments required. Open out the holes to 8mm diameter and a depth of 10mm. I used firstly, a 7.5mm drill, then an 8mm diameter four-flute end mill to obtain to desired 10mm deep flat-bottomed hole. Repeat for all the other holes in the sliding clamps.

Attention now turns to the fixed clamps. Ensuring that you are machining from the correct side, align the clamps in the mill vice and open up the dowel holes to a depth of 15mm using the same method as used on the sliding clamps to maintain accuracy. This where earlier stamping numbers on the matching pairs pays dividends.

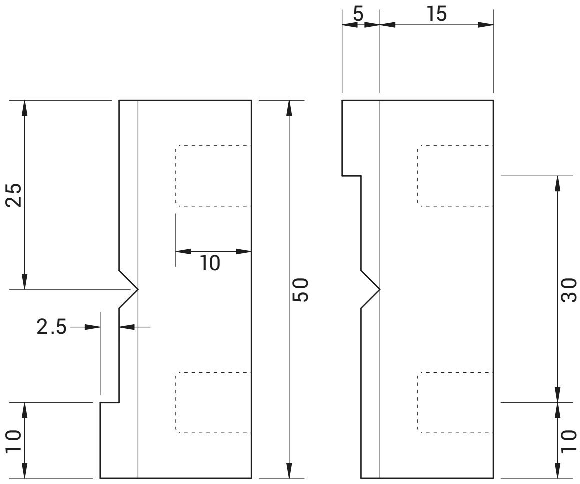
Fit the dowels to the sliding clamps and check that the matching fixed clamps close up completely to them. The dowels will eventually be fixed in the sliding clamps - I used Loctite.

Unless you are using material to the size shown in the drawings, reduce the height of the fixed clamps to 20mm and that of the sliding clamps to 15mm. Drill the 10mm fixing hole centrally in the fixed clamps and form the 16mm diameter recess for the bolt head to a depth of 5mm.

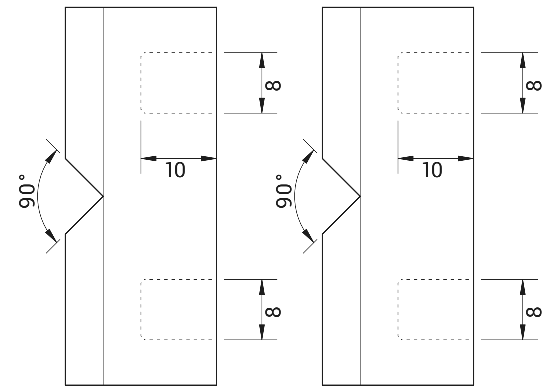
Turning our attention to the sliding clamps, mill away material to form the 4mm and 8mm steps in respective pairs. Turn through 90° and mill the relief to make the steps on the handed pair of sliding clamps as shown in the drawing. Finally, mill the 90° cut-outs in the clamping faces of each of the sliding clamps so that the point of the vee is in the middle of the slide. Fit the dowels and sliding clamps with Loctite or similar and allow to dry. Remove any excess adhesive and assemble the pairs to check the fit. A suggested use for the clamps are shown in **photo 2**. ■



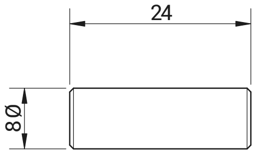
Clamping an irregular workpiece.



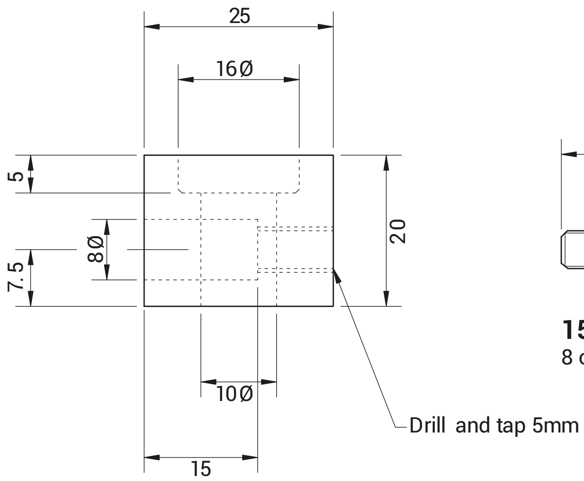
Anchor Slides
1 off each hand for each height

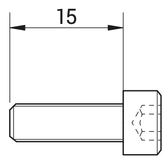


Clamping Slides
2 off each size

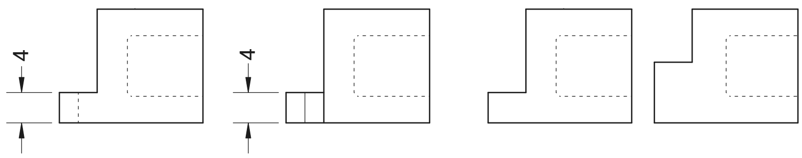


Dowels
16 off

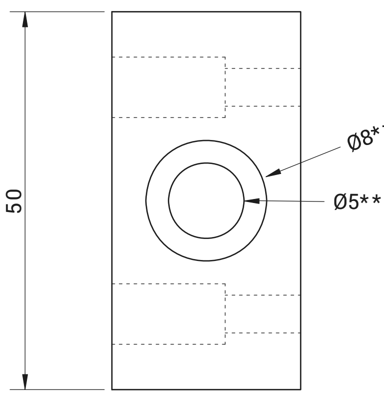




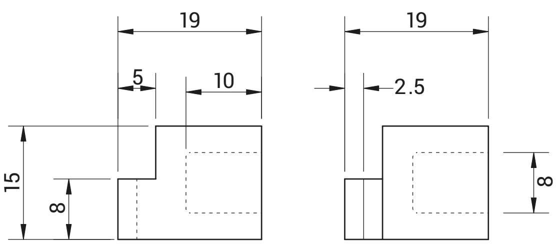
15mm x 5mm Socket Head Screw
8 off



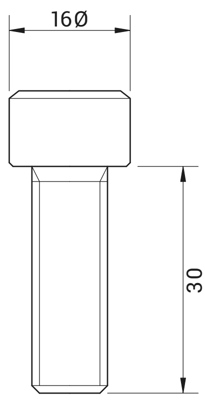
Slides For Material >5mm Thick



Fixed Clamps
4 off



Slides For Material >10mm Thick



30mm x 10mm Socket Head Bolt
4 off ** (size to suit mill table tee slots)

Axminster Engineer's Trade Vice

Michael Cox reviews a new vice.

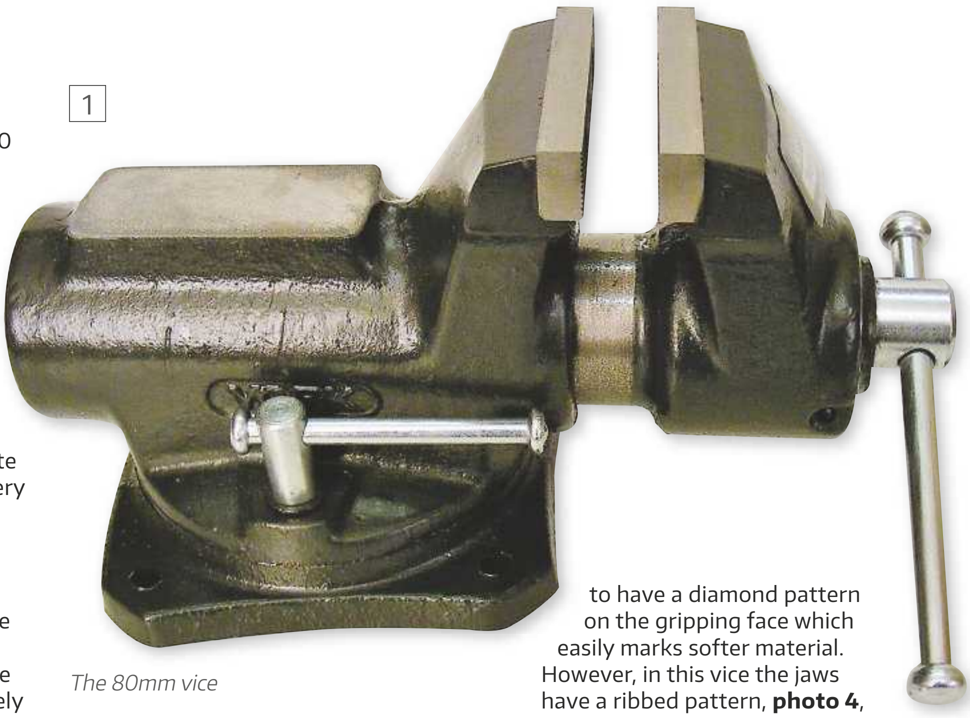
Axminster have a new range of 'trade vices' for engineers. These vices come with a range of jaw widths ranging from 80 mm to 150 mm This review relates to the vice with an 80 mm jaw width, **photo 1**.

The vice, made in the Czech Republic, is a substantial chunk of cast iron weighing 6.1 kg. and very solidly constructed. The vice itself can be swivelled on the base by about 40 degrees in either direction by loosening the clamp screws on either side, **photo 2**.

The jaw width is 80 mm and the opening at maximum is 70 mm, **photo 3**. Opening and closing the vice was quite hard work at first and this was due to very minimal lubrication of the as supplied vice. After oiling all the sliding surfaces the vice was much easier to operate. When opened to the maximum extent the screw disengages and to get the vice to screw in again it is necessary to push the screw in whilst turning it at the same time. The screw thread itself is completely enclosed so it is relatively immune form dust and swarf. However, the down side to this is that there does not seem to be any easy way to inspect or lubricate the screw.

It takes 22 turns to open the vice from its closed position to fully open (70 mm).

1



The 80mm vice

This means that the screw pitch is around 3.18 mm which is almost 1/8". This, non-metric, pitch seems a little unusual for a European made vice.

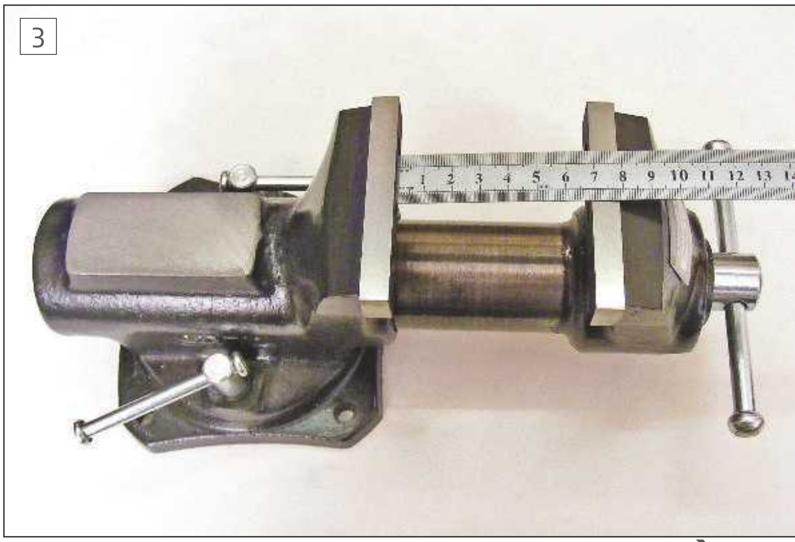
The jaws of the vice are hardened steel. Most general-purpose vice jaws seem to have a diamond pattern on the gripping face which easily marks softer material. However, in this vice the jaws have a ribbed pattern, **photo 4**, and tests showed that this grips well and causes much less damage on soft materials.

Photograph 5 shows the underside of the vice. Of note here are the circular slots that permit the vice to be swivelled on it base casting. The underside of

2

Top view of the vice

3



Measuring jaw opening

The ribbed jaws

Underside of the swivel base

the casting is not very smooth and this make swivelling the vice a little jerky. The other thing to note is the groove in the sliding component to stop it rotating. The packaging states that the anti-rotation key is a roller but I could not confirm this.

The vice tommy bar is captive in the head of the vice screw and the bar is peened over at the end stops to stop them unscrewing. The edges on the peened part were quite sharp, **photo 6**.

In summary, the vice is a good solid piece of engineering and my only gripe would be the lack of lubricant on the sliding parts of the as received unit and the sharp edges on the tommy bar. Both of these are trivial and easily rectified. ■

End of the tommy bar

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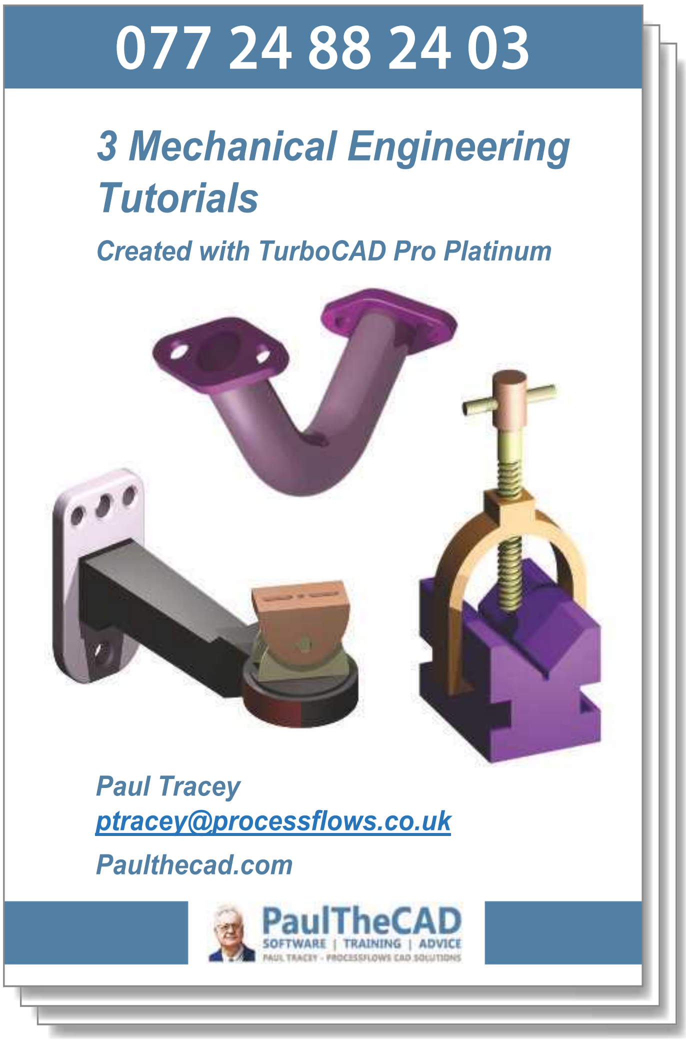
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Measuring Minute Power Levels with a Dynamometer

SillyOldDuffer follows on from his Arduino dynamometer experiments with a home-made torsion dynamometer.

In a previous project, I used an Arduino Uno Microcontroller, **photo 1**, to collect pressure, temperature and rpm data from a Jan Ridders Coffee-Cup Stirling Engine. The data was used to draw Indicator Diagrams (aka Pressure-Volume Loops) and to calculate the "Indicated Power" of the engine, **fig. 1**.

The measurement of indicated power has a long history. First applied to steam engines by James Watt, the measurement gives considerable insight into the health and efficiency of an engine. Indicator information can be used to confirm performance, detect faults and inspire design improvements.

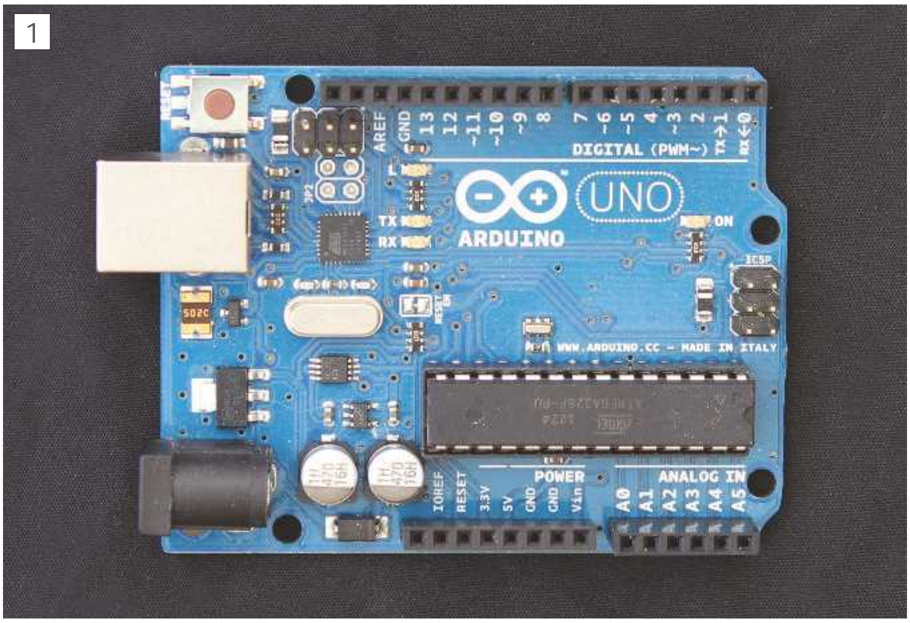
The classic Engine Indicator was a mechanical device that measured pressure inside an engine cylinder as it changed relative to the rotation of the engine and recorded it on a graph for later analysis.

Although Indicator Diagrams provide valuable information they are far from being the whole story. Indicator Diagrams measure the true power actually developed inside the cylinder, but this power typically far exceeds that available at the engine's output. This is because the process of converting heat to power in a practical engine is itself hard work and there are many losses. Before useful power can be output, the engine must do work moving its own components. Friction is unavoidable. Heat is leaked accidentally by radiation and conduction, some parts may have to be deliberately cooled, and in any case the laws of thermodynamics mean that only a proportion of the heat available can be converted into motion.

Given the scale of these losses it is essential to also know how much power an engine actually outputs. Only then can questions about engine efficiency, fuel economy, power to weight ratio and fitness for purpose be answered.

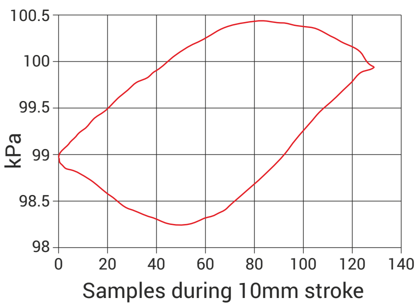
Successful measurement of my not particularly well made example of the Jan Ridders design revealed that the indicated power of my little engine running on 400ml of hot water peaked under 5mW

1



Arduino Uno

Fig.1



Coffee Cup Engine Indicator Diagram

and stalled at about 1mW. Indicated power averages to about 2mW over a 40-minute run. Encouraged by getting the engine to work at all, and then being able to capture data allowing me to assess indicated power, I wanted to see if I could also measure my engine's actual power output. Given my clumsy workshop skills this was quite a tall order because the actual power available at the flywheel of the engine would be much less than 5mW.

Dynamometers

An engine's power output is measured by an instrument known as a Dynamometer. Dynamometers exist in various forms, but they all work by measuring the force, or couple, that acts to change an object's state of rest or motion.

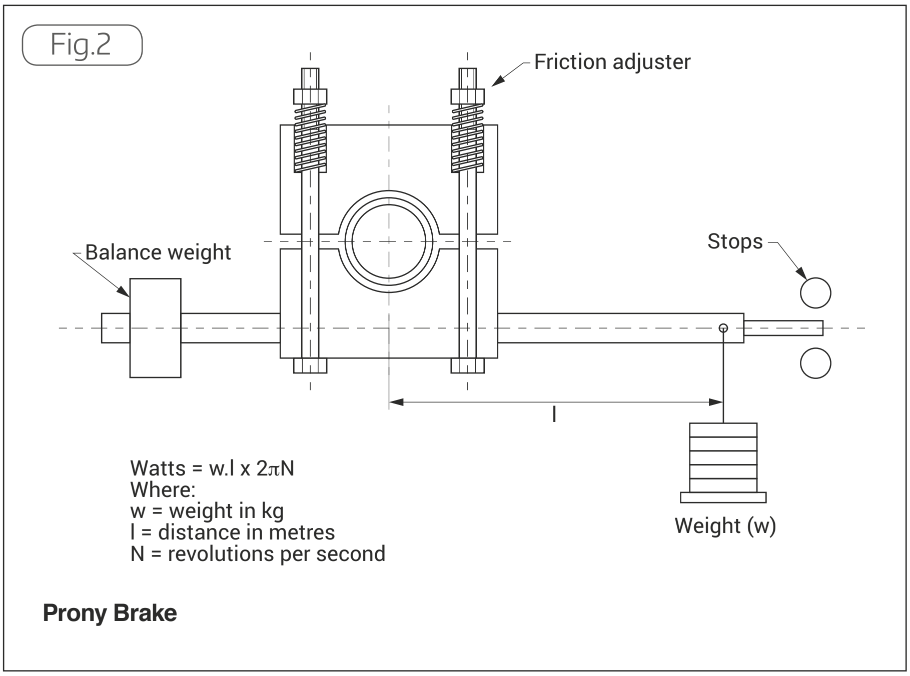
Mathematical relationships between Force, Work and Power were established by scientists during the Nineteenth Century. A Force is anything that moves a mass. Work done is mass moved over a distance in the direction of the force. Work is measured in Joules, or Foot-Pounds or Ounce-Inches in Imperial parlance. The definition of the Joule demonstrates the advantage of the Metric System's internal consistency. A Joule is either a kilogram Metre Squared per second per second; or a Newton Metre; or a Pascal Metre Cubed, or a Watt Second, or a

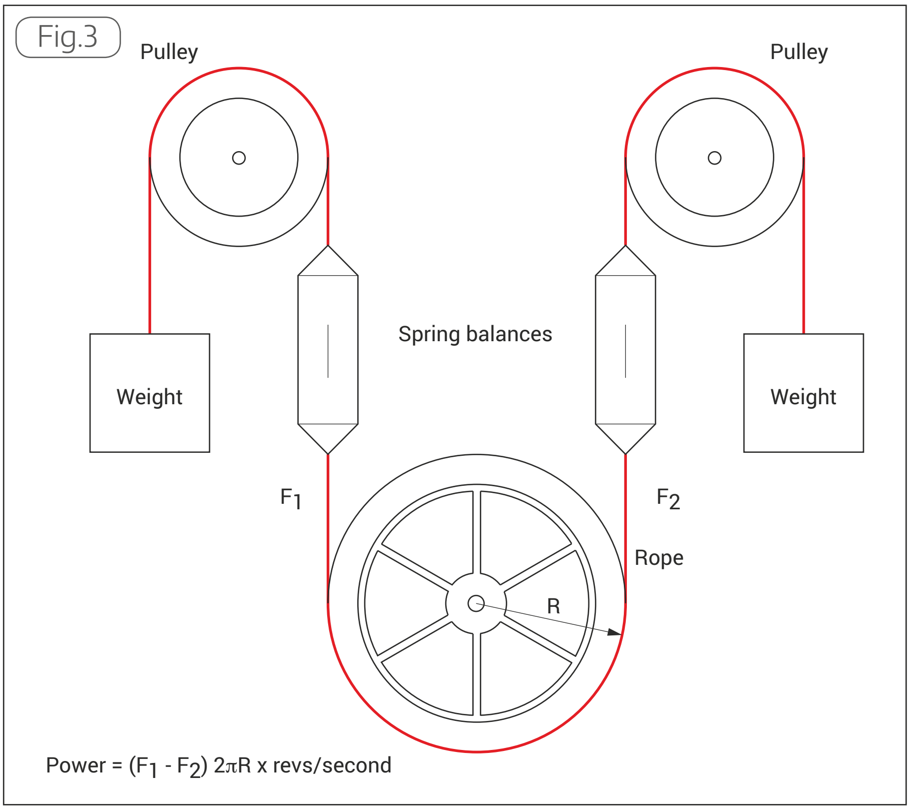
Coulomb Volt.

Power is Work Done per period of time. Power is measured in Watts, and a Watt is one Joule per second. One Horsepower is 550 foot pounds per second, or about 750W.

From these definitions, it is apparent that more power makes it possible to do a given amount of work proportionally more quickly. We know from experience that a lathe with a big motor makes swarf faster than one with a small motor!

It's worth mentioning that real engines do not have a single simple power output. Rather, power output varies with load, rotational speed and other factors. It should be represented by a graph. Where a figure for power output is quoted, it is only accurate under the test condition applied. Whilst we hope when buying a motor that the power output quoted will match our intended usage there is opportunity for misleading marketing. For example an electric motor temporarily overdriven for advertising purposes may have an impressive power output but it won't last very long if used that way for any length of time!





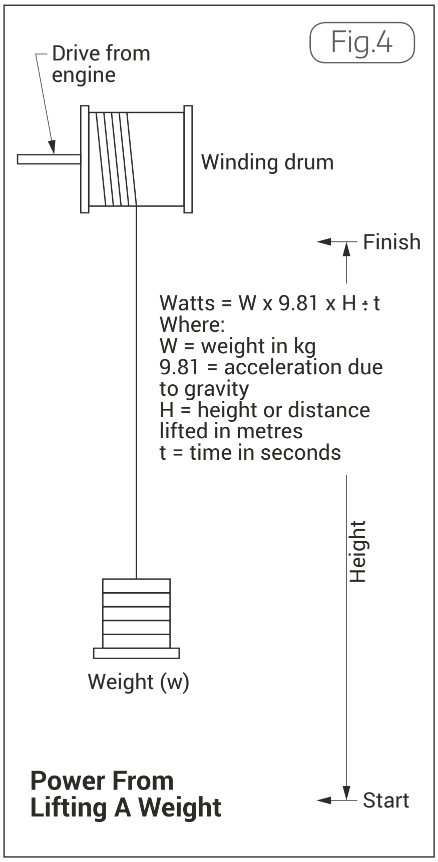
There are two main types of dynamometer: absorption types and transmission types. An absorption type absorbs output power, usually with a brake, whilst a transmission type passes power through more or less unchanged.

A simple form of absorption dynamometer is the Prony Brake, named after the French engineer Gaspard Clair François Marie Riche de Prony who invented it in 1821, **fig. 2**. The use of a brake for power measurement is the origin of the term Brake Horse Power, or BHP.

A Prony Brake is rather like a set of scales balanced on a rotating fulcrum. It measures the force trying to unbalance the scale and is set up by first adjusting the two weights so that the Brake Shoe and Load Arm assembly is balanced between the two stops whilst the drum is being driven counter-clockwise by the engine. The friction adjusters may be used to alter the torque required to turn the drum, and this and the load weight are changed as necessary to match the power of the engine.

I rejected the idea of making a miniature Prony Brake to measure the very lower power expected from the Coffee-Cup Stirling because I doubt my ability to build a sufficiently fine mechanism. The brake would have to apply a minimal amount of finely adjusted friction, which indicates a need for precision engineering. In addition, I imagine setting up a Prony brake would be tricky with a low powered engine that stalls easily. Perhaps a horologist could do it!

Another type of absorption dynamometer is the rope brake. This type is promising because there's a version



specifically designed for low power engines.

Although this variation of a Rope-Brake Dynamometer, **fig. 3**, is intended for low-power measurements, it is clear that "low-power" is relative. For use with the Coffee-Cup Engine's milliwatts, two sensitive spring balances or strain gauges would be required. The "rope" would have to be a fine thread, and some lightweight means of keeping the thread from slipping off the engine's flywheel would be needed. I put this approach on the back-burner in the hope of finding something easier to make. Whilst I enjoy a challenge, engineering is about getting acceptable results with minimum cost.

James Watt's original determination of Horsepower was based on averaged observations of the rate at which horses are able to lift weights up a mine shaft. Later he measured the work done by a horse-mill grinding malt for a Brewery. A grinding mill is very like a brake and perhaps this is what inspired the development of brake dynamometers. The average amount of work over time done by horses turning a horse-mill was found to be the same as that done by horses lifting weights, **fig. 4**.

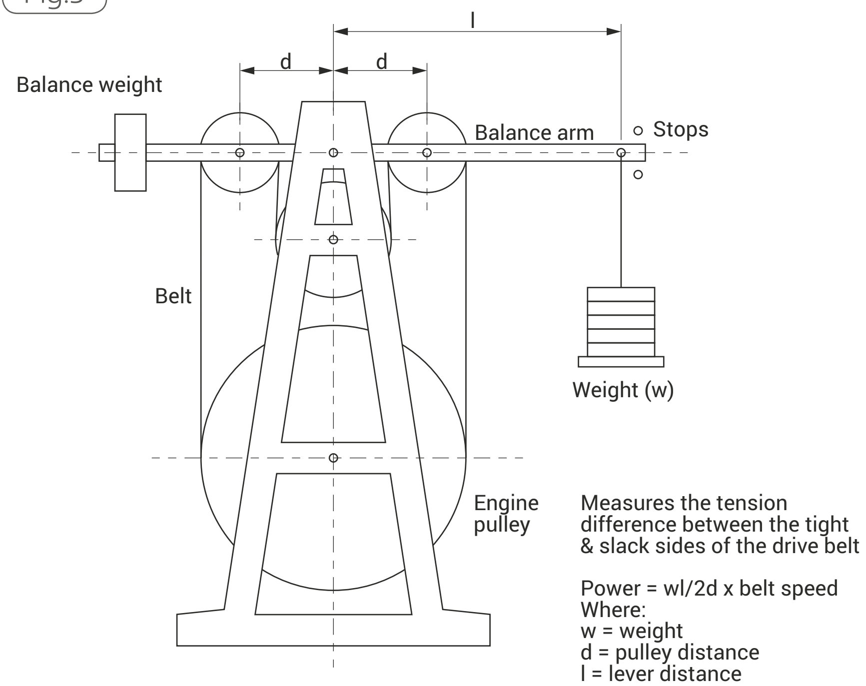
Weight lifting has attractions for low-power measurement, but there's a key disadvantage in this application. It is that the Coffee-Cup engine is rotative, and, unlike a horse, poor at stop-start work. The engine is flip-started by putting external power into the flywheel, is easily stalled, and takes time to get up to speed. Therefore, the behaviour of the engine during start-up is likely to be ill-defined. Furthermore, the power measurement can only be estimated for the time it takes to complete a lift, whereas it would be better to monitor the power output of a rotating engine continuously. In the hope of finding something better I put this one on the back-burner too. I did however make a mental note that a variation of the approach would be good for measuring the power output of a locomotive. It would be relatively straightforward to derive the power output of a locomotive by measuring the draw-bar pull needed to haul a truck of known weight over a known distance within a known time.

A Belt Dynamometer, **fig. 5**, is a transmission type that samples a proportion of the power delivered from the test engine to the load. As such it is aimed at the larger engine. As the Coffee-Cup Stirling Engine is a low power device, I couldn't conceive a way of making a sensitive dynamometer using the belt principle.

My attention was drawn to the means by which the output power of a ship's engine is determined. As the output of a ship's engine certainly isn't "low-powered", it's ironic that this is the method I chose to assess the puny power output of the Coffee-Cup engine!

The output of a ship's engine is often expressed in "Shaft Horsepower". The method depends on the fact that a turning

Fig.5



Belt Transmission Dynamometer

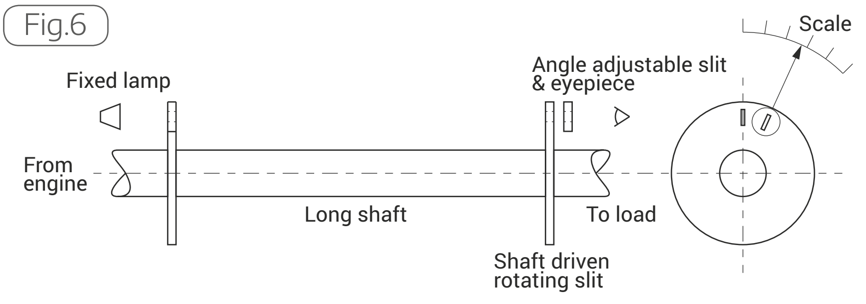
propeller shaft behaves as a spring. When the engine rotates, it applies a torque or turning moment to the shaft. At the other end of the shaft, the propeller spinning in water absorbs power and resists the torque. Consequently the propeller shaft twists slightly as it turns. To take a measurement a steel shaft must be at least 40 times longer than it's diameter to give a satisfactorily large twist. In this form of dynamometer the propeller acts as a brake, and the shaft functions as a kind of spring balance. The elasticity of a shaft can be calculated from the properties of the steel from which it is made, or the shaft can be calibrated by measuring the twist caused by applying a known moment to it (weight x distance).

Once a shaft's elasticity has been obtained, some means is needed to ascertain by how much the shaft is twisted by the engine when the ship is under way. The degree of twist is proportional to the work being done by the engine and knowledge of the engine's rpm allows the power output to be calculated.

One way of measuring the twist is optical, **fig. 6**. A lamp is fixed at the engine end of the propeller shaft. A disk mounted on the shaft with a hole in it causes light from the lamp to flash down the shaft tunnel each time the shaft rotates. At the propeller end, an observer looks through a slit in a similarly rotating disk. The two disks are aligned with the engine stopped so that the lamp can be clearly seen. Then with the engine running, the viewpoint at the propeller end is rotated around the shaft's axis until flashes are most brightly seen. The angle through which the viewpoint has been turned is measured to reveal how much the shaft is twisting under load.

In a full-size Flash Dynamometer the optical apparatus is somewhat elaborate. Means are provided to centre the scale in parallel with the shaft. A vernier or microscope allows accurate scale readings

Fig.6



Shaft Dynamometer
Flashlight type

and a periscope is provided so that the operator need not have his head too close to the shaft.

With an Arduino to hand a simpler solution is available. Rather than have an operator test for optical alignment it is possible to determine the angle of twist by electronically measuring time differences. Once inside a computer the machine can also do the sums for us.

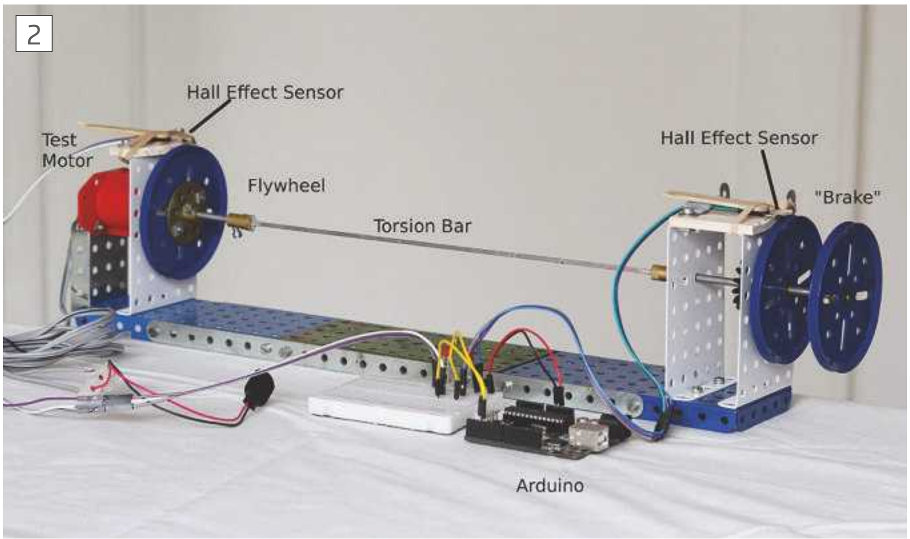
When two disks connected by a torsion rod are rotated, the load-end disk will lag behind the engine-end disk as the rod is twisted by the applied torque. A sensor pair used to detect a known point on each disk will allow the time lag between disks to be found. If rpm is also known, then the angle of twist can be calculated.

Despite the apparent disparity of scale between a ship's engine and a Coffee-Cup Stirling Engine, a variant of the shaft dynamometer seemed to be very promising. The full-scale version uses the existing propeller shaft as a spring but that's not practical or necessary in this case. All that's needed to measure small powers is a suitable spring.

To test whether or not a shaft dynamometer could be used with a small spring I built a prototype out of Meccano, **photo 2**. The Torsion Bar was a steel strip salvaged from the innards of an old windscreen wiper blade.

Despite the obvious crudity of the Meccano Prototype I got a result indicating that the red motor was roughly 40% efficient under my test conditions. The power input to the motor was measured accurately using a voltmeter and ammeter. The output was measured by using the Arduino to determine RPM and angle of twist from time lag. After calibrating the spring the maths revealed the motor's approximate output power to be comfortably within the expected range bearing in mind that the power output, torque and efficiency of a DC motor all vary with speed and load.

On the downside, a couple of watts input were needed before the load represented by the Meccano dynamometer would turn, even though the "brake" is only friction in the absence of a bearing. It was obvious that that a dynamometer capable of measuring milliwatts would have to be better engineered.



Meccano Experiment

Mk.1 Dyno

A few hours work with a lathe and milling machine produced the Mark 1 Shaft Dynamometer, **photo 3**. This featured bearings, the couplings needed to connect a Coffee-Cup Engine, a torsion bar made of 0.9mm diameter piano-wire and some brake wheels of different weights.

The Mark 1 was a failure. Even though much easier to spin than the Meccano prototype, it was still too heavy a load for my Coffee-Cup Engine. This led to an urgent design review that focussed on the bearings. Firstly, the bearings were a somewhat stiff cheap type and secondly there are four of them! At the same time, calibrating the piano-wire torsion bar showed that it would be too stiff to be twisted through a measurable angle by the low power likely to be output by the Coffee-cup Engine.

A rethink suggested that all the bearings at the engine-end could be eliminated, a longer torsion bar used to increase elasticity and the heavy "brake" wheel replaced with a lightweight one made of black polystyrene recycled from frozen pizza packaging.

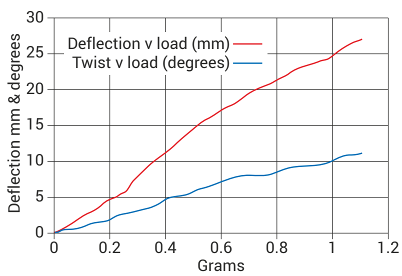
The dimensions of the Mark 2 Shaft Dynamometer were:
Tension Bar: Piano-wire. 350mm long, 0.9mm diameter.
Brake wheel Assembly: Total Weight 15.1g
Stand: Bright Mild Steel. 240 x 40 x 8mm with bolted on foot 60 x 40 x 8mm.
Wheel: Black polystyrene. 110mm diameter x 4.5mm. Cut from a frozen pizza tray.

Dimensions are not particularly critical, **drawing 1**, except that the axle of the dynamometer wheel, **photo 4**, must be mounted at the same height as the axle of the engine under test and at right angles to it.

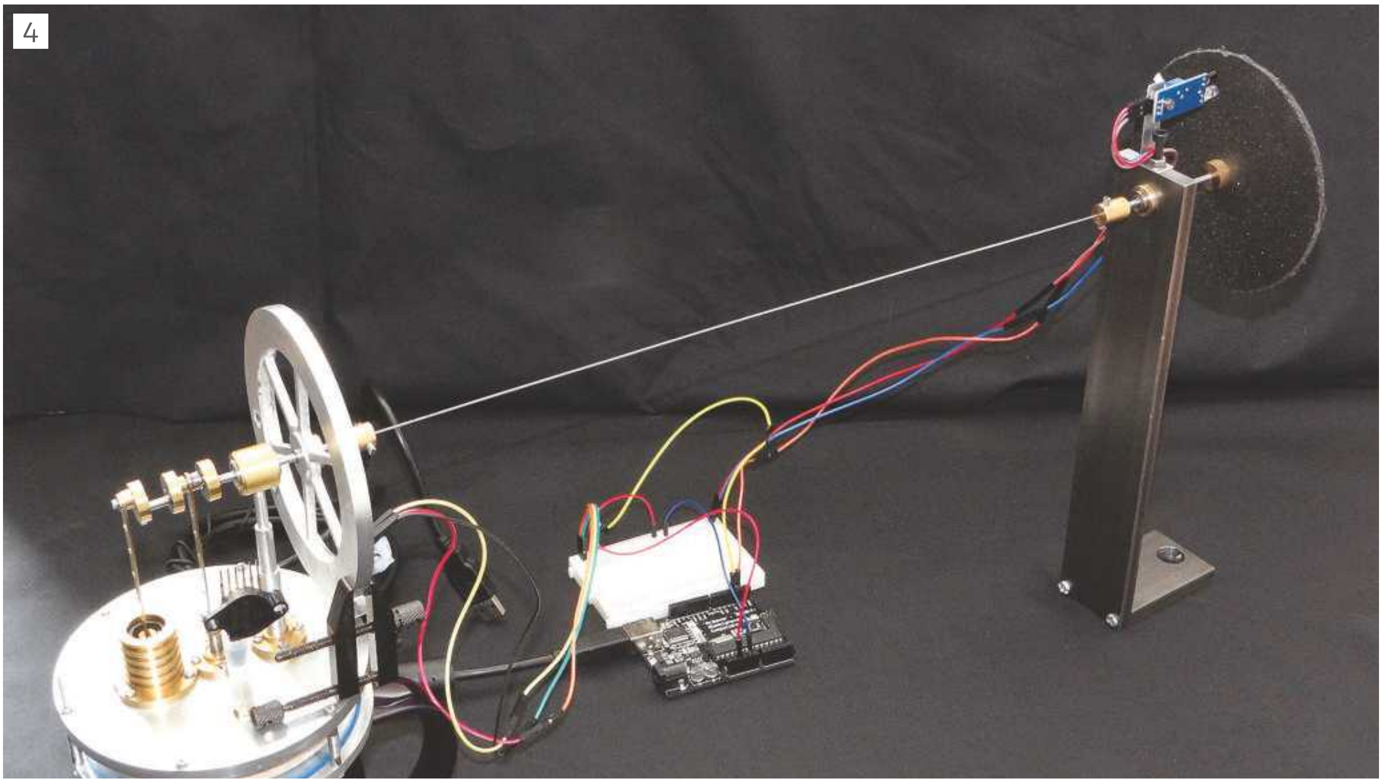
Normally my Coffee-Cup Engine runs at about 130rpm. My engine labours with the dynamometer attached, initially turning no faster than 40rpm. Nonetheless, I was pleased it worked at all. I was able to take measurements and calculate a result.

Later the dynamometer was improved by replacing the stiff bearings with a better-quality type. This "improvement" revealed a problem, which is that there is a delicate balance between the power of the engine, the elasticity of the torsion rod, and the friction applied by the brake. If friction is too great, the engine stalls. Another issue is that the twist angle will be insufficient

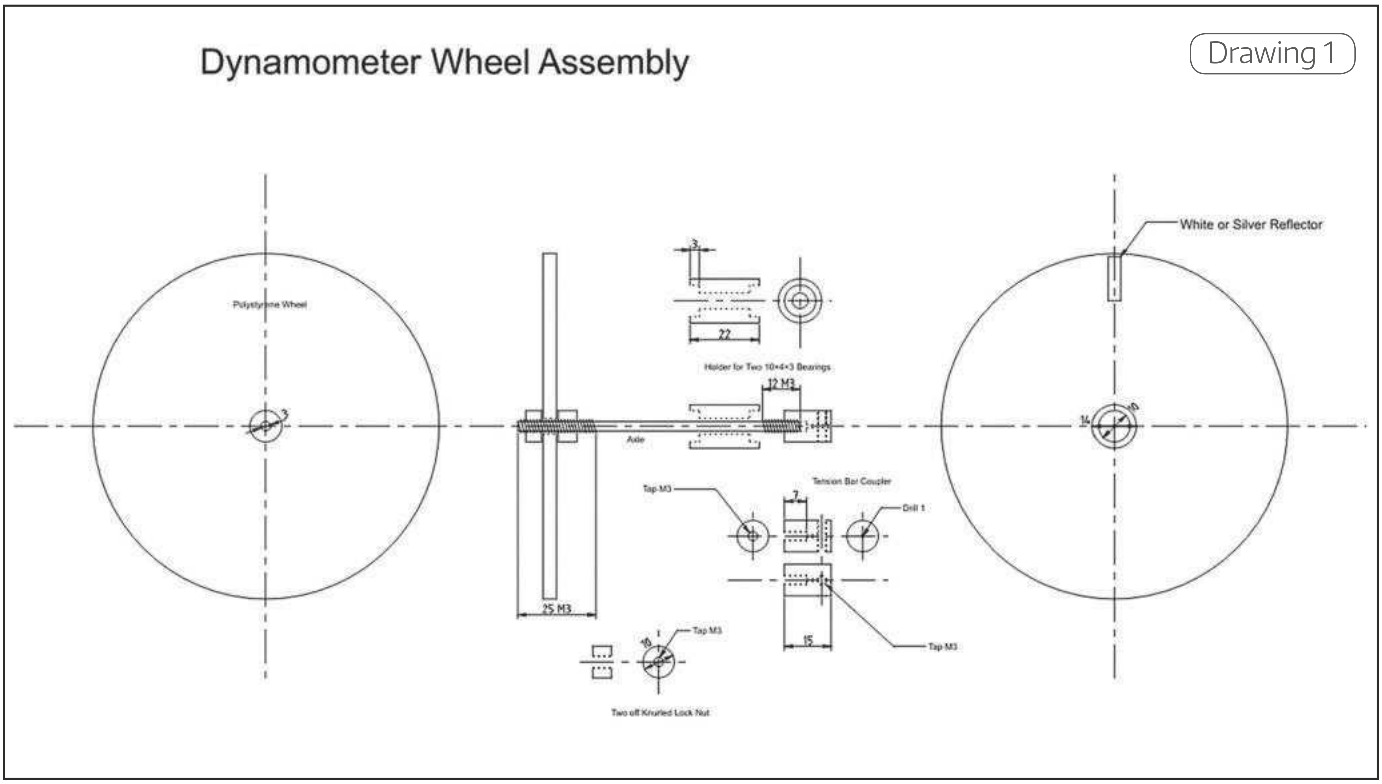
Fig.6



Low Power Dynamometer Torsion Spring Calibration



Mk2 Dyno



if either the brake friction is too small or the torsion rod is too stiff. Stiffness is reduced by using a longer torsion rod but an overly long elastic torsion rod will sag, so there are practical limits to the size and material used to make the torsion rod. By chance the cheap stiff bearings I initially used provided a reasonable load, whilst better bearings reduced friction too much to give a substantial twist. More research is needed. A post on the Model Engineering forum suggested using a plastic torsion rod: I think this is a good idea but my junk box failed to produce a candidate.

Once a reasonable balance between spring and brake action is achieved the utility of the dynamometer could be increased by giving it a variable brake action. This might be done by: using brake wheels of different weights; or by adding drag by running the rim of the polystyrene brake wheel though a liquid; or with electromagnet braking brought about by inducing eddy-currents in aluminium foil glued to the polystyrene wheel.

Calibration

It is necessary to calibrate the spring of the torsion rod before using the dynamometer. length), where deflection is measured in mm above base using the steel rule.

To be continued

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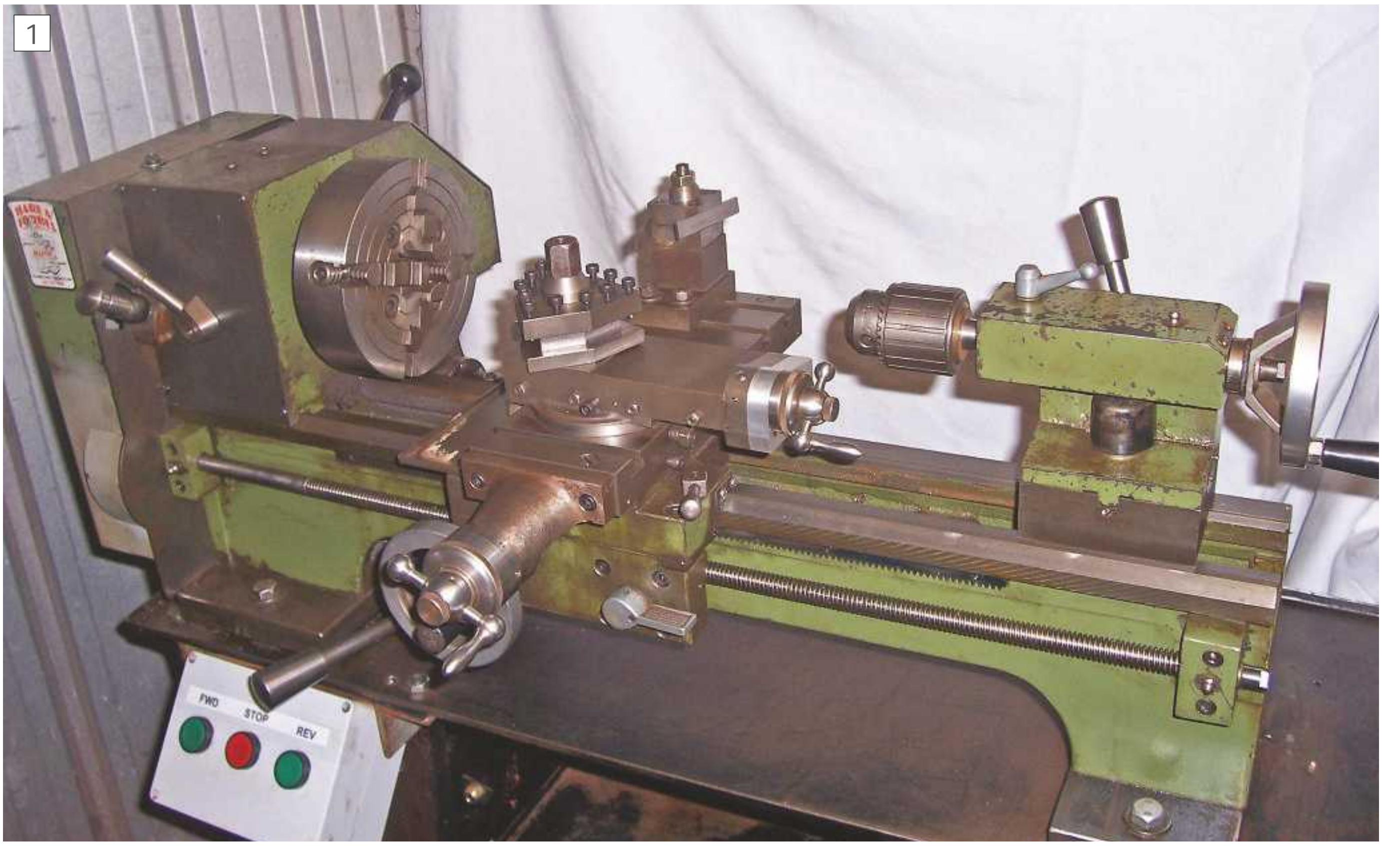
One Man and his Lathe

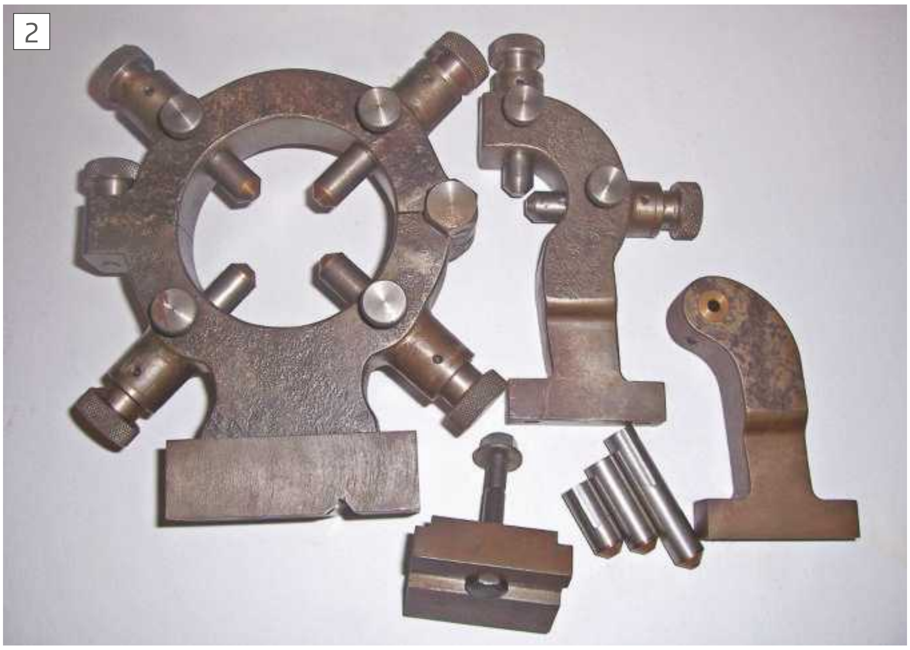
Brett Meacle and his Taiwanese AL150



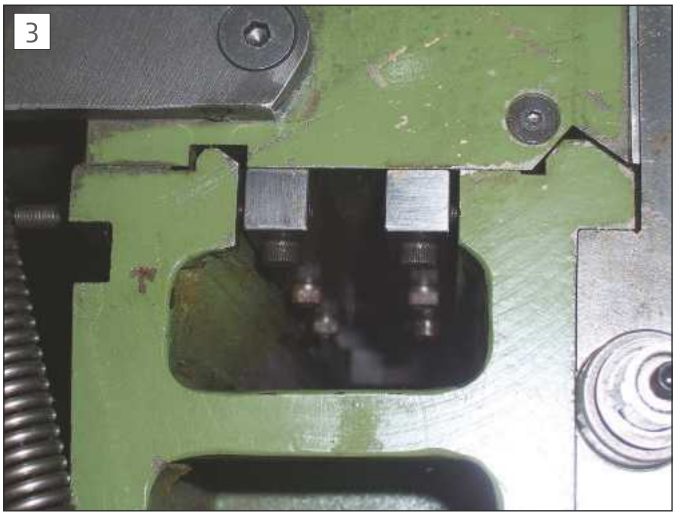
Modified lathe.

When I was younger I always knew I wanted a lathe, I didn't really know what I'd use it for but I purchased this lathe in 1991. At the time, I had never heard of Model Engineer or MEW, I discovered MEW Issue 9 at a newsagents and haven't stopped reading it since. The lathes model number is AL150 but is similar to Compact 8, CT 918 and 920 Lathes. This style of lathe has been around for almost 25 years, so I assume there are numerous examples in workshops around the world. While not to the high standard of the Myford lathes, I feel these lathes are a good starting point for entry into the world of engineering. Most of the modifications and items I have made are not required on a Myford, and to be honest had I purchased a Myford I may have been too scared to modify it. Working on this lathe has given me the experience and confidence to buy and recondition a more classic machine in the future.

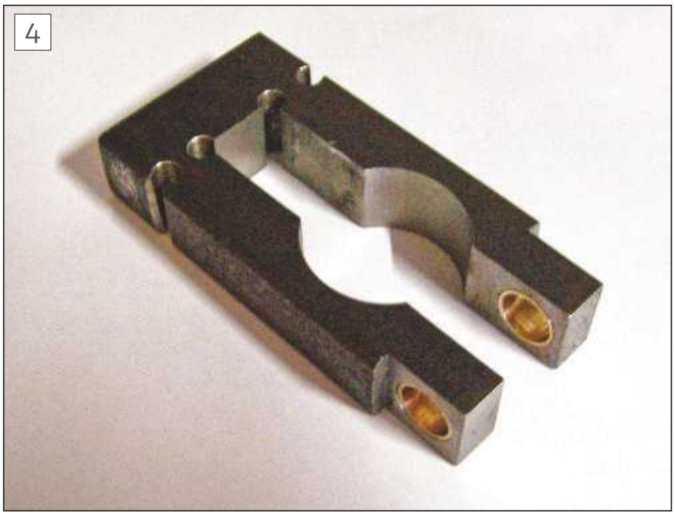
This article details the changes I've made to my machine and will hopefully assist



Fixed and Travelling Steadies including Travelling steady for small diameter work.



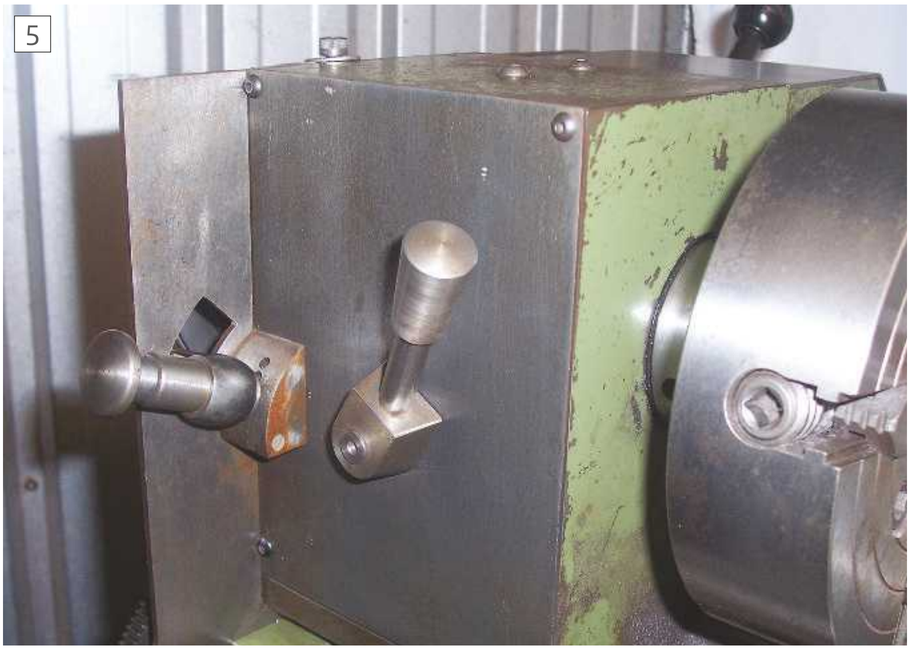
Shows the bars and grub screws for adjusting the headstock alignment.



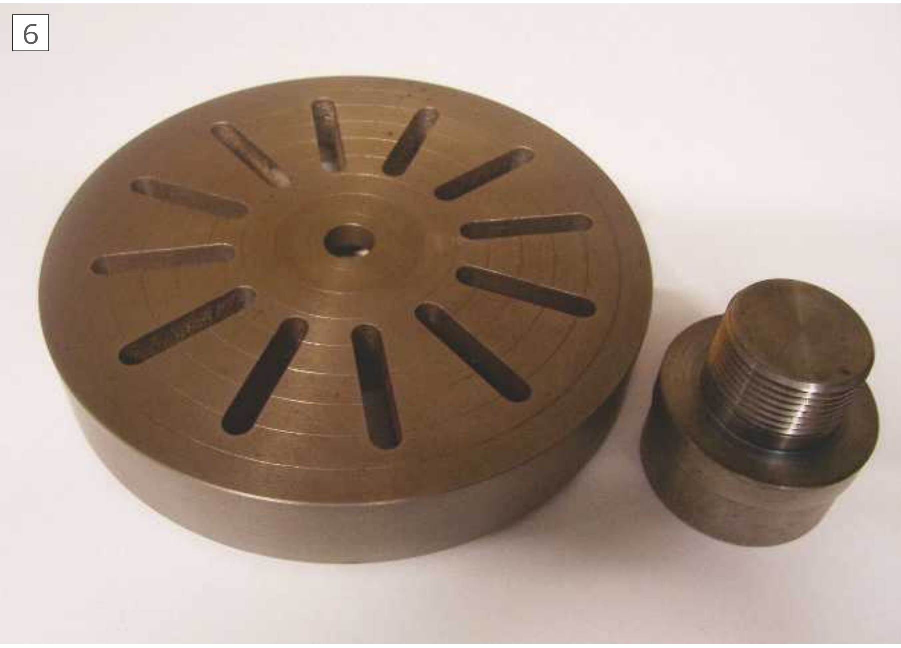
Spindle Lock body

others with ideas to improve their lathes. Most of the ideas are not original but have come from reading Model Engineer, Model Engineers Workshop, The Workshop Practice Series and many of the other classic books on lathes and turning. I then modify and adapt the design to suit my requirements. Although having been schooled in the metric world, I can work with imperial dimensions, converting between the two systems. The design is then drawn up full size in a CAD program to check for any errors and any problems with clearances between parts. Drawing the parts also gives a feel for what the part looks like and how you will machine it. The drawing is then dimensioned and printed out for use in the workshop.

The first modification performed was a tailstock clamping lever to replace the spanner and nut combination. The Clamp plate is tightened via an eccentric shaft and lever. This small mod makes using the tailstock much easier to use and has been documented many times over the years, **photo 1**.



Headstock showing the spindle lock handle in the clamped position and the tumbler reverse lever.



Faceplate and Dummy Spindle.

The lathe although new had only basic accessories eg 3 and 4 Jaw chucks, centres and drill chuck, but not such items as a drive plate for between centres work, faceplate or fixed/travelling steadies.

The fixed and travelling steady designs were scaled down from a larger lathe incorporating removable fingers of different lengths to cover a large range of sizes. The fixed steady was made with four support fingers, and can support work up to 70mm. The fingers are tipped with gunmetal for general turning and another set using hardened steel tips are used in the travelling steady for the threading of long components. **photo 2** shows the fixed steady and two travelling steadies including one for small diameter work using replaceable gunmetal bushes.

The headstocks on this style of lathe are bolted to the bed by four M8 bolts, with no fixed datum for aligning the spindle to the bed. To assist in aligning the headstock two 12mm Sq bars were bolted to the underside of the headstock. These bars are cross drilled with two grub screws each that

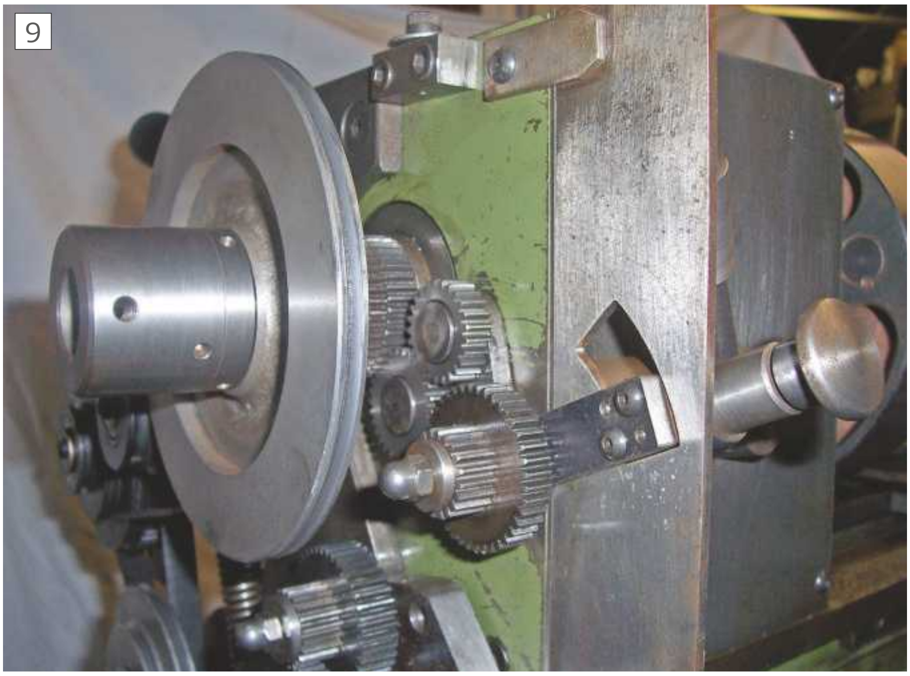
Master and Slave chuck and Internal stepped Collet Chuck.

New Cross-slide and Top-slide.

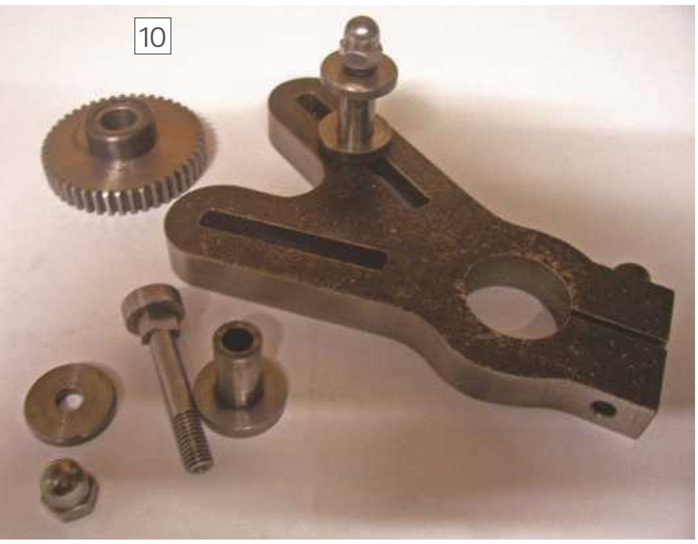
register against the inside faces of the bed. Using a Test mandrel these grub screws allow minute adjustments in alignment of the spindle. The headstock bolts when tightened do not disturb the alignment, only clamping the headstock to the bed. **Photograph 3** shows the bars fitted to the underside of the headstock.

A spindle lock has been fitted to clamp the spindle in any position. The body of the clamp is shown in **photo 4**; this is bolted inside the headstock casting. The handle operates a threaded shaft and nuts to compress the clamp onto the spindle. Both LH and RH Acme threads are used to double the clamping movement and reduce the handle movement. The spindle lock handle is shown in the locked position in **photo 5**.

A rear spindle steady has been incorporated into new bearing adjustment locknuts. The rear steady is useful when working with long stock that extends past the end of the spindle bore as it supports the work from whipping around violently. A work piece centred accurately in the rear steady allows more accurate work to be performed at the chuck end. The Adjusting grub screws are tipped with brass to reduce marring of the work. Photograph 9 shows the rear steady, the adjusting screws are removed when not being used, as they interfere with the mandrel handle when it's being used.



Tumbler reverse and the rear spindle steady.



Gear quadrant and gear studs.

A larger 4 Jaw independent chuck was purchased and required a backplate so a dummy spindle was made to allow machining of the backplate thread and register. Using the dummy spindle a backplate, drive plate and faceplate were all machined to fit the lathe spindle.

The faceplate made from patterns and a casting is 185mm in Diameter, extra thick and has 12 machined slots for mounting work. The faceplate with the dummy spindle is shown in **photo 6**

The dummy spindle was later used to machine the threads and register for a Collet chuck using ER32 collets, a Master and Slave chuck system and large version internal stepped Collet chuck. The last two items are described by Tubal Cain in his book Work holding in the Lathe. **Photograph 7** shows the master chuck and some slaves and also the internal step collet chuck and a couple of collets. Master and slave chucks are used for second operation work on components. The slaves are a close fit in the master bore and will always be concentric and exact length each time they are used. The internal step collets cover sizes from 25 to 60mm, and are excellent for holding thin flat components and delicate rings.

As with all small lathes parting off was a problem, inspiration came from the invaluable works of George Thomas. A lot of the accessories and modifications I make are to the designs and writings of G H Thomas.

A rear parting tool holder was made and fitted to the cross-slide. This was initially fitted to the original cross-slide using an extension plate as the standard cross-slide was only 160mm long with travel of 110mm.

Fine feed attachment, used with a 100T gear on the Leadscrew.

Because the slide was so short the saddle dovetails were open to swarf and dust at each end. The limited travel also meant the topslide had to be moved between the 2 mounting positions on the slide for different jobs. The topslide was held on by a flimsy plate and two 6mm T-bolts, and the sturdiness of this setup left a lot to be desired. As the Myford lathes are the pinnacle of small lathe design, I decided to make a topslide and cross-slide along the lines of the Super 7. Patterns were made and a local foundry produced some castings of excellent quality. After a period of seasoning, they were machined and fitted to the lathe. The rear parting tool now bolts onto the longer cross slide and the dovetails are covered at all times. The new arrangement can be seen in **photo 8**.

The larger topslide, more robust leadscrews, larger micrometer dials and longer travels on both slides make the lathe much easier to use. The extra rigidity has improved accuracy and the surface finish in parting, facing and turning remarkably.

Screwcuttting

The original low speed of 100RPM is too high for most screwcutting jobs. The spindle thread on this lathe is M40 X 2.5mm and in the spindle accessories short in length ending in a blind hole. To complete the dummy spindle and thread the spindle accessories a mandrel handle was made. The handle allowed these jobs to be completed without undue stress, but I still prefer to use it for longer jobs. It's good exercise and the slower turning of the handle produces a superb finish on the thread.

As experience was gained in screw cutting and new projects required the cutting of LH threads another shortcoming of this lathe style was made apparent i.e. the lack of a tumbler reverse. I wanted a design that allowed LH and RH threads with a central position to disconnect the lead screw from the spindle. The tumbler plate bolts to the headstock but allows the 40-tooth tumbler pivot gear to be replaced with a 20/40T gear. In **photo 9** the 20/40T gear is shown fitted to the tumbler pivot.

As a result of adding the tumbler reverse the long tee bar used for the original gear trains was not useable. A new Gear quadrant was made allowing a more compact and easier to use arrangement. **Photograph 10** shows the new gear quadrant and stud arrangement.

My lathe is not fitted with a quick-change gearbox, which I don't see as a problem as although the gearboxes allow quick changes, they limit the range of threads and worms that can be cut.

To reduce the amount of gear changing between screwcutting to fine feeds and back again, a self contained fine feed attachment designed and made. With the movement of a stud and the substitution of one gear on the fine feed attachment and the replacement of the 40/40T tumbler reverse gear with a 20/40T gear, feeds of 0.2, 0.1 and 0.05 mm are possible. When changing from fine feed to screwcutting, the fine feed attachment is replaced with the changegear quadrant. The fine feed attachment is shown in **photo 11** with the 20/40T gear fitted. To increase the feed rate the stud is unscrewed allowing the 20/40T gear to be removed. The stud is then fitted in the second hole seen in the photo with the 40 Tooth gear.

After a reasonable amount of screw cutting the 1.5mm pitch lead screw and clasp nuts were wearing out. A length of 3mm pitch trapezoidal threaded rod was purchased and replaced the existing leadscrew. New heavier duty clasp nuts were made to suit the new lead screw. A new Screwcutting chart covering a larger number of pitches was also produced covering all metric pitches from 0.25 – 4.5mm.

Clutch Unit

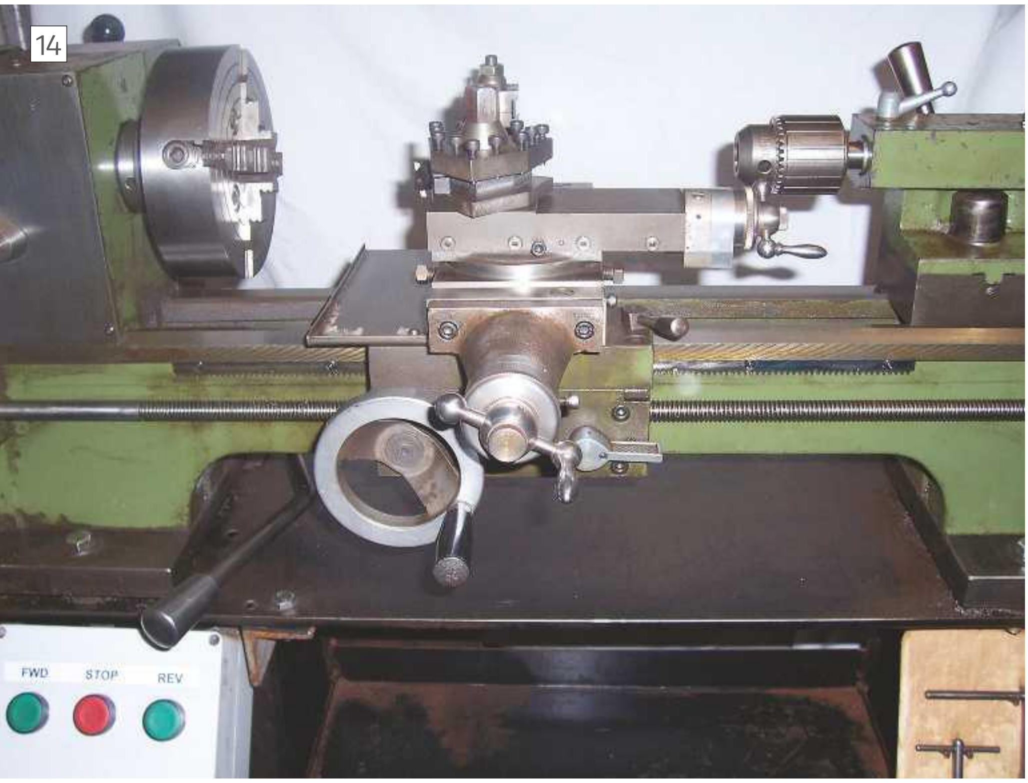
One of the major problems with small hobby lathes is the lack of a clutch.

Single phase motors do not like frequent starting/stopping, although the motor on

Clutch unit.

Clutch unit fitted to rear of lathe.

14



Lathe controls showing push buttons on left, clutch lever and the tool board is partially visible on the right.

my lathe has worked perfectly for over 18 years. The Fwd/Rev rotary switch mounted on top of the headstock was the weak link and was replaced with push buttons and no volt release contactors fitted to the stand.

Another reason for the clutch assembly was to rectify another flaw on these lathes- 100RPM low Speed- actual measured speed 130RPM.

Low speed attachments have been described before using extra pulleys and belts on the headstock, but I wanted to incorporate a speed reduction and clutch into the one unit. Newer lathes are being produced with variable speed DC motors or 3 phase motor/inverter drives solving the speed reduction problem.

A clutch had been planned for a number of years, but working with Vee Belts, Timing belts and associated pulleys was producing a design both large and complicated to machine.

The turning point was the discovery of the Multi vee Serpentine Belt. The Multi vee belt allowed a more compact design with speed reduction achieved using only two pulleys instead of three pulleys. Also, the pulleys for the Multi vee belts are much easier to machine. This allowed a speed reduction of 2.9 - 1 and a 1.1 – 1 increase to give 12 speeds covering a wider range 45 – 1985RPM. The original pulleys and belt tensioning mechanism on the headstock was retained.

The clutch is a basic cone clutch using a spring to compress the plates together. wThe movable clutch plate is keyed to the driveshaft via a hexagonal section. The clutch is operated by a cam and pushrod moving the coned clutch plate away from the pulley section. The Multi vee pulley section is fitted with ball bearings and rotates freely on the driveshaft when the clutch is disengaged. **Photograph 12** is the complete clutch unit on the bench.

The clutch unit takes the place of the motor on the rear of the headstock, **photo 13** and the original motor pulley is fitted to the end of the clutch shaft. The motor with a new pulley is relocated in my case into the base of the stand but could be mounted behind or even above the headstock. A belt tensioning mechanism is required for whatever mounting position decided on. The original flimsy stand has been modified at present but a new more substantial stand is planned to incorporate the motor, drawers and compartments for storage.

The clutch lever is underneath the lathe bed and not up high like the Myford, this suited my working style as my lathe is mounted higher than usually seen- spindle centre 1275mm High. In operation, the Stop/ Start buttons are pressed with the left hand which then only moves a short distance to operate the clutch lever and saddle movements. A tool board is mounted on the tailstock end of the stand also down low. **Photograph 14** gives an idea of the layout. The clutch handle is shown in the disengaged position, to engage the clutch the lever is moved towards the headstock.

This lever position may not be suitable for lathes with a gearbox and by using an extension the clutch lever could be mounted above the headstock.

Another possible benefit of the clutch is to allow the spindle to run up to speed slower, protecting the tiny and expensive 5M V belt from breaking. Belt breakage is a common problem on these lathes; some of the newer machines have beefed up the size of the headstock belts and pulleys to rectify the problem. Since the clutch has been added no belts have broken and the clutch has given faultless operation for over 12 months. The constant stopping/starting for measurements, clearing swarf and tool changes is now just a flick of the clutch lever.

Conclusion

Works in progress include a new lathe stand, a headstock dividing attachment using GHT's VDH components. The square aluminium hand wheels will be replaced with cast iron round section hand wheels and some ball handles have to be made. The feedscrew dials although graduated require numbering, a job once a universal pillar tool is completed. When all the work on the lathe is complete, everything will be stripped down and receive a new coat of paint.

In the intervening years since this article was written, the clutch and other modifications have worked very well.

I purchased a second later version 920 Lathe and completed the same additions and modifications, with the exception of the Tumbler reverse.

For Screwcutting I had read about Graham Meeks Screwcutting Simplified Clutch so I made and fitted an adaption of his clutch to this second lathe, **photo 15**.

The clutch and a retracting topslide has made this task a breeze without the need for a mandrel handle.

I appear to be in a cycle of making tooling to make more tooling but each new tool or modification allows the following jobs to be produced with greater ease.

With each job, you gain more experience and confidence and one day a more traditional model engineering project will appear from the swarf.

I hope this article will assist other readers and if there is any interest I can write up constructional articles for any project. ■

15

Screw cutting Clutch set up on the headstock of improved lathe Mk11.

Extending the capabilities of the Jacobs Gear Hobber.

Differential indexing, worm gears and more. By Chris Robinson – Part 3

With the gear shaper mounted on what is normally the workpiece arbor (set at an angle equal to the lead angle if the Mod 1.25 hob), and the worm blank mounted in place of the hob the worm was machined in 4 cuts using the same speed and feed as for hobbing the shaper, **photo 20**. The worm wheel was made in the same way as described earlier and the finished worm and wheel are shown in **photos 21** and **22**. Another example was made using a 5/16" x 16 tpi RH ACME tap as the hob. This can be seen in the foreground of photo 29 (see later). The single start worm meshes with a 40T worm wheel.

Helical gears of high helix angle.

With the modifications made so far, because of the geometry of the Jacobs machine, it is only possible to hob helical gears with a helix angle not exceeding 30° for RH gears and not exceeding 45° for LH gears. However, gears with a much greater helix angle are commonly used in industry, usually in 90° drives. An example is the car speedometer drive shown in **photo 23** where the helix angle of the driving gear is about 60°. This will mesh with a gear of 30° HA of the same hand to give the 90° drive. Note that with all the helical gears discussed so far, the helix angle is quoted with reference to the rotational axis of the gear. As the helix angle of a gear is increased it looks more and more like a worm gear. A worm gear is only a helical gear with a small number of teeth and a high helix angle. However, it is more usual to quote the lead angle of a worm gear (the angle of the teeth relative to a normal to the rotational axis). So, a single start worm gear, Mod 1 with an OD of 16mm is usually quoted as having a lead angle of about 4°. It is also a single tooth helical gear with a helix angle of about 86°. The helix and lead angles for any one gear are, of course, complementary (i.e. helix angle plus lead angle = 90°)

To make these high helix angle gears with the Jacobs hobber it is necessary to change its geometry. An adaptor plate was made up, **photo 24**, to turn the hob spindle housing and the index gear "L" bracket through 90°, so when the cross slide angle is set to zero the axes of the hob and workpiece are parallel. Cross slide angular settings either side (with allowances for hob lead angle) will allow high helix angle gears with either LH or RH to be made within the range 60° to 90°. These are equivalent to worm gears in the range 0° to 30° lead angle. In addition, a new bevel and worm index drive was made up, **photo 25**, to allow the cardan input and output shafts to be parallel. It also has a 16:1 ratio, recognising that high helix angle gears will generally have low tooth numbers. This changes the machine constant from 40 to 16.

The process for determining index and feed gears is just the same as any helical gear and the higher helix angle must be input. However, for the revised machine geometry using the adaptor plate, the component of the feed normal to the hob motion is in the same direction (toward the hob spindle housing) for both RH and LH gears. This is because the feed direction has been reversed for RH gears compared to the standard machine set up. In both cases, therefore, the corrected index ratio is less than the standard (spur gear) ratio. For both handed gears in this case the "Hand of Helix" indicator is set to -1 as in a LH gear for the standard set up. **Photograph 26** shows the setup for hobbing a 27DP, 5 tooth LH gear with a helix angle of 78°. This can also be described as a five-start LH worm having a lead angle of 12°. **Photographs 27** and **28** show the setup for hobbing a 22DP, 7 tooth RH gear with a helix angle of 73° (a seven-start RH worm having a lead angle of 17°). In this case the rotation of the workpiece is reversed by

20

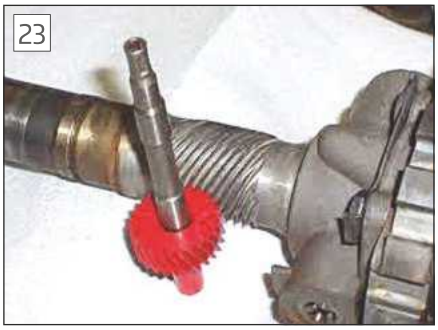

Cutting the double enveloping worm

21


The double enveloping worm

22


Double enveloping worm and wormwheel



Car speedometer drive

turning the top bevel through 180° to drive the worm from the rear and in the opposite direction. However, this also reverses the cross-feed screw rotation so to maintain the direction of feed a LH feed screw and nut are required. In both cases a 10T pinion was made to mesh at 90° and the results are shown in **photo 29**. **Table 3** shows the spreadsheet output for these two gears using the improved spreadsheet described below.

A simplified method of index correction

In the 2010 MEW article on hobbing helical gears, two sets of four compound gears, a standard "spur gear" train and a "corrective" train were used for index correction when making helical gears and worm wheels using tangential feed. With the addition of 4 gears for the feed train and two for the drive train, this is a total of 14 gears.

In commercial hobbing, machines only use one set of four compound gears for the index train. What prompted the use of the extra "corrective" train was my lack of a knowledge at the time as to a simple way to determine the gears to be used for just the one set of four. I eventually realised that this can be done using the same method of continuous fractions as used for determining the feed train.

The original Excel spreadsheets for determining feed gears for helical gears and for worm wheels using tangential feed have been expanded to determine compatible trains of index and feed gears without the use of the extra "corrective" train. This has a number of advantages:

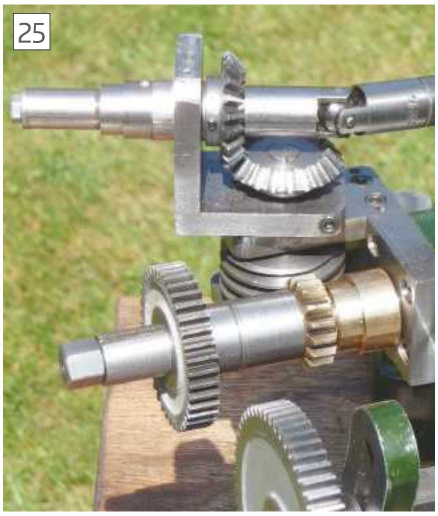
- Only 10 gears instead of 14 are required for any one setup.
- Only one gear of each tooth number is required as opposed to two of each for 30 - 55 for the corrective train.
- Helical gears and worm wheels having prime numbers of teeth can in most cases be made without already having a spur gear of the prime number of teeth (or multiple thereof), or a differential. The exception is for helical gears with long leads.

Finding compatible index and feed trains using continuous fractions

Helical Gears

The index gear ratio "I" is defined as: Number of turns of the index worm for one turn of the hob. For a spur gear, this is simply M/T. To calculate the index gear ratio

900Adaptor plate



16:1 bevel and worm index drive

"I" for a helical gear we need the following data:

T = number of teeth on gear to be cut, Mod = module of gear to be cut, M = Machine constant, Ps = Profile shift ratio

α = Helix angle of gear, p = Pitch of feed screw, R = Gear ratio workpiece : feed screw (feed ratio).

The feed ratio R is defined as: Number of turns of the workpiece for one turn of the feed screw. Normally profile shift ratio Ps = 1. For an explanation of profile shift ratio, see the note at the end of this section. From the above data, the PCD of the gear D = T x Mod x Ps/cos α.

Figure 8 represents the motions for helical gear hobbing with a right-hand hob. Note that the gear helix angle α is relative to an axis parallel or normal to the hob tooth motion, i.e. offset from the hob axis or normal to the axis by the hob lead angle. Consider first a RH helical gear. For each revolution of the workpiece the distance normal to the motion of the hob teeth travelled by a point on the PCD of the gear being cut, relative to the cross slide = $\pi D \cos\alpha$. However, the cross slide itself will have moved a distance = $p \sin\alpha/R$ in the opposite direction, so the motion relative to the hob is less and equal to $\pi D \cos\alpha - p \sin\alpha/R$. To correct for this the motion must be speeded up by a ratio equal to:

$\pi D \cos\alpha/(\pi D \cos\alpha - p \sin\alpha/R) = 1/(1 - p \tan\alpha/\pi RD)$ for a RH gear

In the case of a LH gear the motion is greater by the same amount equal to $\pi D \cos\alpha + p \sin\alpha/R$. In this case the motion must be reduced by a ratio equal to :

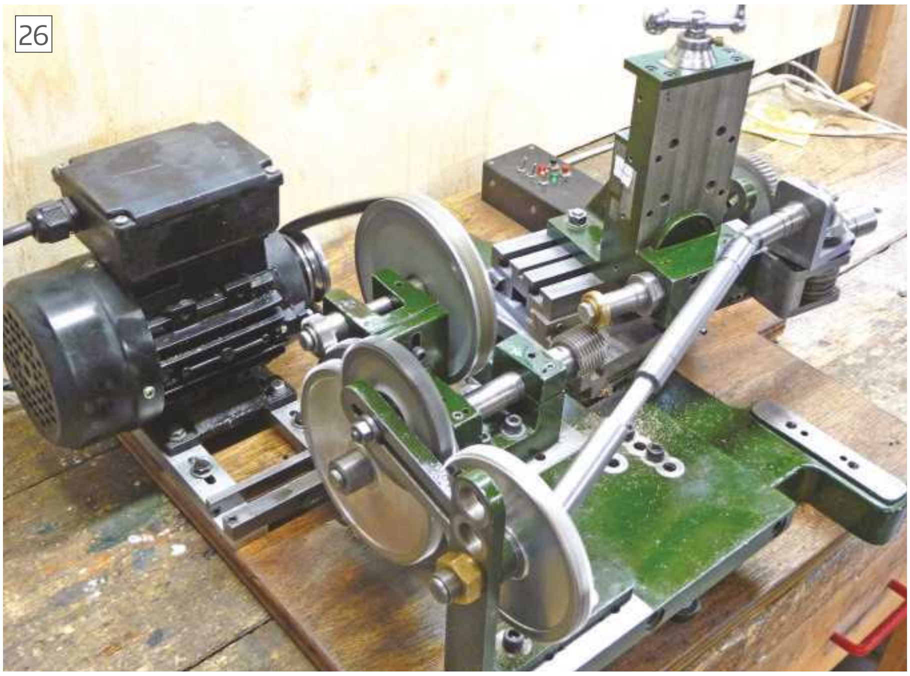
$\pi D \cos\alpha/(\pi D \cos\alpha + p \sin\alpha/R) = 1/(1 + p \tan\alpha/\pi RD)$ for a LH gear

The index ratio for a spur gear = M/T, so the index ratio for a helical gear is :

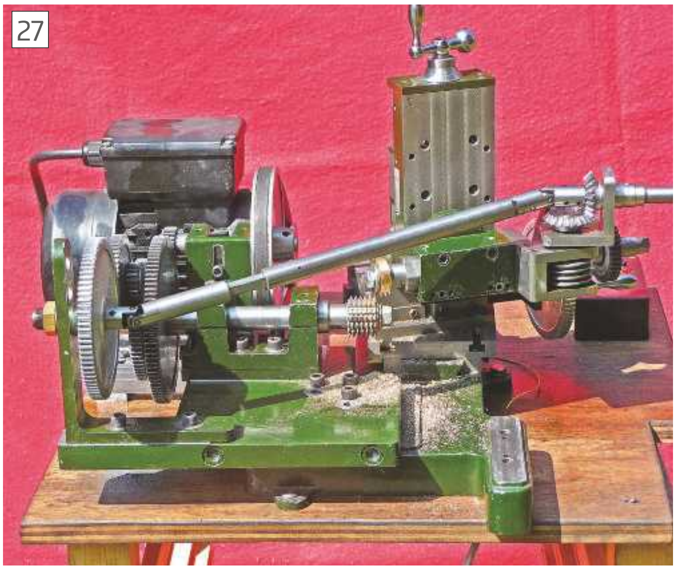
$I = M/\{T \times (1 - p \tan\alpha/\pi RD)\}$ for a RH gear

$I = M/\{T \times (1 + p \tan\alpha/\pi RD)\}$ for a LH gear

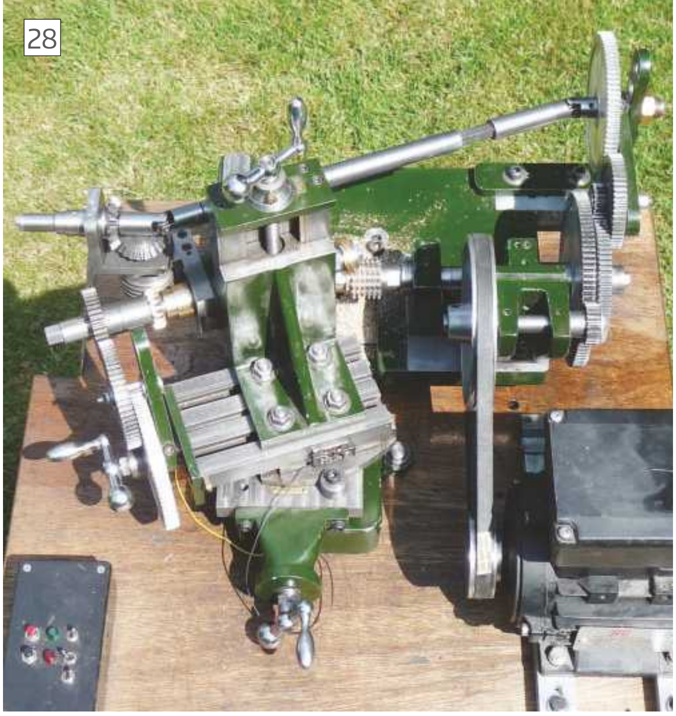
Now consider a practical example. We wish to cut a Mod 1, 20T gear with a RH helix angle of 200 with no profile shift (Ps=1). The PCD of the gear D = 20 x 1 x 1/cos 200 = 21.28 mm. If the machine constant M = 40 and the pitch of the feed screw p = 1mm and we



Setup for hobbing a 5T 27DP 780 HA LH gear

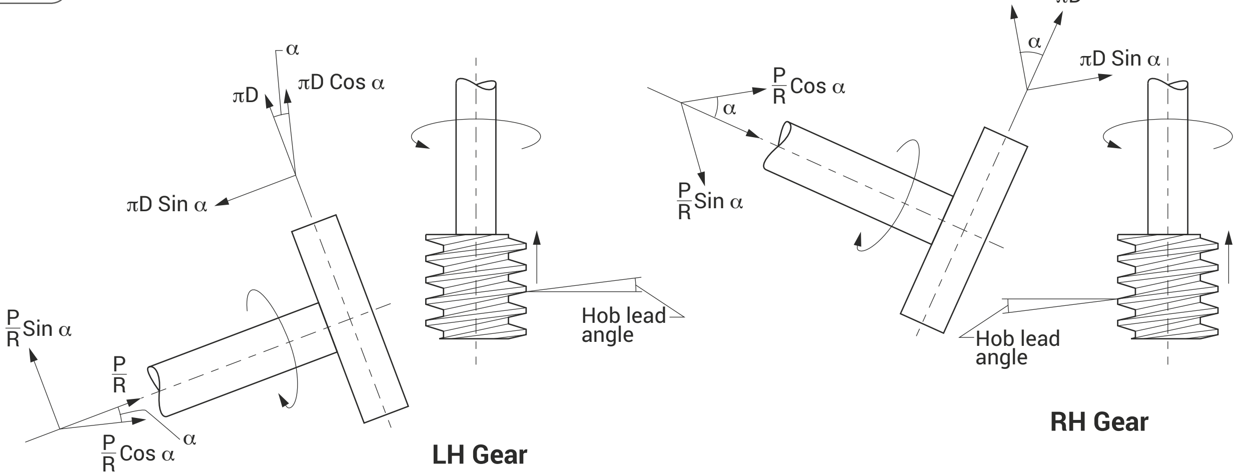


Setup for hobbing a 7T 22DP 730 HA RH gear



Plan view of hobbing a 7T 22DP 730 HA RH gear

Fig.8 *Motion diagram for hobbing helical gears*



choose a trial feed ratio R = 10 then the index ratio is :

I = 40/20{ 1 - [1 x tan 200 / (π x 10 x 21.28)]} = 2.0010893

If we wish to cut the similar gear with a LH helix then the index ratio is :

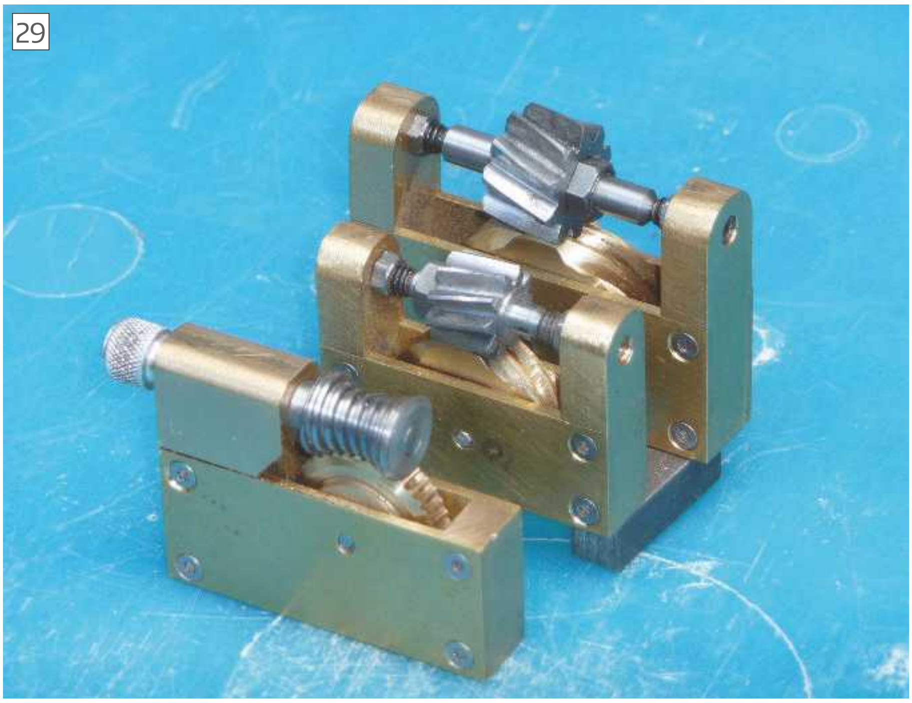
I = 40/20{ 1 + [1 x tan 200 / (π x 10 x 21.28)]} = 1.9989119

These are awkward ratios. However, help is at hand with a mathematical device called continuous fractions which is described simply in Ivan Law's excellent book, Gear and Gear Cutting on pages 92-94.

Method of determining compatible combinations of Index and Feed gears

A hobbing machine has two key sets of gear trains, the index train and the feed train. Each train is usually a set of four gears compounded making a total of eight. To make a satisfactory helical gear the ratios of each train (I for the index train and R for the feed train) must be related as per the above formulae and be exact within a small error not greater than a few parts per million (ppm).

It is feasible to test all possible combinations of 4 gears compounded to find the closest approximation. If we have



The finished high helix angle gears with a 16tpi pitch double enveloping worm and wheel.

80 gears, say 21T to 100T, then the total possible permutations of 4 in a compound train is 80P4 = 80!/(80 - 4)! = 80x79x78x77 which is about 38 million. But because the effect of the same two gears in the first driver/driven pair or the second driver/driven pair is the same, it is half of this, about 19 million, still a lot. While this can be done in Excel using macros it would use much computing power and memory. Such a method is termed "brute force".

A more elegant alternative is to use a mathematical concept called a continuous fraction. Referring to **fig. 9**, This states that any real number R can be expressed by a series of integers in the form of a continuous fraction as shown. When the fraction is rearranged the resulting integers can represented by gears tooth numbers. The further the fraction continues the nearer the approximation to the exact value. Figure 9 also shows the first 5 integers for the continuous fraction for π and how they are calculated. This leads to the well known second approximation 3 1/7 or 22/7 which has an error of 402 ppm. What is less well known is that the third and fourth approximations approach the exact value with errors of 27 ppm and less than one part per 10 million respectively and are achievable with practical gears. For example, 333/106 = 30/20 x 111/53 for the third and 355/113 = 71/20 x 100/113 for the fourth.

A spreadsheet has been written using this process to identify a compound set of four gears which will closely approach any given ratio. It first looks at the combinations of four gears to approach the exact index ratio required. If we take our example of a Mod 1, 20T gear with a RH helix angle of 200 and a trial feed ratio of R = 10 (see table 4), we need an index ratio of 2.0010893. The spreadsheet searches pairs of 16 driver gears and 58 driven gears, i.e. 928 combinations (as opposed to 19 million required by the brute force approach) which when combined with two other gears will closely approach the exact value. Examination of the driver/driven pair 89/82 reveals that when combined with the pair 59/32 delivers a ratio of 2.0011433 which is exact within 27 ppm. The gear cluster also has to have a minimum centre distance, about 5.5" for the Jacobs hobber. Gear combinations which do no meet this requirement are rejected.

Now recalling that the exact ratio was for a TRIAL feed ratio of 10 we can refine the solution by back calculating the exact feed ratio needed to produce a required index ratio of 2.0011433. The result is 9.527799. Using the same process to find a set of four gears to approach this exact ratio we find when examining the driver/driven pair 24/77 that when combined with the pair 33/98 delivers a ratio of 9.5277778 which is an error of 2 ppm.

Now although this error is very small, it accumulates with each workpiece revolution that is needed to fully cut the gear. This will depend on the feed, the gear width and the helix angle. **Table 4** indicates just over 91 revolutions in this example. The aggregate error will result in an error in tooth thickness of the gear. In this case, it is under 5ppm which is negligible. For the vast majority of gears a model engineer needs to make, solutions can be found in this way with tooth thickness reduction errors of under 20ppm whereas up to 250 ppm is more than acceptable. 250ppm is an error of 0.00025" (a quarter of a thou per inch of tooth width). A 20DP gear has a tooth width of 0.062" (1.57mm), so the linear error is 0.00016", under two hundredths of a thou. Setting errors will greatly exceed

Table 3 *Spreadsheet output for hobbing high helix angle gears*

HELICAL GEAR HOBBING CALCULATOR

27DP 5T Left Hand Gear 78 Deg HA

No teeth of gear	T	5	
Module	DP 27	0.94	
Helix angle	A	78	Deg
Machine constant	M	16	
Hand of helix. RH = 1, LH = -1		-1	
Cross feed pitch	p	1	mm
Width of gear	W	7	mm
Trial Cross feed ratio	Rt	25	
Standard index ratio		3.2000000	
Corrective ratio for trial feed		0.9973593	
Corrected ind ratio for trial feed		3.191549622	
Corrected ind ratio used		0.99735015	
Cross feed ratio exact		24.9138191	
Depth of cut D + f		2.029	mm
Cross feed ratio used		24.91379310	
Helix angle radian	A rad	1.36	radian
Cos helix angle	Cos A	0.208	
Tan helix angle	Tan A	4.705	
Pitch diameter of gear	D	22.62	mm
Pitch circumference of gear		71.07	mm
OD of gear		24.51	mm
ID of gear		20.45	mm
Lead		15.11	mm
Corrective ratio exact		0.997350146	
Corrective ratio used		0.997350143	
Exact feed ratio		24.913819	
Feed to traverse gear		33.668	mm
Cross feed per rev of wk arbor		0.0401	mm
No revs of wk arbor to cut gear		838.80	
Dist normal to hob teeth/rev exact		14.7379638	mm
Dist normal to hob teeth/rev used		14.7379637	mm
Tooth thickness error/rev		0.000000041	mm
Tooth thickness error total		0.000034178	mm
Thickness of tooth		1.48	mm
Thickness reduction		23.13	ppm
CP		2.96	

Feed gears		Ratio	24.91379310	Total
Driver 1	Driven 1	Driver 2	Driven 2	teeth
29	68	8	85	190

Index gears		Ratio	3.19152047	Total
Driver 1	Driven 1	Driver 2	Driven 2	teeth
59	72	74	19	224

HELICAL GEAR HOBBING CALCULATOR

22DP 7T Right Hand Gear 73 Deg HA

No teeth of gear	T	7	
Module	DP 22	1.15	
Helix angle	A	73	Deg
Machine constant	M	16	
Hand of helix. RH = 1, LH = -1		-1	
Cross feed pitch	p	1	mm
Width of gear	W	7	mm
Trial Cross feed ratio	Rt	25	
Standard index ratio		2.2857143	
Corrective ratio for trial feed		0.9984957	
Corrected ind ratio for trial feed		2.282275814	
Corrected ind ratio used		0.99850478	
Cross feed ratio exact		25.152652	
Depth of cut D + f		2.490	mm
Cross feed ratio used		25.15263158	
Helix angle radian	A rad	1.27	radian
Cos helix angle	Cos A	0.292	
Tan helix angle	Tan A	3.271	
Pitch diameter of gear	D	27.64	mm
Pitch circumference of gear		86.84	mm
OD of gear		29.95	mm
ID of gear		24.97	mm
Lead		26.55	mm
Corrective ratio exact		0.998504785	
Corrective ratio used		0.998504783	
Exact feed ratio		25.152652	
Feed to traverse gear		23.942	mm
Cross feed per rev of wk arbor		0.0398	mm
No revs of wk arbor to cut gear		602.21	
Dist normal to hob teeth/rev exact		25.3518174	mm
Dist normal to hob teeth/rev used		25.3518174	mm
Tooth thickness error/rev		0.000000031	mm
Tooth thickness error total		0.000018517	mm
Thickness of tooth		1.81	mm
Thickness reduction		10.21	ppm
CP		3.63	

Feed gears		Ratio	25.15263158	Total
Driver 1	Driven 1	Driver 2	Driven 2	teeth
19	59	10	81	169

Index gears		Ratio	2.28229665	Total
Driver 1	Driven 1	Driver 2	Driven 2	teeth
53	88	72	19	232

Fig.9

Expression for continuous fractions and 5 approximations of π

$$R = N_0 + \cfrac{1}{N_1 + \cfrac{1}{N_2 + \cfrac{1}{N_3 + \cfrac{1}{N_4 + \text{etc}}}}}$$

Where N_0, N_1, N_2, N_3, N_4..... are integers.

Taking π as an example. Working to 6 decimal places π = 3.141593. If we subtract the whole integer part 3 (which can be considered as a first estimate we are left with 0.141593 whose reciprocal is 7.062513. So the second estimate is 3 + 1/7 - 22/7. Continuing the process, if we subtract 7 from 7.062513 we are left with 0.062513 whose reciprocal is 15.99596. The integer part of this is 15 soo the third estimate is 3 + 1/(7 + 15) = 333/106. Going one step furhter if we subtract the integer part from 15.99596 we get 0.99596 whose reciprocal is 1.003417 so the next integer is 1 giving our fourth estimate as 3 + 1/(7 + 1/(15 + 1/1)) = 355/113.

$$\text{Pi} = 3 + \cfrac{1}{7 + \cfrac{1}{15 + \cfrac{1}{1 + \cfrac{1}{292 + \text{etc}}}}}$$

Exact 3.14159265

(to eight decimal places)

Approximate number	Numerator	Denominator	Decimal	Error ppm
1	3	1	3	-45070
2	22	7	3.14285714	402
3	333	106	3.14150943	-26.5
4	355	113	3.14159292	0.085
5	103993	33102	3.14159265	-0.0002

›

Table 4 *Spreadsheet output for 20T, Mod1, 20 Deg HA helical gear*

HELICAL GEAR HOBBING CALCULATOR

20T, Mod 1, 20 Deg PA RH GEAR

			Input	Unit
No teeth of gear	T		20	
Module	DP	25.4	1.00	mm
Helix angle		A	20	Deg
Machine constant	M		40	
Hand of helix. RH = 1, LH = -1	h		1	
Cross feed pitch	p		1	mm
Width of gear		W	9	mm
Profile shift ratio		Ps	1.00	
Trial Cross feed ratio	Rt		10	
Standard index ratio		Is	2.0000000	
Corrective ratio for trial feed	Ct		1.0005446	
Corr'd ind ratio for trial feed	Ic		2.0010893	
Corrected ratio used		Cu	1.0005716	
Cross feed ratio exact		Re	9.527799	
Depth of cut D + f		Wd	2.157	mm
Cross feed ratio used		Ru	9.5277778	
Helix angle radian		A rad	0.35	radian
Cos helix angle		Cos A	0.940	
Tan helix angle		Tan A	0.364	
Std PCD of gear		Ds	21.28	mm
Pitch diameter of gear		D	21.28	mm
Pitch circumference of gear	Pc		66.86	mm
OD of gear		OD	23.28	mm
ID of gear		ID	18.97	mm
Lead		L	183.71	mm
Corrective ratio exact		Ce	1.000571646	
Corrective ratio used		Cu	1.000571648	
Exact feed ratio		Re	9.527799	
Feed to traverse gear		Ft	9.578	mm
Cross feed per rev of wk arbor	Fr		0.1050	mm
No revs of wk arbor to cut gear	N		91.25	rev
Dist nml to hob teeth/rev exact	Se		62.8677707	mm
Dist nml to hob teeth/rev exact	Su		62.8677708	mm
Tooth thickness error/rev	e		0.000000079	mm
Tooth thickness error total	E		0.000007254	mm
Thickness of tooth		t	1.57	mm
Thickness reduction		tr	4.62	ppm

Feed gears		Ratio	9.5277778	Total
	Driven	Driver		
Driver 1	1	2	Driven 2	teeth
24	77	33	98	232

Index gears		Ratio	2.0011433	Total
	Driven	Driver		
Driver 1	1	2	Driven 2	teeth
59	82	89	32	262

this. For example, an error of one minute of arc (1/60th of a degree) in setting the helix angle for this example will lead to an error of 1600 ppm (1.6 thou/inch) and a linear error in tooth width of 0.001''.

Worm gears using tangential feed

As already discussed, the index ratio for hobbing a worm gear with tangential feed:

$I = M/\{S \times T(1+ p/\pi RD)\}$

At this point, exactly the same process is used in the spreadsheet as for helical gears to find compatible combinations of index and feed gears.

Note: The profile shift ratio (Ps) for most gears is 1, i.e. no shift. However, when cutting gears having low numbers of teeth (say less than 13) this ratio can be set above 1 to avoid undercutting the teeth. This is more severe with hobs having a 14.5-degree pressure angle than those with a 20-degree pressure angle. For a 10-tooth gear with a 14.5-degree PA hob the ratio Ps needs to be about 1.1 to avoid undercutting. This essentially means that the gear is cut on a PCD 10% greater than standard. It also means that the effective pressure angle is greater which increases the separating force between the gears in operation. On the bottom left of photo 30 can be seen a 20DP, 14.5-degree PA, 5 tooth pinion which is highly profile shifted to avoid undercutting. This gear is unsuitable for power transmission due to having a low tooth contact ratio but is fine as a feed gear. Another application is to meet a requirement for two gears of one tooth difference having the same PCD for instance in the design of some epicyclic gears. If a 40-tooth gear has a Ps = 1.012 and a 41 tooth gear has a PS = 0.988, they will have a common PCD.

30

31

Examples of gears made on the Jacobs Hobbing Machine

Conclusions

The Jacobs hobber, while not sturdy enough for production work is capable, with simple modifications, of performing most of the functions of an industrial universal gear hobbing machine. A great variety of satisfactory spur, helical and worm gears can be made in most sizes required by the model engineer. As well as the standard powered cross feed, automated plunge and tangential feeds can be accommodated. The range of gears that can be made is illustrated in **photo 30** and **photo 31**.

If any reader would like further details, or a copy of the Excel gear calculator spreadsheets, please contact me through the Model Engineer Forum[4] thread titled "Gear Hobbing (mechanical)".

References

1. College Engineering Supply. www.collegeengineering.com
2. Model Engineers' Workshop No.169 pp 36-42, No.170 pp 32-35, No.172 pp 44-48 2010/11
3. Gears and Gear Cutting. Ivan Law Workshop Practice Series No.17 Nexus 1988
4. www.model-engineer.co.uk ■

Readers' Tips

CHESTER MACHINE TOOLS

Tailstock Mod

TIP OF THE MONTH WINNER!

This month, Howard Winwood wins this month's Chester Vouchers with a simple tip for owners with wayward tailstocks!

A lot of far eastern lathes have a similar arrangement of lever locking tailstock and I would imagine all based on the same principle of pulling a plate up onto the underside of the lathe bed, thereby clamping the tailstock.

I have been cussing and swearing at mine for ages as the bolt used to position this locking plate, gradually works loose. It might only be about an eighth of a turn, but it is enough that the locking lever ends up vertical without providing full locking force. I then have to delve under the lathe bed and try and turn the bolt a fraction with my fingertips to get back to status quo.

I then thought I have got to do something as my hair is thin enough as it is.

The solution was easier than I had imagined, as it only needed a small spring between the bolt head and the locking plate to effect a cure. I just used what I had available that would fit over the bolt threads, from a cheap box of mixed springs that are widely available.

I am sure there are other things that could be used such as soft rubber/foam pad/washer in place of the spring or one of those curly locking washers. I have included photos so readers can see if it resembles the locking arrangement they may have.

Having done it, I still kick myself for not having done something about it sooner, one lives and learns I suppose.

Toolholder Modification

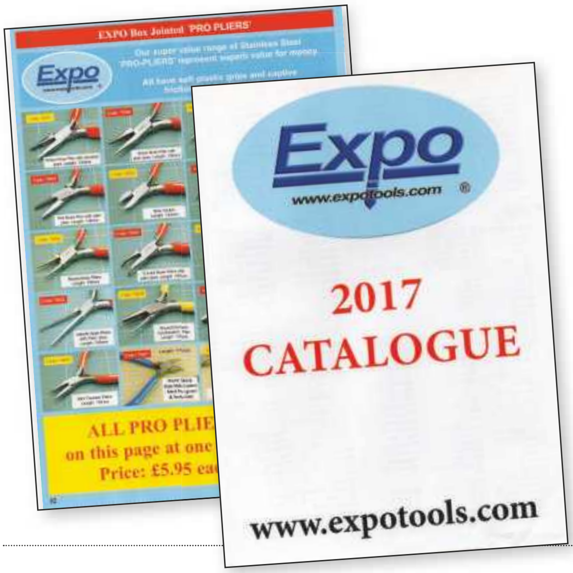
Runner up Alan Wood likes to keep his workshop tidy. He wins a prize from the MEW lucky dip!

I am a lover of tool boards so tools etc have a known home. Many tools have a 'hole for hanging' and my solution for hanging is to use standard 100mm x 4.5mm galvanised nails shaped and cut to length for my tool boards. The head of the nail is already ideal in that some tools will drop over it and be retained. If the tool will not pass over the head as standard then I turn the head down and the adjacent length of nail body and then cut the rest of the nail to a length that is the depth of the hanging back board. After shaping the head and cutting to length a crude chamfer is put on the sawn end with the bench sander and the nail driven into a 4.4mm hole in the backboard to the depth of the unturned section. If you change the tool you can easily pull the nail and turn a new profile on a new nail for the new tool.

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 I'll chose a selection for publication and the one chosen as Tip of the Month will win £30 in gift vouchers from Chester Machine Tools. Visit **www.chesterhobbystore.com** to plan how to spend yours!

Please note that the first prize of Chester Vouchers is only available to UK readers. Other prizes are at the discretion of the Editor.

On the Wire NEWS from the World of Hobby Engineering



New catalogue from Expo Tools

The new catalogue form expo Tools has arrived, now over 130 pages long its packed with tools, materials and other items for a wide range of modelling work. Of particular interest to readers will be things like the excellent selection of small hand tools as well as paints and adhesives. They stock the full range of Albion Alloys materials such as small section tube and shimstock.

If you like making working models and mechanisms, then you will find Expo's range of small motors, gears and other accessories particularly useful. Their motors with built-in gearboxes are ideal for driving display models when a supply of steam or compressed air is impractical.

Proxxon MICRO mills for the model engineer

Brimarc Tools & Machinery has introduced two MICRO mills to its Proxxon range of model engineering machinery.

The FF 500/BL mill and CNC version both feature a brushless direct drive motor. Both are quiet and vibration-free and operate with a high level of precision. The MICRO mills have a wide speed range, variable from 200 to 4,000rpm, with a clear 4-digit display. Electronic speed control and speed sensors guarantee high torque when using large milling cutters at lower speeds.

The milling head can be angled both left and right by 90° either way. The spindle sleeve is lockable and pre-machined should you wish to fit the optional fine feed. Both models include four ER20 collets which fit directly in the spindle.

The CNC version features double roller bearing, re-circulating ball spindles at all three axes. Each axis has a powerful step motor (replacing the hand wheels) driving the compound table and the milling head. The package includes user-friendly software that runs under WINDOWS®.

Two freely usable output relays in the casing of the control unit manage additional functions. The CAD window automatically displays when the programme starts. At the click of a mouse, the programming converts the finished drawing into instructions for the machine. Machining can start immediately. However, manual machining is still possible with the help of cursor buttons.

The manual Proxxon FF 500/BL MICRO Mill is priced at £2,296.04 and FF 500/BL-CNC MICRO Mill costs £4,948.55 (prices include VAT and were correct at time of going to press). For more information and to find a Proxxon retailer, visit brimarc.com/proxxon or call 03332 406967.

Proxxon FF 500/BL MICRO Mill

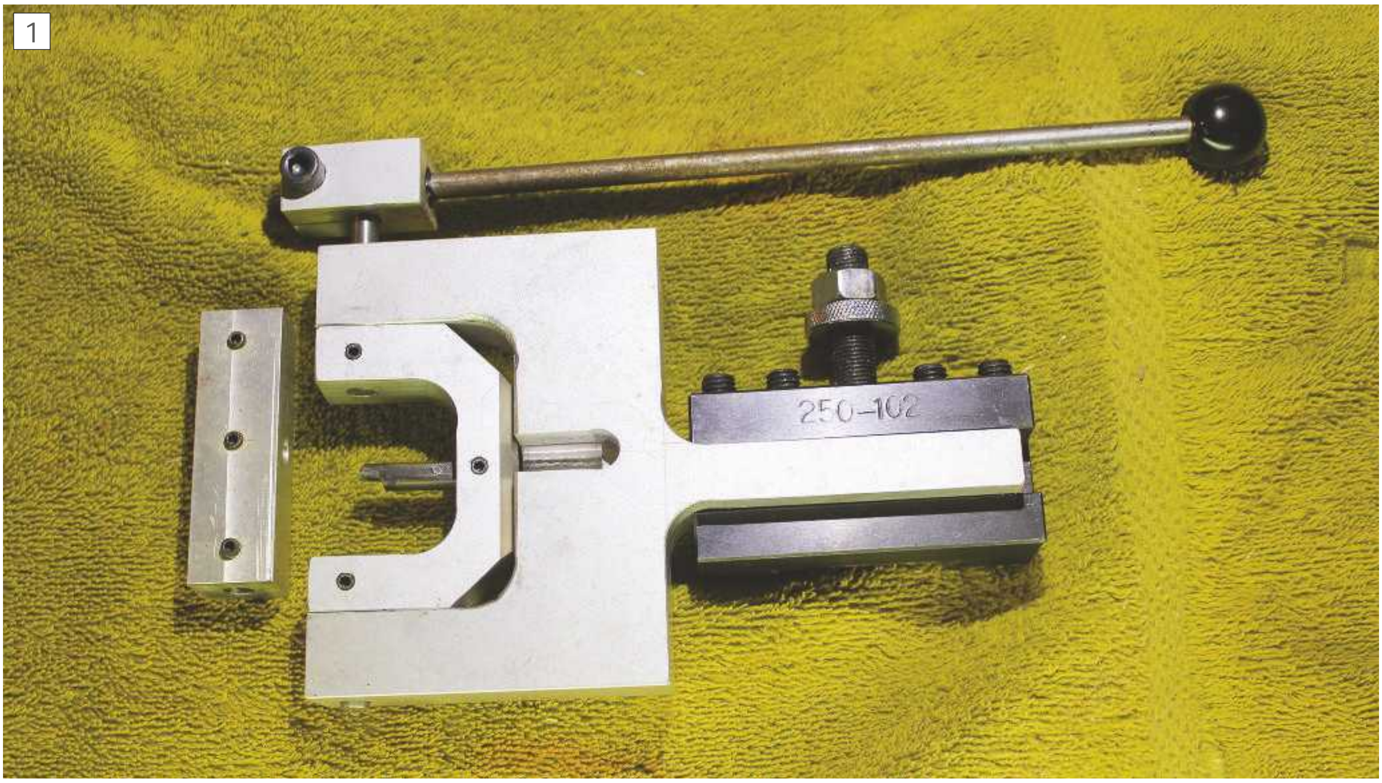
Proxxon FF 500/BL-CNC MICRO Mill

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

Write to The Editor, Neil Wyatt, Model Engineers' Workshop, MyTimeMedia Ltd., Suite 25, Eden House, Enterprise Way, Edenbridge, Kent TN8 6HF. Alternatively, email: neil.wyatt@mytimemedia.com

Creating compound curves in the lathe

David J Graves

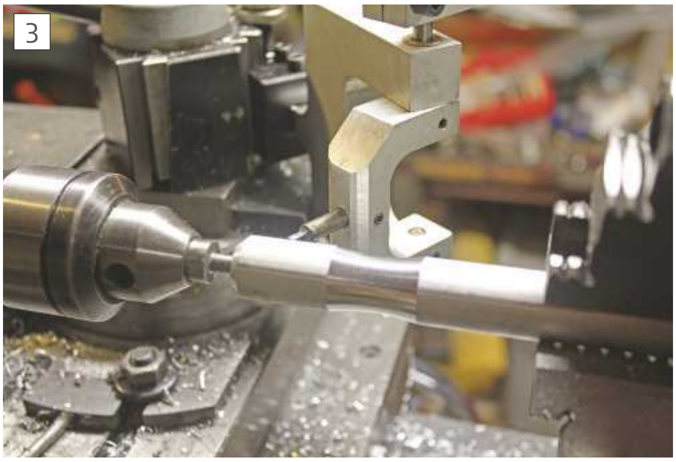


The C-style rounding tool

Introduction

The lathe in its normal configuration is a great tool to create cylindrical, conical, and flat surfaces, but sometimes these shapes are not enough. How do you make a compound curve such as a fillet (cove), bead, roundover, or section of a sphere? Actually, these forms should really be called solids of revolution, where the generating curve is part of a circle, but the simpler designation should be clear. Most commonly, creating a complex surface is accomplished with an add-on tool. Other than using a CNC machine, which few of us can afford to buy or have the patience to build, several ways to accomplish the goal exist, most of which are really just simple variations on the theme of rotating the cutting tool around an axis. Since compound curves add a bit of elegance and are sometimes essential in producing a turned object, I have used them and find that creating them can be fun as well as utilitarian. Our editor, Neil, suggested

A column base with cove and roundover features



Forming a concave surface on a handle

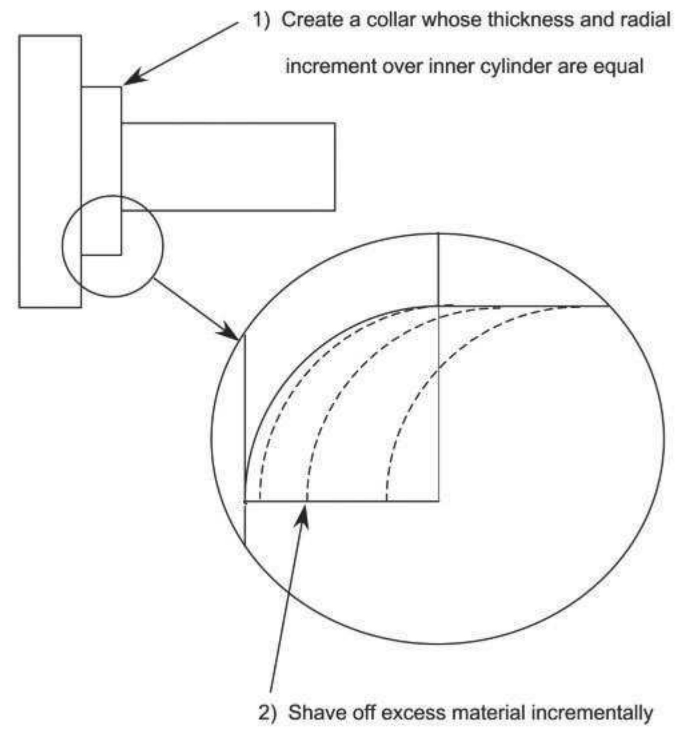
that readers would appreciate a general review, even though all the methods to be discussed are well known.

I use several methods on a regular basis (as much any amateur activity can be considered "regular"). Two of these involve using a jig mounted on the cross slide or top slide that can swivel about an axis. The compound or top slide in theory could be used, but since one often wants the tip of the cutting tool very close to the axis of rotation, the top slide axis is generally not very useful by itself. Fortunately, add-on devices are not difficult to build, and some can be purchased, although the price of a commercial version can vary considerably from one design to another. Recently, I have even seen a commercial variation of this method with two separate vertical axes that apparently offers increased versatility in the type of curves produced, but I have no experience with such a tool. Two common variations I will cover are rotation about the vertical and horizontal axes. I will also mention a method that might be called HNC (human numerical control) that is not nearly as tedious as it sounds, along with presenting a simple computer program to generate the x,y coordinates for HNC. In addition, I will give some examples of real applications using each method, including a step-by-step development of ball handles (with a spherical section at each end) based on the work of George H. Thomas in one of his books (ref. 1).

Rotation Around a Vertical Axis

The first sphere-forming tool I made was based on a C-shaped support with an extension that can be clamped in a standard lathe tool holder, **photo 1**. This was at least fifteen years ago, based on a design discovered on the Internet. I believe that the design I used was that of Tuckwood (ref. 2), but I am not sure. There are so many such designs currently available that it may have preceded or followed this one. Inside the major C frame piece on an axis near the outer edge is a second C-shaped holder for a cutter (for large curves) or a straight holder (for small concave ones). Both concave and convex cuts can be produced, depending on the orientation of the tool holder. The actual cutter was made from 1/4" drill rod, which is easy to harden and temper. Commercial versions of such a device are available and plans for homemade ones are available on the Internet. I made mine from 1" aluminum and used sintered bronze bearings for the axis rod to ensure that there was no slop in the rotary movement. **Photograph 2** shows a piece that was turned, using such a tool to produce roundovers and a cove for a column base. The most difficult part of using any of these rotational tools is setting it up properly. The tip of the cutting tool must be level with the lathe axis, the distance of the cutting tip from the tool holder axis must be accurately set, and the

Fig.1



Creating a cove by starting with a collar

4

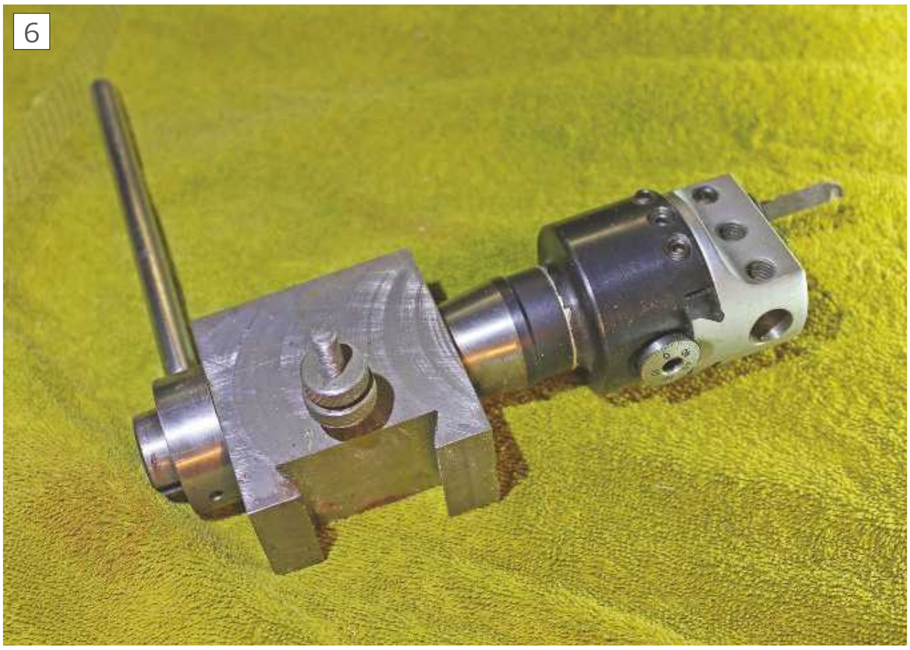
The handle after polishing

x and y coordinates on the lathe have to be correct.

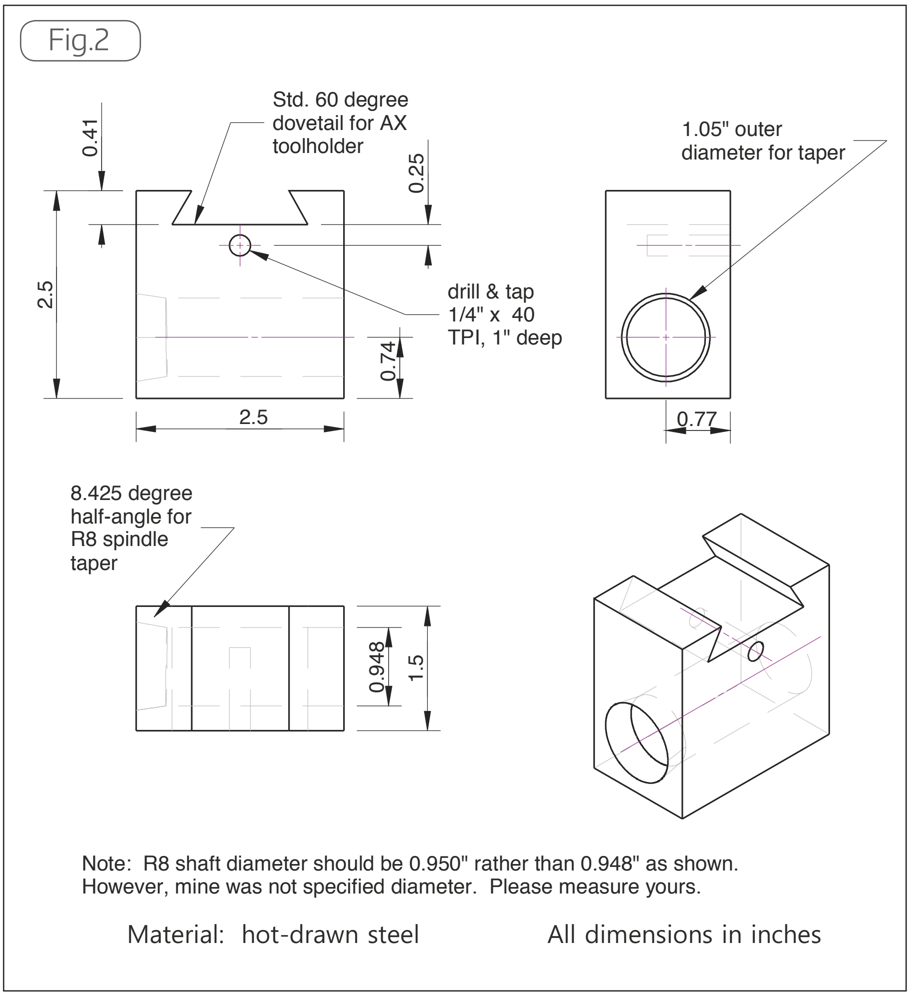
The cove cut is more difficult than the roundover, and a digital readout on the lathe is particularly useful so that one can "sneak up" on the correct profile without undercutting either of the adjoining surfaces seen in the photo. Since the curved surfaces are more likely to be aesthetic than to require dimensional precision, a bit of additional trimming after an undesirable undercut normally is not a disaster. **Figure 1** shows in cross section a suggested way to cut a cove starting from a cylinder and base with an intermediate collar that will be cut off for the cove to eventually appear. **Photograph 3** illustrates a common use for this tool: creating a comfortable handle. This one is part of a tapping tool. **Photograph 4** shows the handle after polishing, and **photo 5** illustrates the completed tapping device with two handles.

The major limitation of this type of vertical axis tool is that the swinging C and the handle used to rotate it can foul the lathe chuck if one is trying to turn more

A pair of handles on a tapping device



The "up-and-over" tool



than a hemisphere on the end of a short piece of stock. In fact, it may be impossible to use for certain jobs, such as ball handles. My search for the original "C" design showed that a variation of the vertical axis tool seems to be more favored recently and appears quite different. Rather than having a bearing at each end of the axis of rotation, a short stubby cylinder supported at only at the bottom end is used (fig. 3). The cutting tool extends only slightly above the cylinder, creating a lower chance of fouling the lathe chuck. However, there is another way to create largely spherical objects: changing the axis of rotation. This leads us to the second variation.

Rotation Around a Horizontal Axis

The first photo of Chapter 8 in Thomas's book shows a special tool he made to create ball handles, and it looks very much like a standard boring head. He called it an "up and over" tool for obvious reasons. Making one of these to create ball handles looked like a lot of work to me. But I had a cheap boring head that was sitting idle once I purchased a much better one that could actually be adjusted accurately to the desired radius. (This is a warning to anyone contemplating the purchase of such a cheap imported head to bore large holes accurately.) The cheap boring head works fine as a dedicated sphere cutter, however, provided that you are content to make some trial-and-error cuts on scrap pieces to get the radius exactly right. And if you have multiple pieces to make, do not be tempted to touch the radius adjustment until all have been cut to the desired size.

Since this is a new design that others might wish to copy, I have provided a dimensioned drawing of the major item in my version as **fig. 2**. My boring head was supplied on an R8 shaft and the mount is a standard AXA size dovetail quick-change type, **photo 6**. Note that only a small portion of the taper extends into the mount. The collar at the other end secures the R8 shaft in the mount, and a handle is brazed into the collar. This is simple and appears to work nicely. However, other shafts such as Morse taper and other types of toolholders could be accommodated with a few changes in design. I did find that the head tended to unscrew itself from the shaft because of the back-and-forth motion during use and I loctited it to the shaft. Again, you can now find many plans for this type of tool on the Internet. (Something I discovered after patting myself on the back for cleverness.) Note that the "C" tool and the "up-and-over"

Ball creation and closeup of cutter tip

Front view of partially completed ball

tool are really complementary. Some shapes are more easily generated with one type of tool and some with the other.

Photograph 7 shows the assembled tool viewed from the rear of the lathe and doing its work. As with the vertical rotation tool, alignment is important. The rotational axis must pass perpendicularly through the lathe axis. With the tool rotated toward the tailstock, the tool axis also should be located exactly one radius from the end of the ball. (Normally, it can be set slightly in from the end, so that the cutter will shave a bit off at the axis of the stock). Since the ball-cutting radius is fixed in my method, cuts are taken by moving the cross slide inward, rocking the tool back and forth until the sphere centerline has been reached. You may find (especially with brass) that on parts of the cut, the surface can be rather rough and will require cleaning up with a file and abrasive paper. **Photograph 8** shows a ball being formed at an intermediate stage.

I have tried various cutter shapes to give smoother results with brass but so far without success. A large part of the problem was that brass can be difficult to machine with any significant positive rake on a tool. A negative rake is often specified, though that might not work in this case without having the tool rub. Photograph 7 also shows the shape of my most successful tool so far. It has a symmetrical beak shape so that it can cut on both edges as the cutter is rocked back and forth. I have tried cutting in one direction only and withdrawing the tool to return for another cut, but this is tedious and did not help with smoothness. However, filing in the lathe after turning the ball is not very time-consuming. Typically, I then start polishing with 150 grit abrasive paper and work up to 3000 to give a mirror-like finish after filing. In the States, the very fine grades of abrasive papers can be found at automotive product suppliers more easily than the usual industrial suppliers. I don't know if a similar situation exists in the United Kingdom. When the handles are to be plated, they are given a final buffing with a rouge-loaded cloth wheel. **Photograph 9** shows a ball end at three different stages of surface finish. Remember that plating will

Fig.3

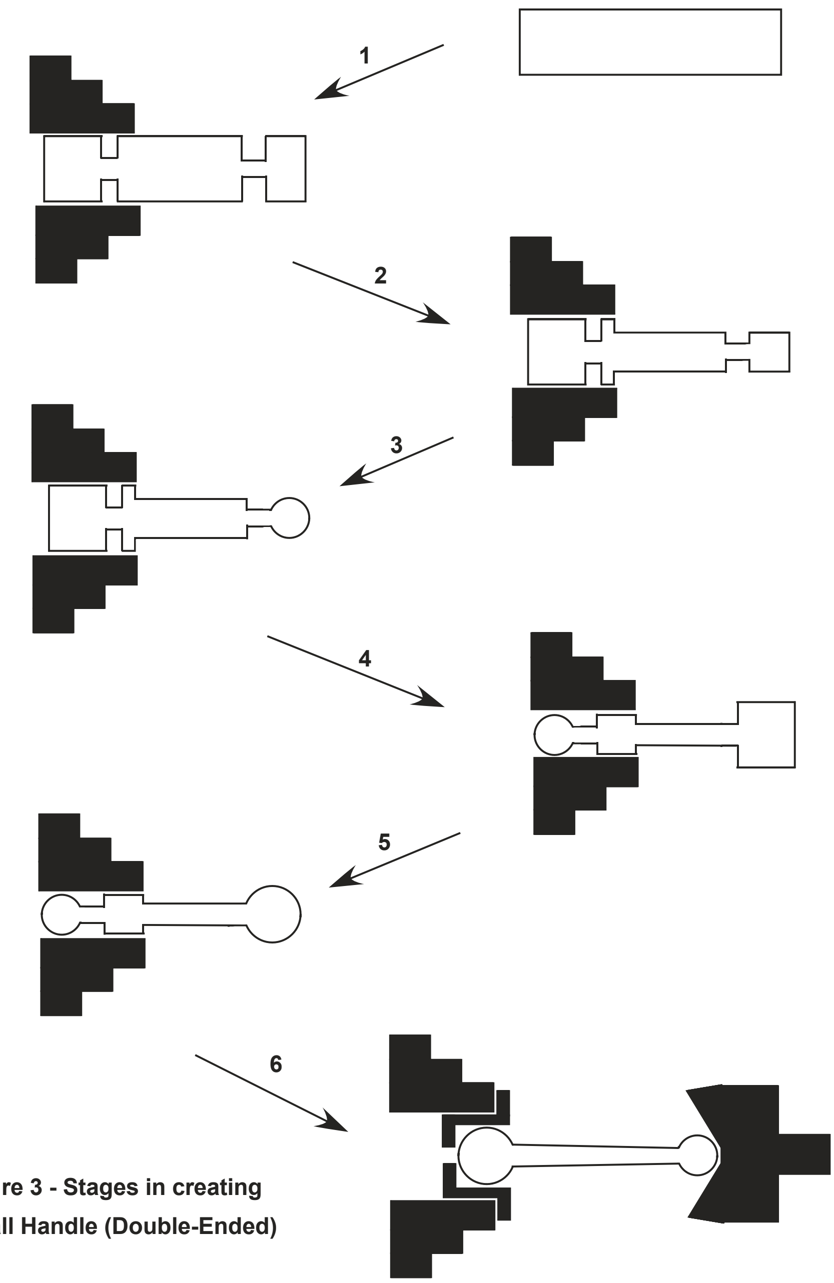
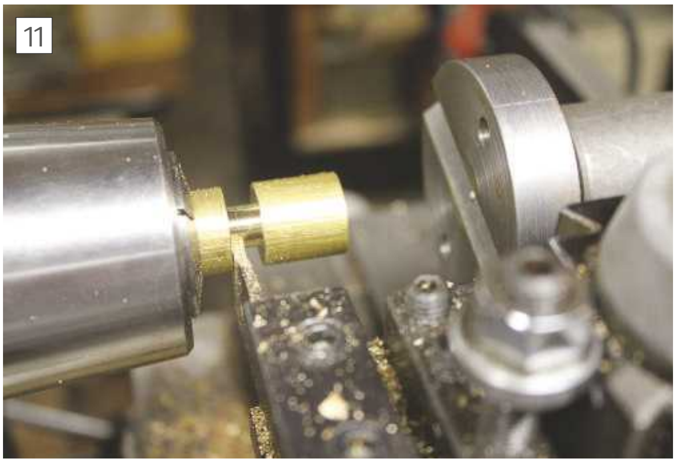


Figure 3 - Stages in creating a Ball Handle (Double-Ended)

Three stages of ball smoothing

The "top hat" and conical holding jigs



Grooving stock prior to turning a ball

Full set of handles with one ball end

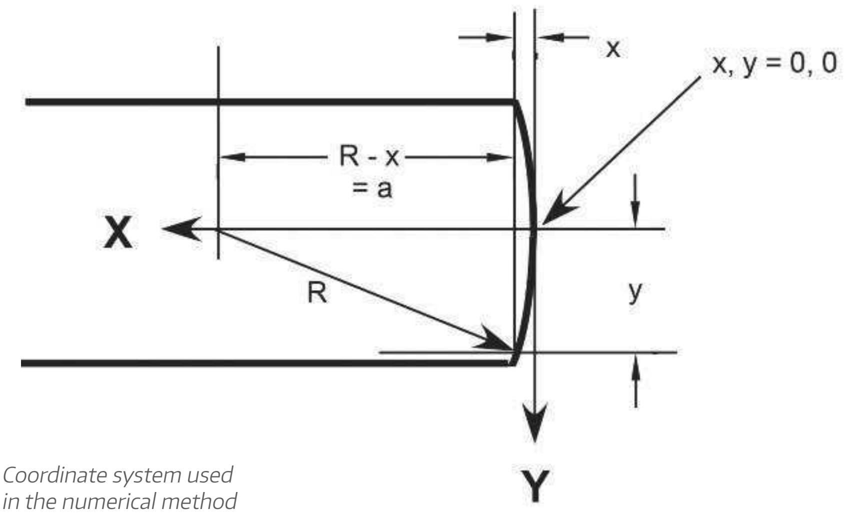
accentuate scratches rather than covering them up.

Two-Ended Ball Handles

I have seen a number of articles (including Thomas's book) in which the authors have created ball handles (with balls on each end) where the first ball was machined from a piece of stock and the second ball was threaded or loctited on the other end of a tapered shaft. This seems somewhat more time-consuming than the alternative, which is to machine balls on both ends of a single piece of stock. Chaddock, in his book on the Quorn, shows handles machined on a single piece of stock (ref. 4). Ron Chernich (ref. 5) gave the actual dimensions for Quorn cutter and grinder handles, so I will not repeat them here. However, **fig. 3** shows the sequence of steps to do this. Please forgive the apparently long "stick-out" from the chuck jaws as is shown. This figure is meant to be schematic only. Step 1 consists of using a parting tool to create diameters close to the desired final shaft dimensions and wide enough to permit the sphere-forming tool to swing in close to the axis. In step 2, one end and a significant part of the stock is reduced to slightly larger than the small ball diameter. Step 3 is simply forming the first ball. In step 4, the handle is reversed in the chuck and a significant portion of the shaft is reduced in diameter. If the first ball end is smaller than the cylindrical portion that is gripped in the chuck, the ball will not be damaged as the large cylindrical portion is clamped in the chuck jaws. In step 5, the larger ball end is formed. Finally, in step 6, the tapered shaft between the two ball ends is finished.

A crucial part of this last step is to have two special jigs on hand to hold the ball ends. At the headstock end, the jig looks like a top hat with a hole in the top. Two small slits in the top are made 120 degrees apart and a third slot wide enough to let the handle be oriented for facing, drilling and tapping is made through all parts of the hat, again at 120 degrees from the other two slits. **Photograph 10** shows two well-used versions I made for my large and small ball handles. At the tailstock end, a conically depressed support (also shown) is inserted in a live center and snugged up rather tightly on the handle. Both jigs should be made of a material that is not

Fig.4

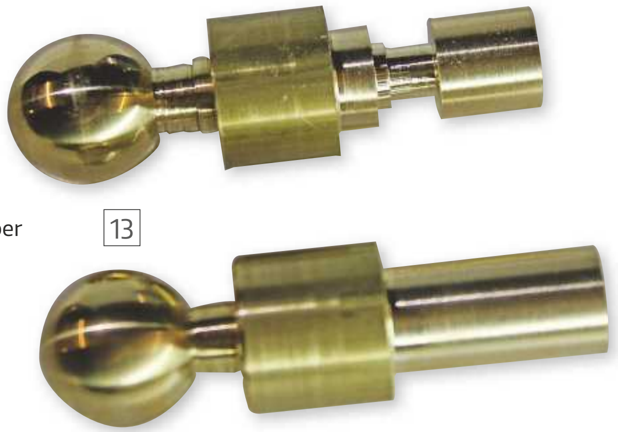


Coordinate system used in the numerical method harder than, and preferably softer than, the material comprising the handle to prevent scratching of the balls. I used brass holders for brass handles, though aluminum would have been better and probably would have prevented some minor scratches that had to be buffed out. Brass would be a good material to hold steel handles.

There is also another minor bit of work that I have not illustrated in fig. 3. The large ball must be faced at an angle, drilled and tapped for the desired size stud. This is seen in photos below. I made a set of handles for my Quorn tool and cutter grinder and liked the look and utility, so I made a second set for a pillar tool. For the latter set, I did have the foresight to record the sequence of steps in photos. If you look at the following photo sequence, you will see that it does not quite match the sequence shown in fig. 3: I did the big ends first rather than the small ones. It does not really matter; in fact, doing the large end first is probably preferable because it leaves a large diameter shaft to grip for a longer time. After polishing, the handles were sent out for commercial nickel plating. It may seem strange for me (a chemical engineer) to do the mechanical portions and then have the chemical part done commercially, but I was not keen on handling the waste products generated by doing the plating myself.

Here is the photo sequence of handle production: **Photograph 11** shows the generation of a clearance slot at one end of the stock. **Photograph 12** shows an entire set of handles with a ball at one end. The stages of reducing the shaft diameter for the small ball and cutting the relief slot are illustrated in **photo 13**. The product of all regular turning operations (without jigs) is shown in **photo 14**. In **photo 15** the setup for reducing the intermediate diameter and turning the taper can be seen. After the reduced cylindrical portion has been produced, I switched to a parting-off tool so I could turn the taper close to each ball end (photo 16). The cutter is rotated slightly from perpendicular to match the desired taper, using the top slide at the required angle. Most top slides have a pair of handles rather than a single one, and I discovered why as I was first learning to make these tapers. When I used only one handle, the taper exhibited a slight but visible spiral of bulges and hollows along its length (after plating!) due to pressure I inadvertently exerted normal to the axis of the top slide movement. I now grasp both handles to advance the top slide without side pressure.

A set of steps that I have not



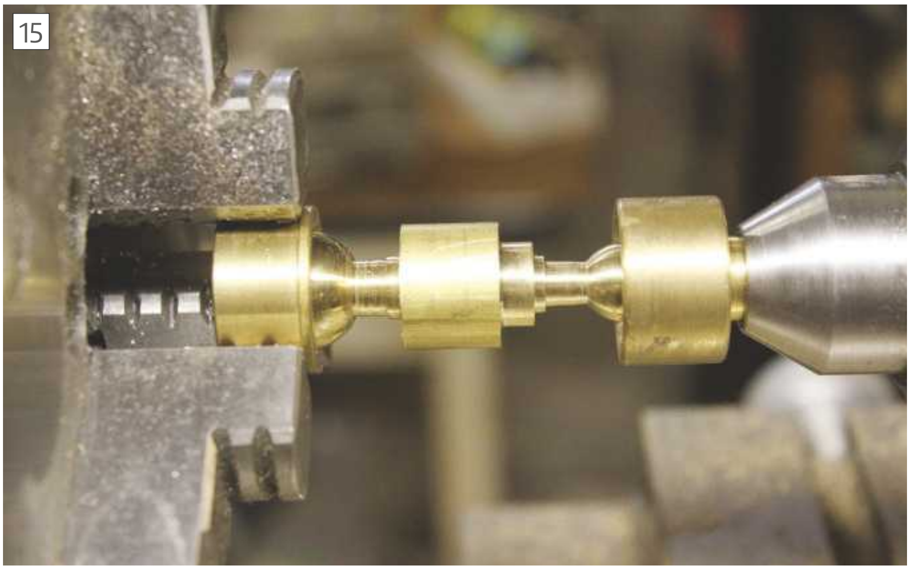
13

Two stages of prep for second ball end

14

Both ball ends complete

15



Mounted in jigs for final forming steps

discussed before is producing a flat on the large ball end and drilling and tapping it for the 1/4" x 20 TPI threaded rod that compresses cotters in the handles' final role. I was fortunate that my lathe chuck was large enough so that the handles could be rotated far enough back to create the desired angle, as shown in **photo 17**. Finally, the handles were tapped, as shown in **photo 18**. For completeness, the set of handles after return from the electroless plating firm is illustrated in **photo 19**. After a number of years of use, I have not had any problems with the plating rubbing off.

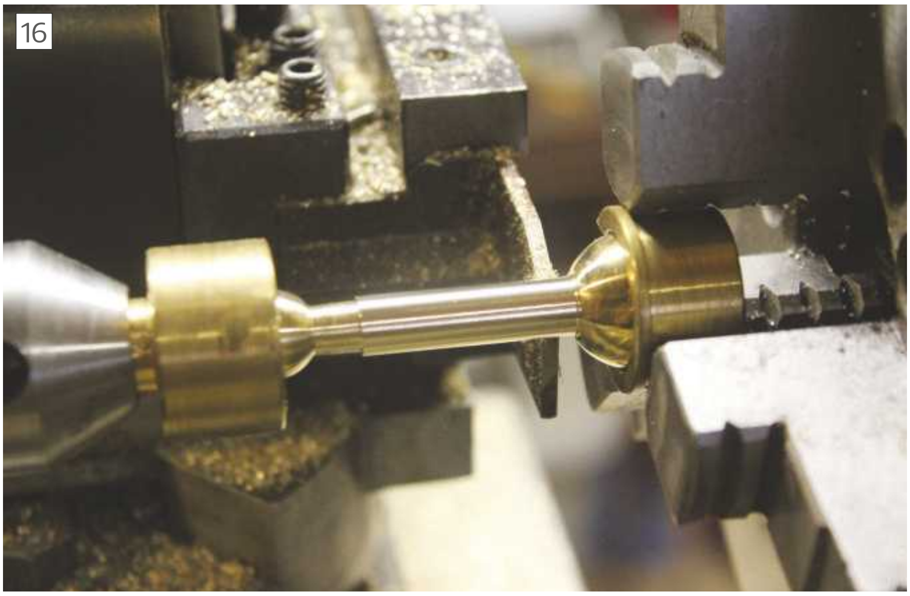
The "HNC" Method

My human numerical control method is quite simple and does not involve any special jigs or hardware. It is best done, however, on a lathe with digital readouts both on the lathe axis and the cross slide. Most such readouts permit presetting digital values, which is especially useful in this application. And, the method is best suited to simple and large-radius curves. The operator has a table of x, y values in front of him and simply adjusts the lathe hand wheels for each subsequent data pair in the table. Although this sounds tedious, I have found it much easier than, say, scribing many index lines on a dial. It does make a small difference whether one changes x and then y or vice-versa, so whatever order is chosen should be maintained throughout the process. I do not use this method often, but if a tablet or laptop computer is handy, it can be useful to provide the table of values. Of course, the stepped curves must be cleaned up with a file and abrasive paper after the initial shaping.

Suppose that one wishes to create a semi-spherical cap on the end of a rod in the lathe chuck, starting at the outside diameter and working toward the center. After a few x, y pairs, it is clear that a long x pass should be taken toward the tailstock to remove excess metal. Then, after returning to the previous x position, the next coordinate pair cut can be taken.

Figure 4 shows the geometry behind such a procedure. I have chosen to measure in a coordinate system where 0,0 is on the axis at the end of the cap and x is positive toward the headstock (backwards from the normal direction). The simple formula
$a2 + y2 = R2$
is used to find x and y pairs, where
$x = R – a$.

A very simple program in Basic providing data pairs is shown in **fig. 5**. The example shown is for a rod radius of 0.5 inch and a spherical radius of curvature of 0.9". However, the starting radius is 0.495" rather than 0.500" to be sure that at least a skim cut can be taken from the rod at the beginning. The formatting commands in Basic round off all x and y values to four significant figures for convenience. In metric, three significant figures would be sufficient. Everything else should be pretty self-explanatory and easy to follow. I chose an advance of 0.003" per step in y as a reasonable value, but this can be changed as desired. **Table 1** gives a few lines of


16

Ready for shaft tapering

Fig.5

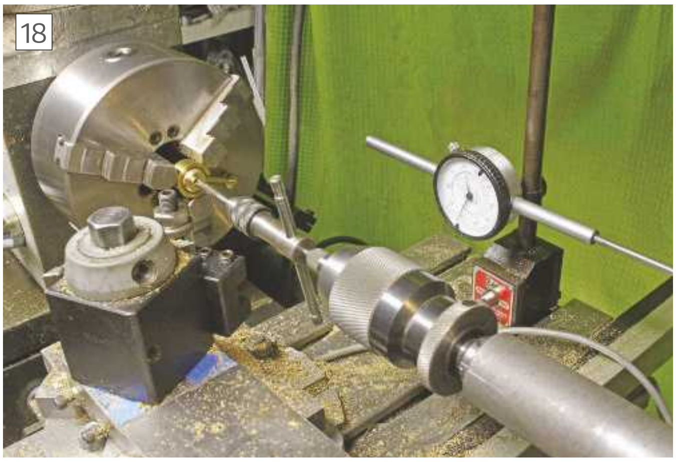
```
! This program calculates x and y coordinates to turn some portion
! of a spherical surface on the lathe.  The example assumes a one inch
! diameter rod and that the desired rod end has a 0.9 inch radius
! partial spherical cap on it.  The final x,y coordinates along the
! lathe axis will be 0,0.  The starting value of y is 0.495 inch
! rather than 0.500 inch to make sure that at least a skim cut is taken
! from the rod.  Place cutting tool at least 0.150 inch from end of rod
! and set digital readout to 0.1484, 0.495 after the skim cut.
!


PRINT "  x        y"
FOR y = 0.495 TO 0.000 STEP -0.003
 a = SQR(0.9*0.9 - y^2)
 x = 0.9 - a
 PRINT USING "#.####"; x;
 PRINT USING "    #.####"; y
NEXT
END
```

Basic program to generate sphere data


17

Setup to flatten one side of ball


18

Tapping a hole for stud

The handles after plating

Table 1

x	y
0.1484	0.4950
0.1464	0.4920
0.1444	0.4890
0.1425	0.4860
0.1406	0.4830
0.1387	0.4800
0.1368	0.4770
0.1349	0.4740
0.1331	0.4710
0.1313	0.4680
[many lines omitted]	
0.0022	0.0630
0.0020	0.0600
0.0018	0.0570
0.0016	0.0540
0.0014	0.0510
0.0013	0.0480
0.0011	0.0450
0.0010	0.0420
0.0008	0.0390
0.0007	0.0360
0.0006	0.0330
0.0005	0.0300
0.0004	0.0270
0.0003	0.0240
0.0002	0.0210
0.0002	0.0180
0.0001	0.0150
0.0001	0.0120
0.0000	0.0090
0.0000	0.0060
0.0000	0.0030
0.0000	0.0000

Sample data produced by the program

output with many intermediate data pairs omitted. You can use your judgement about whether one or more pairs can be skipped when cranking the hand wheels. Obviously the x value would be fixed at zero and y moved to its zero for the last ten or so data pairs.

Photograph 20 shows a knob with its end curvature created by this method. I did not remember the obvious scratches that are visible in this photo and am rather embarrassed to show an example that includes them. This was done quite a few years ago and I suppose I only noticed them after spending a considerable amount of time getting a good polish on the surface. And apparently I was too lazy to go back and eliminate them. I may just have to put the knob back in the lathe now and eliminate the scratches to ease my conscience. The moral is to be careful during the early stages of rough filing so that all of the staircase cuts have been smoothed out before moving on to the finer abrasive papers. A magnifier or hand microscope would be useful to ensure that no obvious defects like these are present at each stage of the smoothing process. An astronomy buff who has ground and polished a mirror will recognize the analogy.

Conclusion

If you have never tried such decorative but useful compound cuts in a project, I encourage you to experiment with one, using any of the methods discussed here. They are not difficult to produce and are actually fun as a change of pace from the usual demands of precision rather than artistry.

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(1) Thomas, G. H., "The Model Engineer's Workshop Manual," W. A. Bennett, ed., TEE Publishing, 1984.
(2) Tuckwood, J., http:/www.metalwebnews.com/howto/baltool/balltool.html
(3) bedair.org/Ball/ball2.html
(4) Chaddock, D. H., "The 'QUORN' Universal Tool and Cutter Grinder," TEE Publishing, 1984.
(5) Chernich, R., "A Rank Beginner Builds the QUORN Universal Tool and Cutter Grinder," http:// Modelenginenews.org, #844, 1996. ■

Rounded end produced by "HNC"

FREE PRIVATE ADVERTS

Machines and Tools Offered

■ Myford metric change gear set by SOBA, complete with banjo plate and studs, unused still in the box. Myford vertical slide and fixed steady, job lot £150, buyer to collect please.
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■ SEIG X2P mill spindle, R8 taper, brand new never used, £16 plus p&p.
T. 01536 482916. Northampton.

■ Cowells B-100 vertical milling machine, excellent condition, as new. Variable speed. Plus box Clarke 20pc end mills, £1,250 ono. Also ARC EMG-12 End Mill Resharpening Module, hardly used excellent condition, £450, ono. Bereavement sale.
T. 01252 615241. Fleet.

■ Meddings drilling machine. 3000 to 12000 RPM . I have owned this machine for some 10 years, there is no wear and it is totally reliable. Spare bulbs are included as are the alternative pulleys for speed changes. Drill capacity 0 to 1/8". The machine is heavy but easily transported by car from its home in Taunton. Only reason for sale is my old age. Price is £100. No offers.
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T. 01280 704072. Brackley, Northants.

■ Moore & Wright 0-1" micrometer, in case, new, £28. Mitutoyo 0-1" micrometer, hardly used, carbide face, £20. Mitutoyo 0-25mm micrometer, hardly used. Carbide face, £20. Draper 25-50mm micrometer, new in box, unused., £25.
T. 02086 414238. Sutton, Surrey.

■ Wabeco D2000E lathe, cylinder guided, v. good condition, 15 years old, metric, change wheels, 3 jaw, stay, tool holder, MT2 centre, manual, little used machine, £800 ONO. Buyer to collect please. **T. 01778 424545. Bourne, Lincs.**

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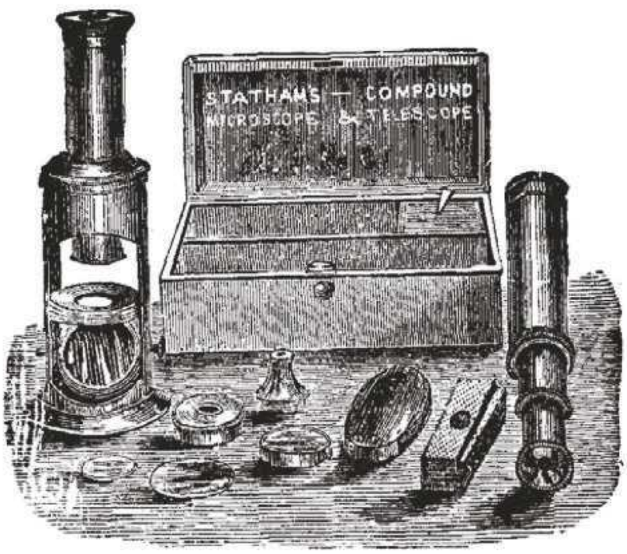

Models

■ Springboik 5" gauge B1, assembled frames with horns and axles, buffer and drag beams. Other parts including laser-cut coupling and connecting rods, plus other motion components. Two sets of four drawings. Worth over £700, will take £200. Phone for details.
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Wanted

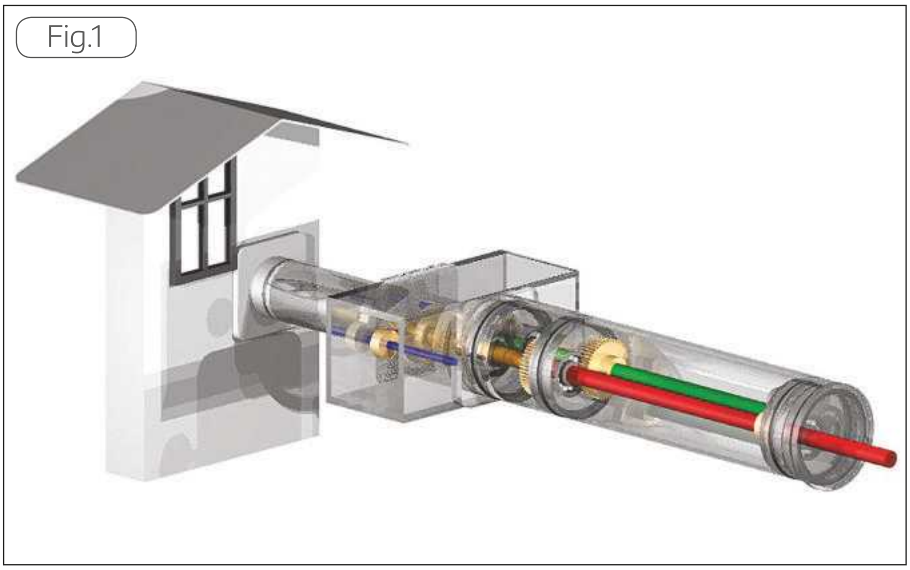
■ Wanted – more time in my workshop and less at this blooming computer - **The Editor.**

A Tale of Two Screens

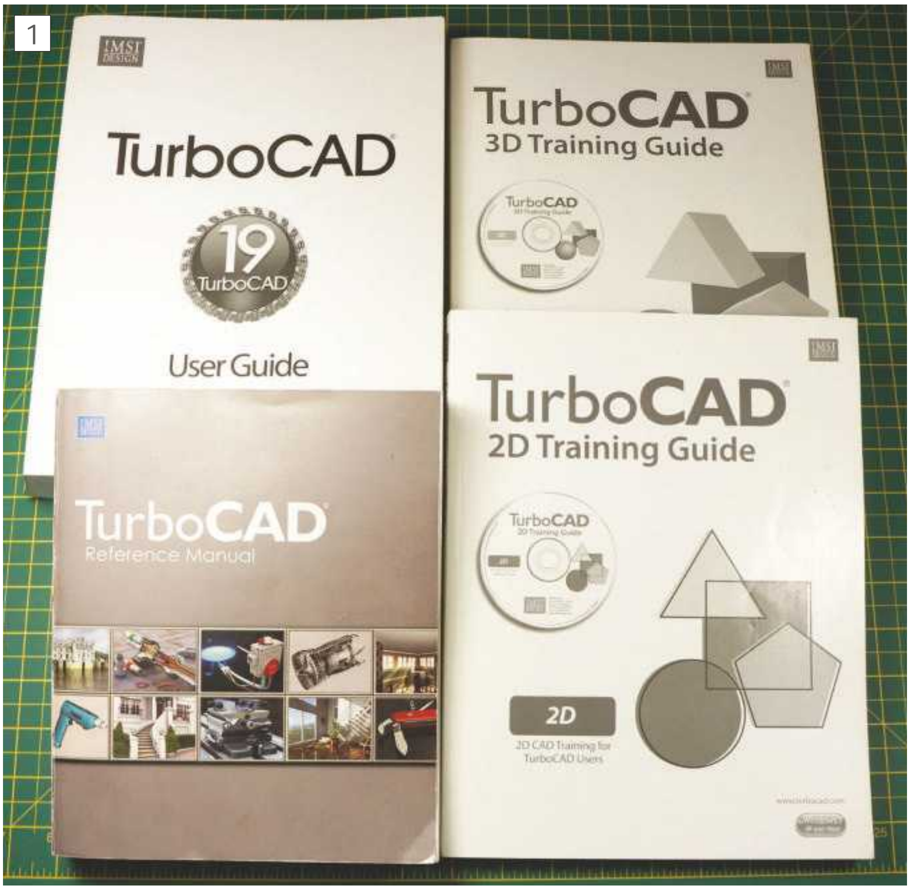
Bob Reeve recounts a story of CAD design with useful tips along the way.

Another year was rolling to a close and I got to thinking about what I had achieved in the workshop this year and, just as importantly, what I had not. The starting point for one significant activity appeared not to be in the workshop where it was still wintery, but a design on the CAD system in my office, **fig. 1**, where it was warmer. What it was intended to be seems unimportant as it was never made. What it turned out to be was an exercise in compact mechanisms and weather protection. It also proved to be a catalyst for significant change.

There are several sets of gears four ball-bearings, some plain bearings, O-ring seals and so on. All in all, it was getting a bit crowded inside. As can be seen, the main casing is rendered transparent to enable conflicts and interferences to be visible just as if the body had been moulded in a transparent Acrylic or glass. This is a definite advantage of working with a CAD system that allows 3-D visualisation, as is the ability to render materials in totally unrealistic bright colours to distinguish, for example, the power input shaft (red) from the lay shaft (green).



Where it all started.



Learning aids.

There are those that consider colour rendered CAD models an unnecessary complication, but for the non-engineer the opposite may be true. Trained engineers learn how to interpret the standard orthographic projections early in their careers but non-engineers do not. By way of a, very unscientific, test I showed the standard plan view line drawing of fig.. 1 to a physicist friend of mine and asked for his interpretation. He had always worked in engineering and already had some background knowledge of the subject. He was therefore able to make a pretty good attempt at a description. He did however miss-interpret some items like the ratchet wheel he thought was a gear. The same view as a colour rendered image allowed him to see the error immediately without comment from me. By then it was my round, and the conversation moved on to other things

My weapon of choice for this activity was TurboCad and at the time I was using Version 20, but there was a snag. As the CAD model got more complex the time taken to render it increased considerably. It got to the point where high quality rendering of the wire frame model was taking just under a minute. This is close to unusable because the slightest change to the model usually results in it being re-rendered, necessitating the use of wire frame models for most of the work. The type of model I was rendering is particularly demanding on the rendering software, partly because of the complexity, but also because the transparent components are more complex problems for the ray-tracing techniques etc. employed. The software has to compute the reflective and refractive effects of the transparent material in addition to its normal workload.

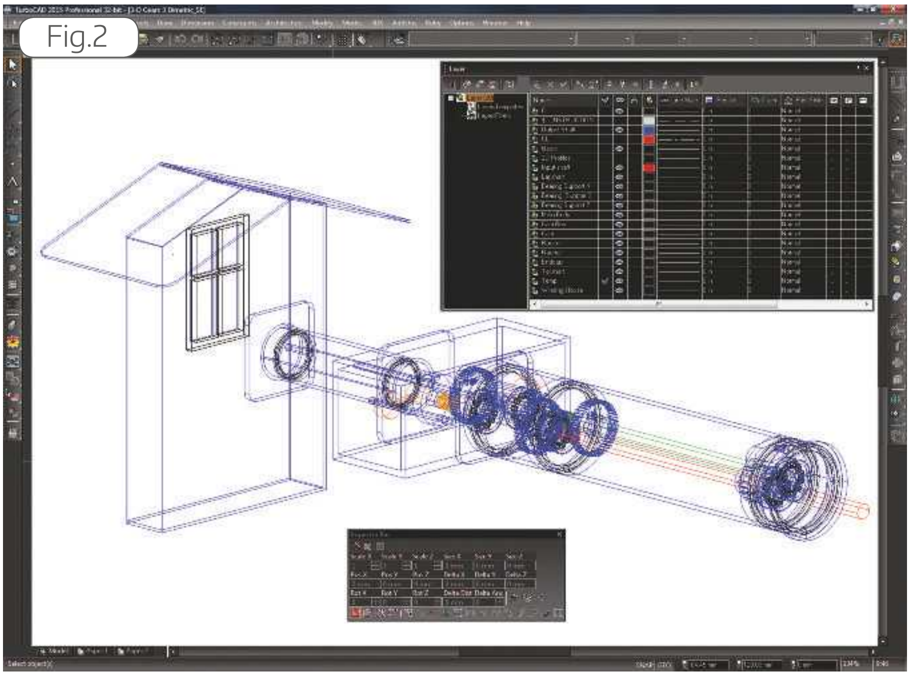
Was the poor performance due to the computer, or the software, or me or some combination of all of them? I e-mailed the TurboCad file to my long-time friend Pete who, fortunately, was running the same version of TurboCad, but on a more recent computer. His times for rendering were much shorter than mine; about half.

So my trusty Dell Dimension 9200 was getting too long in the tooth, as was its operating system, Windows Vista, which those nice people at Microsoft had long since left behind. Some research was required into replacements both for the operating system and the computer. But, just to make life interesting, the latest version of TurboCad, TurboCad 2015, was now available. Should I also upgrade that as well?

I should point out that I don't upgrade software every time an update is available; I'm still running Windows 98 on one machine! I find frequent upgrades unnecessary for the type of work I do. But, on the other hand, by the time the software is around 5 years out of date issues of capability and compatibility start to arise as well as lack of support. Better rendering was promised by TurboCad 2015 but I had already been warned by the earlier TurboCad V20 that my graphics card was not up to scratch so it was beginning to look like a completely new set up.

For those who have yet to get to grips with CAD, I should point out that most newcomers find it less than easy. There are a lot of commands to get to grips with, some of which have unfamiliar names and some of the terms mean something different to when they are applied to a drawing board. for example, I was introduced to splines in my teens when I dismantled my motorcycle gearbox and it was explained to me that the splines allowed the gears to slide about on the shaft. Years later I found that CAD splines were curved lines. It appears that the spline in this context had its origins on the shipyard draughting boards where the draughtsman would use a thin strip of wood, known as a spline, which could be flexed to give the graceful curves of the next ocean liner. Thin strips flexed more than thicker ones and therefore gave the sharper curves. Any of the splines had the ability to generate curves that were not uniform e.g. curved more at one end than the other. Most importantly they are all smooth curves.

CAD, in the early years, had no equivalent, but desperately needed a means of dealing with not only ships hulls, but aeroplane

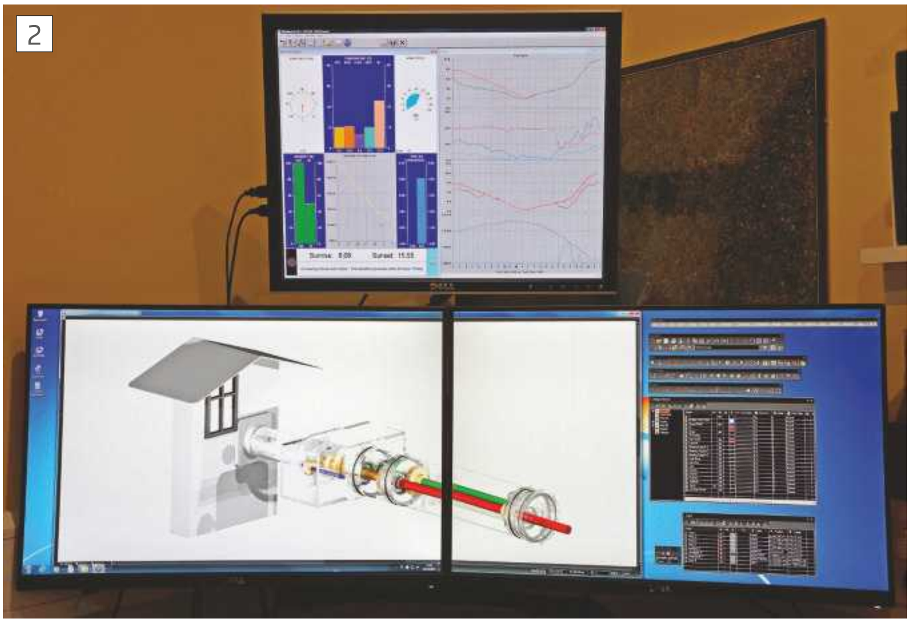


Working area on a CAD screen.

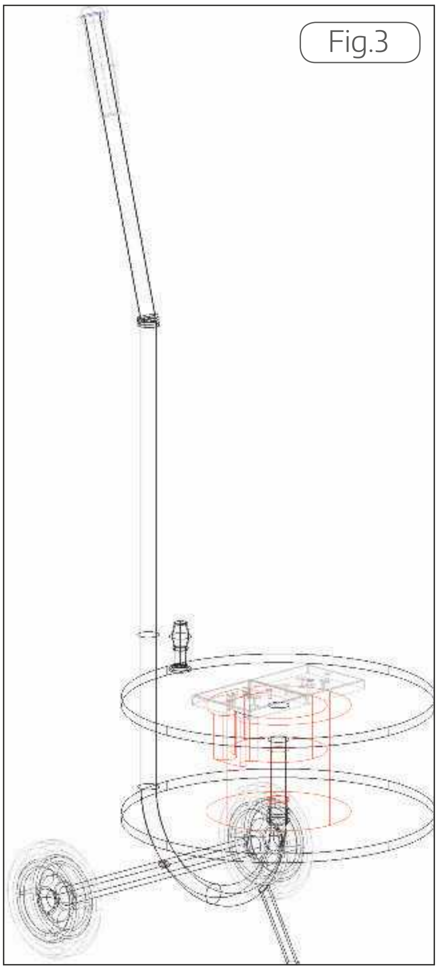
wings and more importantly, in terms of the CAD market, motor car bodies. The first solution came from Pierre Bezier working at a Renault car factory in france. He applied an old and relatively simple bit of mathematics to computer graphics to be followed by the Non-Uniform Rational B-Spline used today. Which is how CAD went from curves to NURBS.

2-D drafting is closer to what happens on a drawing board and is usually where newcomers are recommended to start with a simple component. A flat plate with a sprinkling of holes was where I started. 3-D CAD is by far the more demanding, both of man and machine. fig. 1 shows not only a rendered 3-D model, but a model which is also an assembly. This further increases the level of difficulty since assembling in 3-D requires a certain amount of ability in the area of spatial awareness, but that, like many other skills, can be improved with training and practice.

Somewhere in the 1980's I became responsible for a CAD Training facility and, as a result, my recommendation would be that beginners should undertake some form of structured training. This does not necessarily mean attending a course, I used the TurboCad training packages, usual disclaimer, which are in the form of exercises which become progressively more difficult, **photo 1**. If you are like me, you will also need the reference manual/ user guide. Alternatively, there are training videos conveniently available on a memory stick or CD. I have found these useful for other software packages, but have yet to try the TurboCad version. There is always the temptation to say "I'll have a fiddle with



Multiple screens in use.



Wireframe of the original design.

it and see how I get on". Unfortunately, progress will not be as good as with a structured training approach. The optimum training period for 2D-CAD training in industry used to be 1 week full time, followed by a period to put it into practice. Then further training over the next year to deal with specific topics and problems. The un-tutored might be expected to learn more slowly but eventually catch up. Industry figures show this is not so; they will probably never catch up. One basic problem being that it is not easy to ask the right questions about things about which you have no knowledge. Another problem is that, if push comes to shove, you will always use the method you used before, even though it may not be the best approach. This usually results in a number of the available commands never being used, though they would have been better than the ones that were used. The CAD trainers of the day used to say the most difficult trainees were the ones that were self-taught but had not undertaken a structured training programme. If it helps, think of a CAD training session as the equivalent of time spent with the Professional at the golf club!

At this stage I realised that there was something missing from my appraisal. I had omitted to appraise the monitor. It didn't take me long to realise this was yet another issue that needed more than a casual evaluation. Monitors have improved enormously since the days when they were CRT based. The flat screen LED versions offer good resolution, good colour rendition and are considerably larger and brighter without needing to notify the local sub-station that it is about to be switched on. But I do miss the reassuring thump as the CRT de-Gaussing circuit kicked in.

For those yet to delve into CAD I should explain that the monitor is the equivalent of the old drawing board and, as with drawing boards, generally bigger is better. The added complication with CAD is that, unlike drawing boards, the commands and other information usually take up a significant part of the area available as in **fig. 2**.

But new, CAD size, LED monitors with an aspect ratio of 4:3 like my old one, now cost the sort of money that my nephews buy, old but roadworthy, cars for! Monitors with aspect ratios of 16:9 are cheaper because that is where the television market has gone and the volume has bought the price down. The best aspect ratio depends on the job in hand. The square(ish, screen of the 4:3 aspect ratio I find more useful for components, but not so useful for long things like fig.1 or perhaps an A4 Pacific railway locomotive.

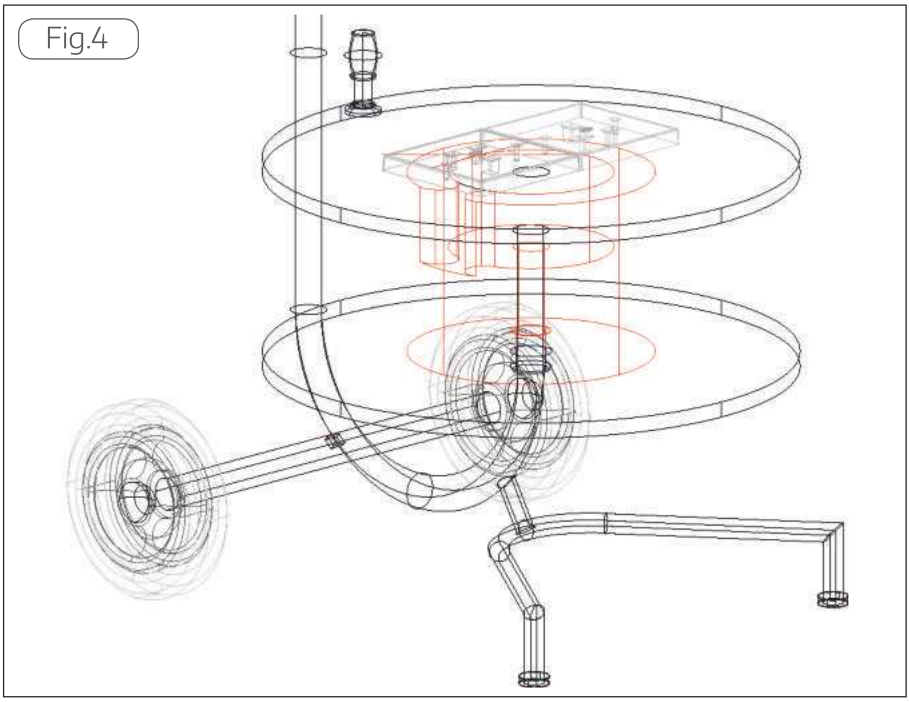
The CAD training facility I mentioned earlier was equipped with monochrome 32 bit Sun workstations, costing megabucks, and 8 bit IBM AT's that were more affordable and could run two monitors. Which meant all the geometry could be on one screen and all the commands could be on another. That sounded like a more flexible arrangement. More research was needed.

My first port of call was to contact Paul Tracy, aka Paul the CAD, ref. 1, who had been supplying me with TurboCad upgrades every couple of years or so from V12, Usual disclaimer. I asked if TurboCad 2015 was capable of running in twin screen mode and if so, how could I do it? After some research of his own, Paul came back to say yes it could and it was just a question of plugging the screens in and telling the computer which was to be screen one.

The next question was about the specification I would need for the computer that was to run it. That was more difficult and the answer was in several parts. The processor needed to be fast enough, the random access memory, RAM, needed to be large enough and most importantly the graphics processor need to be capable of doing the job. The minimum specification is on the TurboCad website to which Paul provided a link, ref. 2. However, the information is vague "A newer generation CPU", "A supported graphic processing unit" and upwards of 4 GB RAM with a caveat that "Newer boards with more power and VRAM generally provide greater performance". The easiest approach seemed to be to look at the offering from the computer suppliers/ manufacturers a select from the ones labelled CAD Workstations or something similar. The price tag initiated a nasty pain near my wallet!

The next approach was more of a bespoke solution; choose the key elements and put them in a suitable case or have the supplier do it for you. Aficionados of computer games do this to get the performance they need where milliseconds count. I suspected that CAD was not quite as demanding but subsequently that turned out to be incorrect. Professional CAD packages like Solid Works costing around £5000 might have to deal with models as complex as a complete motor car which would need to be dynamically rotated and rendered. I was told the graphics processor could cost about half the price of the software.

I don't claim to be a computer buff and the bespoke approach was a little daunting, not



Modified feet.

Queen of the Miceni?

least because of the proliferation of technical detail; but it was worth investigating. first up was the processor; the clock speed and the ability to parallel process seemed key and the quad core Intel I7-4790 appeared the best choice. Next up was the memory, which Paul had indicated needed to be more than 4 GB with an eye on the access time. The really tricky bit was the graphics processor, sometimes called the graphics accelerator card. Paul supplied me with a link to a website where suitable graphics cards were listed by the software house doing the rendering software, ref. 3. The problem was that it was a very long list, 300 pages, and the only way of using it was to go through the offerings from computer vendors and check the specifications in the small print for each one against the list.

By now it was April and time for my annual pilgrimage to Harrogate for the Model Engineering Exhibition. I was able to meet up with Paul, purchase TurboCad 2015, thank him for his help so far and whinge about the difficulty of identifying a suitable computer.

Just when this was beginning to look like a long job, I had a stroke of luck in the form of an e-mail from friend Pete to the effect that there was a computer with about the right specification being offered at a competitive price from Aria computers, ref. 4, who were new to me, Usual disclaimer again. It was their top of the range "Gladiator" business computer with an I7 processor running at 3.6 GHz, 8GB of memory and most importantly a HD460 graphics processor which was on the approved list, ref. 3. Since it was described as a machine intended for business use, a phone call was necessary to confirm that it would do what I wanted. Their helpline was extremely helpful and very thorough before agreeing that from the specifications it would do the job. The only caveat being that, although they knew of it, they had never run TurboCad themselves. However, there was a plan B if needed – the most likely source of problems was the graphics processor which could be upgraded if necessary.

Before I could order I needed to decide on an operating system. At the time Windows 8 was just replacing Windows 7 and Windows 10 was just coming over the horizon. Windows 7 got my vote as the one that had been de-bugged more than the others. So the machine was duly ordered with Windows 7 as the operating system, but without a monitor. I wasn't that confident yet!

The machine arrived promptly, was plugged into my old monitor and fired up immediately. There was then a short intermission while the machine loaded and installed over 1000 updates! It would seem that the debugging had been just as extensive as I expected. TurboCad 2015 was installed in 64-bit mode and to my immense relief it all worked. However, the ability to achieve a "Quality Rendered" model was missing. An e-mail to Paul revealed that this element of the software was now offered as a plug-in at no additional cost and there was a choice of Light Works or RedSDK; which did I want? I had no way of choosing and neither did Paul so we installed both. I'm still evaluating them, but more of that later.

So now the final decision, one screen or two? At this stage, it was in for a penny, in for a pound! Dell Ultrasharp monitors had received good reviews and had the sort of resolution needed for CAD. I found that there was a 24" version, Type U2415, with especially thin edges suitable for twin screen operation. By chance Aria computers were doing a special offer so they got the order. Curiously, the second monitor cost me more than the first. But only by £5 or so. Something to do with loss leaders I was told.

When the monitors arrived, there was a problem with the leads to the computer. Two different leads were required to match the two different output sockets of the graphics accelerator. A phone call to Aria soon sorted that, and a new lead arrived at no extra cost a day later. To my surprise the two monitors configured themselves exactly as they should, with no intervention from me and they behaved not as two separate screens but as one big one. I should have expected the latter, Paul having warned me this was likely. So items could be dragged from one screen to the other or expanded to cover both screens. I am still exploring the possibilities but the installation started to look like the bridge of Starship Enterprise, **photo 2**.

Note that there are three screens in use and the two new Ultrasharp monitors are brighter than the older one. The top screen is still driven by my old Dell and is displaying the output from my weather station, but is equally useful in handling e-mails and photographs. But for panoramic photographs, the twin screen setup takes some beating.

It was by now August and the height of summer, with the grass and hedges growing furiously. I was looking for something that might be a suitable challenge for the new system. I found it in the garden shed when I went for the extension lead to run the electric hedge cutters.

The extension lead in question was a bit out of the ordinary for two reasons; firstly its length of 100ft and secondly it comprises a cable drum with a vertical axis mounted on a two wheeled trolley so designed that it will work with the drum axis either vertical or horizontal. There was no indication of the maker, but I think it was originally an industrial design. I inherited it when the contractors that were using it disappeared without trace. It gathered dust while I waited for the contractor or their successors to reappear, but they never did. Eventually I tried it out and discovered why they had not bothered to reclaim it. It had two fundamental faults. firstly, with the handle and drum axis vertical, it would fall over at the slightest provocation and secondly, the reel would unwind more cable than required resulting in it tangling round the lower part of the trolley rendering the whole thing unusable until it was untangled.

So, a revised design was needed with improved stability and a means of stopping the cable slipping off the drum. This was to be undertaken as a CAD design exercise to be built only if a successful design appeared to be possible. The first stage was to create the CAD model of the existing design then tackle the lack of stability. The wireframe model is shown in **fig. 3**, which also shows the cause of the problem. The tripod base is just too small and the centre of gravity is too close to the edge of the support area.

Three legs were increased to four and the legs extended as far forward as possible without protruding excessively outside the existing envelope. Construction was to be in ½" dia. Steel tube with welded joints where necessary. The attachment point was the existing tripod leg, suitably shortened **fig. 4**.

Next was the problem of the cable spilling off the drum. further analysis suggested there were actually two problems; one to control how the cable unwound from the drum and the other, to control the cable remaining on the drum in the event of over-run.

The solution to the problem of the cable leaving the drum was solved long ago and is the roller fairlead that can be seen on the tender of many traction engines. Essentially this is a frame with guide rollers all round. The traction engine designs are usually rectangular as on the Marshall in **photo 3** where it can be seen in the centre of the coiled water lifter hose.

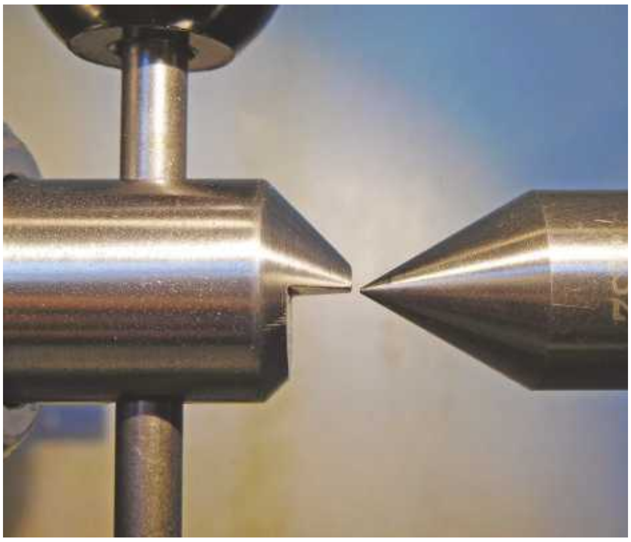
To be continued

Scribe a line

YOUR CHANCE TO TALK TO US!

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

Tool Height Gauge



Dear Neil, I have just made the Tool Height Gauge (MEW 254, p. 14). It is a really nice idea, because it materialises directly the headstock axis, and does not depend on the lathe bed (that is in my case partly V-shaped) or another surface.

I have reduced the diameter on the left to 16 mm, thus I can also mount the gauge into my ER 25 collet. I have tapered the other end (with the first flat) to ease the positioning of the tool close to the axis of the headstock, for the best precision. I replaced the second flat (for the engineer's square) by a vertical slide, that simply rests on any horizontal surface e.g. from the cross slide. It is really precise (my lathe is a Wabeco D6000):

I would further like to thank M. Harold Hall for all his books that helped me so much and for his "advanced grinder rest", obviously. Because I am a beginner, the word "advanced" intimidated me, but to my great surprise, thanks to the clear explanations, I was able to make the tool and to use it! From HSS tool bits, I made an "outside diameter finishing tool" and a "face finishing tool", among many others. I was also surprised by the precision of the angles obtained. However, I was less good in honing the tools because the swarf produced is not really "grinding dust like" as shown in the first book (ha ha), but I obtain good results.

Bernard Zaegel, Leidschendam (Netherlands)

Laser Blazer

Dear Neil, my eye was caught by the article in Issue 253 MEW by Alan Wood. I have also made a similar device but using two lasers. I don't quite see how a single laser can provide a centre position? Alan's fig, 1 is how I've done mine and uses the old "Dambusters" exact height method. My two lasers intersect at a depth of 80mm below the bottom of the mill collet locking ring - so I just roughly align the compound table and object to be milled below the (at this stage) non-intersecting laser beams and then lower the mill head until the lasers intersect - then final compound table adjustment to place the intersecting laser beams exactly over the centre position.

Alan's single laser beam at an angle will vary its impact position at the surface depending on the height above the surface. I do note that Alan's is rotating and therefore can create a laser light cone which will converge to a point with height - but I don't think I like the idea of extra unbalanced weight being thrown around. Mine is non-rotating attached to the bottom of the mill head and runs off a switched 5V 1A DC mains power supply.

I've recently gained a 3D printer and am still converting my CNC engraver to use a burning laser. I'm also building and modifying quadcopter drones for use in environmental boundary layer studies - i.e. what I used to do as a job with high towers and masts I'm trying to incorporate into autonomous GPS controlled quadcopters. Instrument weight is my main problem.

Colin R. Lloyd, Wallingford

A Place for 3D

Dear Neil, I read your review of the Dremel printer in MEW 251 with much interest. I have had a 3D printer for some time which I find to be an invaluable tool in my workshop. There is, as usual, an amount of misunderstanding amongst modellers of all types about this new technology, as there always has been from the availability of chemically etched parts to CNC machining in the home workshop. This ranges from 'Its cheating' to 'it can do everything' all this technology does is allow us to do more in the workshop and frankly have a bit more fun. As with everything there is limitation, and part of partaking in this hobby is working out how you can do something with the tools and skills you have, after all isn't that the real challenge?

I shall be looking forward with great interest to see how you go with your tank project, I have hankering to build a Mark V male tank, and, as you mentioned, the tracks are a big issue. My own solution, which, due to my workshop not being in service yet, I have not had chance to try, is too print the chain and then vac form the plates and glue them in position.

Stacey Baker, Western Australia.

Life's A Gas

Dear Neil, I read in the latest edition of MEW the very comprehensive article by David Banham on silver soldering. Clearly David has carried out a lot of research on heating methods and systems. Just for completeness may I offer 3 additions. David may have considered these items inappropriate so I leave it to your good judgement as to whether you consider them worthy of publication.

1. Oxygen can be purchased in non-rentable, refillable cylinders. The cylinders are available from distributors around the UK. The cylinders are smaller than the smallest BOC cylinders. The companies also offer acetylene and some inert welding gases. Check both Adams Gas and Hobbyweld.

2. Oxygen can be produced by an oxygen generator. A version of these units is often used by people who need oxygen for medical reasons. A commercial version is used in the jewellery world and when used with propane the output can comfortably feed the Smith Little Torch.

3. For small quantities of gas but where a high temperature is needed, such as working with platinum then jewellers use an oxy-hydrogen mix. This is obtained by electrolysis the raw material being water (distilled is best). A consumable component being Methyl Ethyl Ketone (MEK) which is used as a drying agent. The torch however is specific to the generator and produces a very small flame.(2553,2554,2555,2556,2558)

Jeff Gearing. By email

Life, Love and LAL

Dear Neil, I did have a chuckle when I saw the Tap on my Shoulder piece.

With regards LAL it does indeed stand for Lehmann Archer and Lane Hampshire Works Fairlop. My Mother and Father both met there. My mother Marion Bock joined the company in 1957 straight from school aged 15 as a junior office clerk and did various jobs such as taking orders book keeping and answering the phone etc. My Dad Brian Brown also worked there as an apprentice doing milling, turning, thread rolling and grinding. He told me that they also opened a factory in Newton Aycliffe where they made the larger stuff.

Two things off interest which they developed were the blue wizard tap which had a spiral point to move the swarf forwards out of a through hole and a fluteless tap which could swage threads in blind holes without creating any swarf.

The company joined with Nuckey and Scott to form BTD British Tap and Die and then went into making twist drills by purchasing Intal or International Twist Drills. The company was run by Mr H E Lane and then when he retired by his son John Lane. My mother went back to the factory in 1969 with my older brother and sister in tow just before I was born to visit her colleagues so it was still operational then.

As for the workers having dropped off the perch now, fear not Mum and Dad are still with us when I last checked! Now in their 70s Dad still has a catalogue detailing all the products that he helped produce and he has passed on to me a huge collection of wooden boxed sets much bigger than the one shown covering every size imaginable and even a few that are not.

As for me I am slowly plodding through a Don Young Black 5 having picked up the engineering bug.

Rich Brown, by email.

Parting with Pleasure

Dear Neil, Over the years there have been many interesting articles and letters in both ME and MEW on how to overcome the problems of parting off in the lathe. The most memorable being a reader's description of the sound of a parting tool in a large lathe digging in under great power and fracturing - "UNK..."

Having for a long time bought surplus blades and mounting them inverted in a home made holder on the back of the cross slide I have been reasonably successful but not as good as that of the American gentleman subscriber who ran an article on the design and use of a new parting tool for several issues on the run.

When I inspected the catalogue picture of a well known tool supplier I recognised some of that gent's recommendations apparently so I shelled out and bought the holder Arc SLBTN 08 02 and the blade Arc NCIH 19-2, made my own holder for the assembly and very much enjoyed parting tough metals at the maximum power of the motor. I thought you might like to see an action picture.

Peter Peters, by email

Revisiting Lawrence Sparey's Myford Mandrel Lock Spanner

George Winspur revisits a tool that could save you broken teeth on your bull wheel!

1

The Sparey Spanner

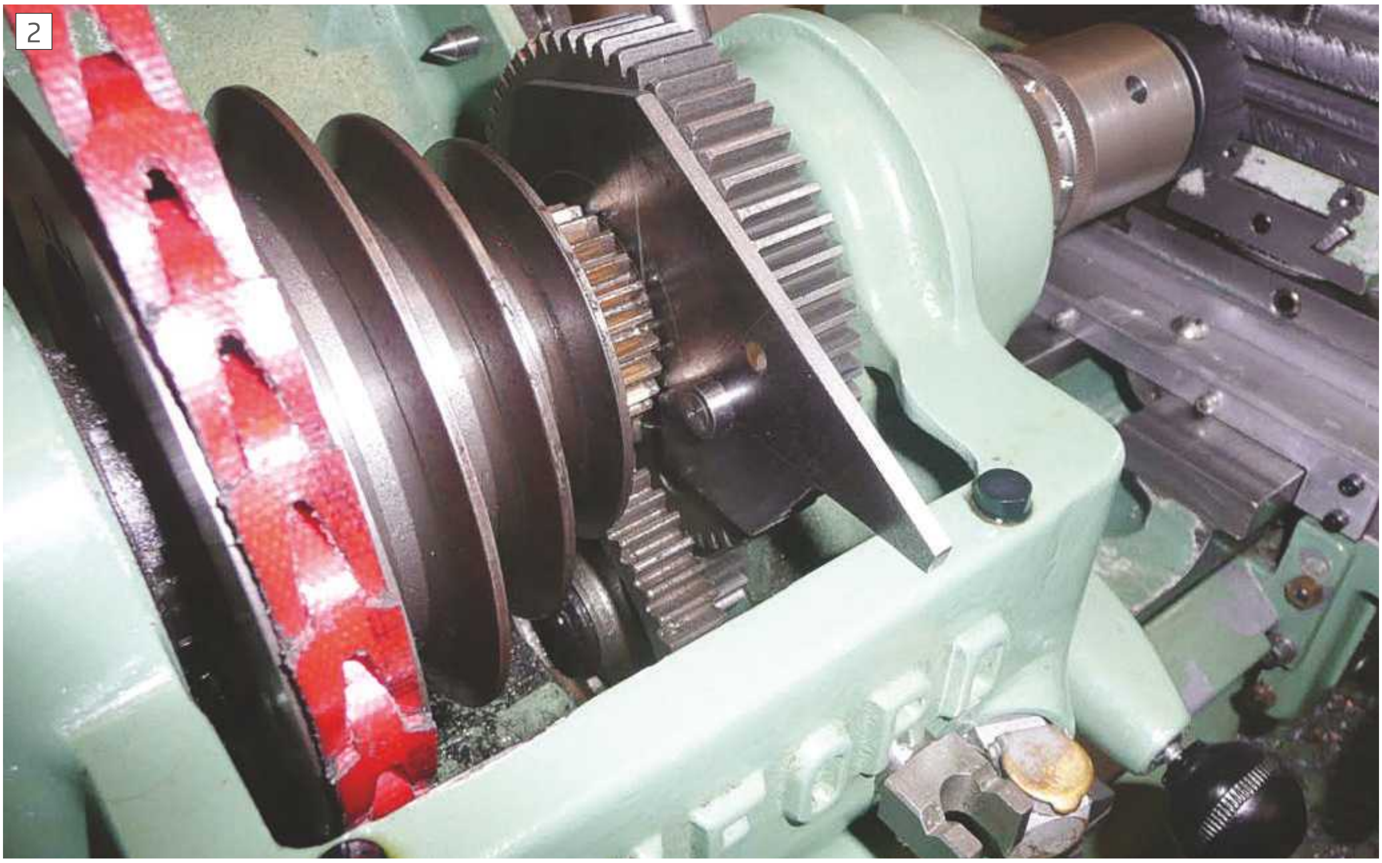
The problem of stuck lathe chucks was raised in a recent thread on the MEW website and reminded me of a simple and effective cure described in Lawrence H Sparey's Myford ML7 manual, A Man and his Lathe.

The device concerned, **photo 1**, is essentially a spanner one end of which is temporarily secured to the mandrel by a pin locating in a hole in the bullwheel. In the case of the ML7, of which I have no experience, it may be necessary to drill this hole but the Super Seven bullwheel is already provided with suitable 3/8" diameter holes. In use, the other end of the spanner rests on the lip of the headstock casting (with a scrap of soft metal underneath to spread the load) and torque is applied to the chuck via a lever gripped in the jaws, **photo 2**.

The spanner is easily made from 1/8" steel by sawing, filing and drilling to the dimensions and approximate shape shown in **fig. 1,** only the large radius and hole being at all critical. The dimensions are taken from my own version for the Super Seven and it would be sensible to make a card template from the target lathe before cutting metal.

A post to the thread pointed out that the Myford bullwheel is secured to the spindle by a key which necessarily accepts the forces involved in using the tool and it might be as well to make the 3/8" pin of brass or aluminium so that the pin will yield before the key. In any event, the tool would only be used if normal methods fail.

The photos show, respectively, the spanner with loose pin and the tool

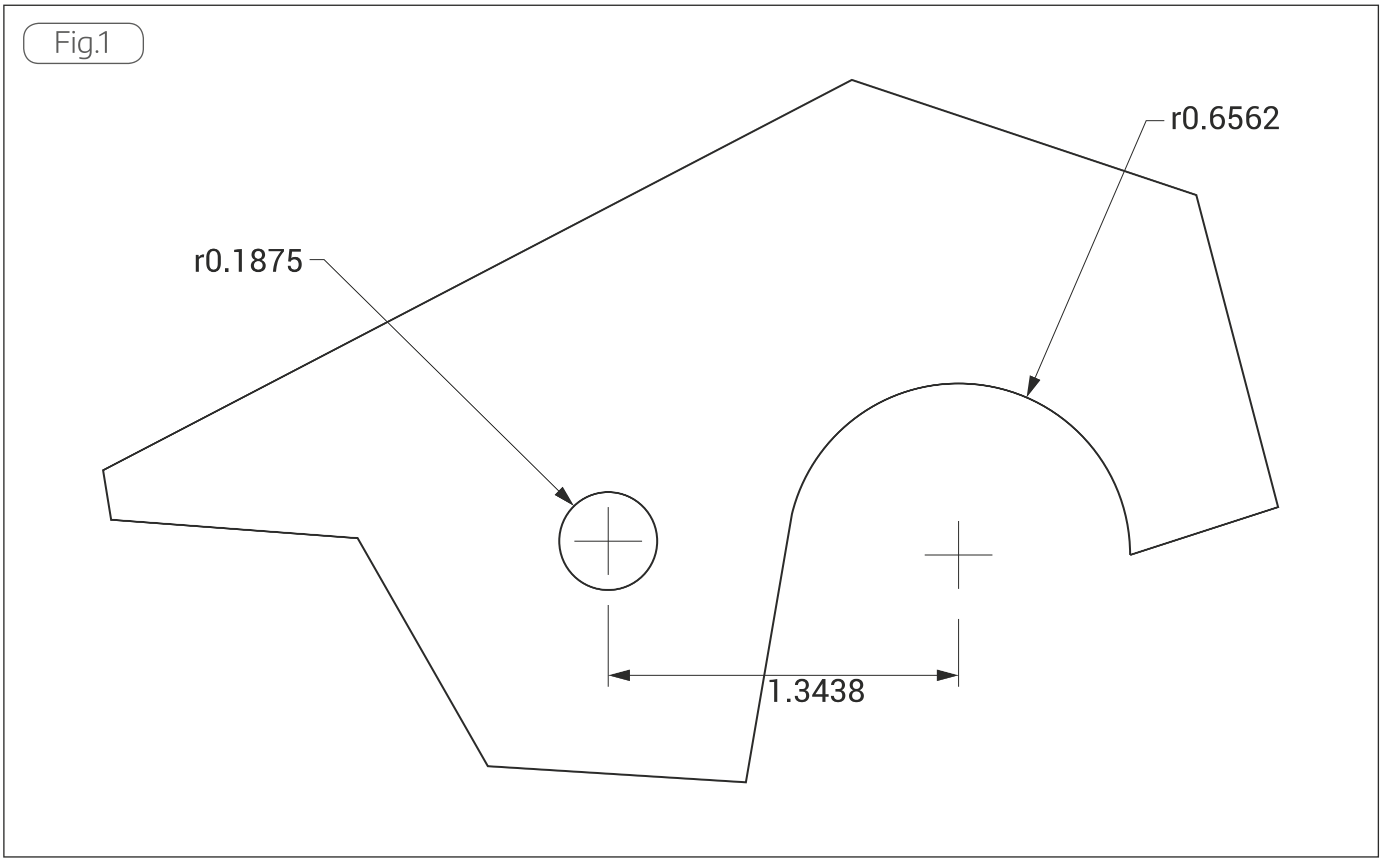


The spanner in use.

installed on the lathe.

Proper lubrication and cleaning of the lathe mandrel nose and chuck should minimise the occurrence of stuck chucks. It is some years since I have been troubled in this way and I don't now remember whether I made the spanner before or after it happened to me. I can say, however, that it solved the problem at the time and I gave thanks to the memory of a great Man!

LHS died in 1986 but his main work, The Amateur's Lathe, is still in print and receiving enthusiastic reviews. ■



Silver Soldering – A Comprehensive Guide

David Banham gives a wide-ranging overview of this important technique for metal joining – Part 2

The basic platform is a square thin-walled steel tube welded together, with the frame covered by a sheet steel top attached via a few short welds. Dimensions are 27 by 14" and the legs are 5". The whole thing was constructed in a couple of hours. This has several advantages, fire bricks, or a jeweller's soldering pad (or both) can be placed on the flat surface.

One idea, not currently done on my hearth is to incorporate a detachable steel sheet back, about 12 inches high.

The steel sheet top allows magnets with pillars attached, to be placed to support work. A few 3/8" UNC nuts are welded to the underside of sheet steel top, with holes through the top, and are used as support pillars. The whole thing can be stowed out of the way when not in use.

If you will use your hearth as a place for soft soldering as well, then get a sheet of metal to place over the refractory components when soft soldering. Soft solder does not get on well with silver soldering or brazing. The sheet will collect the solder splats and beads of solder which get created during the soft soldering process. Soft solder will ruin a silver soldered or brazed joint if it gets close.

A hearth makes a good place for hardening and tempering activities. Hardening and tempering is an important activity when manufacturing shop-made cutters.

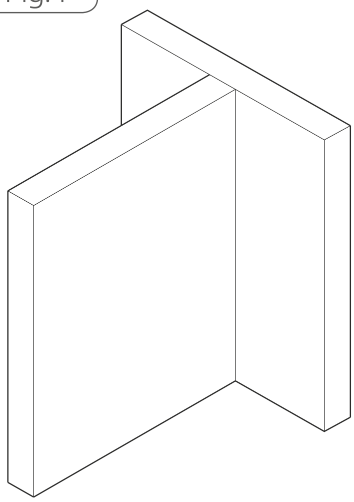
The heat generated by a large torch is enormous, and the fumes from its use are significant. If the hearth is inside a building, it may require a hood with an exhaust fan, plus adequate space for all the equipment and fuel tanks, and additional fire and heat protection. Alternatively, in moderate climates, consider having an outside hearth for large operations.

My workshop is very small, but has an adjacent crawl space about 4 feet high with a concrete floor and door to the workshop. I store much equipment on wheeled benches in the crawl space, one of which is dedicated to soldering and brazing. In the basement workshop I open the window, and start an extractor fan, to ensure good ventilation. Large or lengthy soldering is conducted outside in the garage with the door open. The portable tubular hearth, described above, can be moved to the workbench, outside or to the garage, in about 5 minutes.

13

Solders and Flux

Fig.4



Butt Joint - Not Recommended

You can buy or make a hearth which has more features, but this either takes more money, or much time, and may not be a valuable asset unless you spend a considerable amount of time soldering and brazing.

Bear in mind when you design your space, you need space for:

- A hearth and movement around it
- Space for your fuel cylinder(s)
- Space for your pickle container and lid
- Space for your tools, which must be handy
- Space for your supplies

Refractory and Insulation

Refractory bricks are the cheapest form of insulating material, but their disadvantage is the absorb a lot of heat, instead of reflect the heat. Refractory bricks are available in a half thickness (9 x 4.5 x 1.25") compared to a full refractory brick used for most industrial work, and these are adequate for most model engineering purposes. A couple of full sized bricks may also be useful. The easiest way to buy them is to find a company that specializes in fireplaces, and chimney repair, as they usually have a stock at their premises, and they are often quite willing to sell a few bricks, if you explain why. A second problem with the refractory bricks is that they make your hearth heavy if it needs to be moved.

You can buy refractory pads which are more expensive but reflect more heat and are extremely light weight. A pad about ½" thick will protect the underlying surface even when using a soldering torch for long periods. However, if you are applying a lot of heat for long periods, mount the pad on some form of hearth. These pads can be purchased from jewellery industry supply › houses. They come in various types and costs depending on type, size, material, manufacturer, and their ability to resist various temperatures. Since you will likely not require to solder platinum at very high temperatures, select the basic types. They are also available in hard, soft, and cellular types. The hard are obviously a little more rugged, but the soft, and cellular types offer useful features. The soft allow you to stick pins into the pad to allow the positioning and sometimes the securing of very small parts. The cellular type allows the crannies to be used to jam wire or other components into the crannies to aid with alignment and reducing the chance of movement. A supplier for 12'' square, hard or soft sheet is provided at the end of the article.

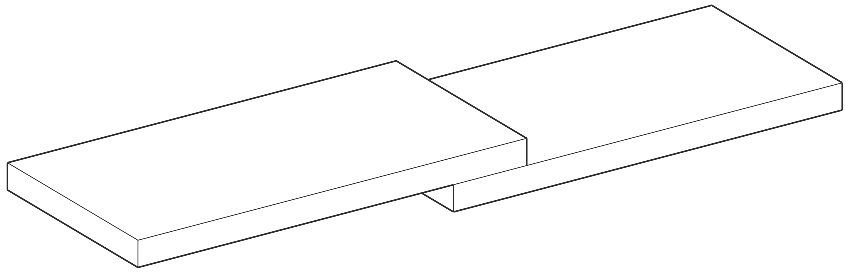
Two of these pads will cover the brazing table described above, and allow space around the edges for fire bricks.

If you want to create a small booth or space for silver soldering and brazing, you could frame-out an area and then line it and the bench with a double layer of Magnum Board which is an inexpensive alternative to dry- wall (plasterboard) normally used in the construction industry. Magnum Board is flame and heat resistant and a fire retardant. This would allow you to point your torch from the hearth without setting anything on fire. It is available in the UK from Panaloc.

A second alternative is to build your booth with walls of cement backer-board used for shower enclosures. It is fire proof and low cost. Easily screwed to a frame it can be used to form the bench top, walls, and a hood.

The hearth, consisting of the support structure, steel sheet base, and refractory would be arranged within the booths described above. Such a booth could store the operating fuel cylinder underneath, and for additional safety an extraction fan could easily be installed as part of the hood above the hearth.

Fig.5



Lap Joint Flat Shape

Integrated Clamps and Supports

You may wish to consider several of these items as you conduct more complicated work. First, you need a few clamps that are used only for soldering work, as they will quickly get oxidized and rusty. A couple of simple, quick to make, toolmaker's clamps are most useful, along with a round bar (say 3/8'' diameter) that can be installed above the hearth and can then be used to attach other arms, carry or hold various forms of clamps, secondary supports, tweezers, tables, and wire clips and patent devices. Such clamps and attachments and aids can be added to your 'kit' as required.

A couple of magnets with round bars attached are useful. The magnets can be purchased, and a suitable bar attached as you see fit.

More ideas describing supports and work holding are described later in the article.

Finally, you may want to equip the hearth with a support for the torch so that you do not have to hold it continually on long jobs, and a hook for the torch for when it is not in use.

Pickle Baths and Pickles

The most suitable pickle bath for small parts is a slow cooker or Crock Pot, as the pickle can be warmed, the porcelain inner is acid resistant, and it comes with a lid. Some jewellery supply houses sell slow cookers as pickle baths, but usually it is cheaper to buy one on sale at a cookery supply store or hardware store, or try a garage, or car-boot sale. I went to a couple of charity shops and found both had slow cookers for $5 to $8. Obviously, large work requires containers big enough to contain the object being soldered.

Four common substances are used as a pickle, and are referred to most often in the literature:

- A solution of 5 to 10% sulphuric acid.
- A solution of Sodium Bisulfate (NaHSO4) - It is available as PH-Down which is available at swimming pool supply stores and is an economic source (do not confuse this with sodium bisulphite, they are not the same).
- A solution of 10% citric acid, which is slower but a much safer pickle to use.
- Commercial pickles such as Sparex #2 or OttoTech Citri-Pickle (North American brands).

Sometimes it is worth adding a few drops of washing up liquid to the pickle to increase its wetting capability.

Sulphuric acid is hazardous and for model engineering in the amateur shop is not essential, although it is most often quoted in the literature. The alternative 10% solution of citric acid works very well if the solution is kept warm (50C or 120F).

Citric acid crystals can be purchased from brewing and wine making suppliers and cheaper at Arabian/Asian food stores. Check the packaging for the acid crystals to add to water for a given strength. Citri-Pickle is available from jewellery supply merchants.

If you purchase new battery acid as a source of sulfuric acid it will likely be 33% concentrate (read the label carefully), ALWAYS ADD ACID to WATER. Wear the safety gear detailed above. Remember the catchy phrase 'Do as you oughta, add acid to wata', or AAA (Always Add Acid). Consider a label on your pickle container with the reminder. Under no circumstances should water be added to the acid. If you are not sure of the concentration of the acid to be diluted do not use it. Clean-up any spilled acid with copious water (many sources recommend a weak alkali such as washing soda or baking soda, although this will foam up. Ideally buy a spill kit and keep it handy – Ed.). Do not use old battery acid as it contains lead.

Used pickle should be disposed of in accordance with your local regulations. For those on septic tanks, dispose of as hazardous, as you don't want to upset the PH balance in your septic tank.

Soldering Materials
Silver Solders

Silver solders is often supplied as a rod 1.5mm (1/16'') diameter by 600mm long. Also, available are other forms including 0.5, 0.7and 1.0mm wire for small fittings etc.,

Table 2 - British Standard Specifications

BS Name	Silver %	Cadmium	Solidus	Liquidus
AG1	50	Yes	620	640
AG2	42	Yes	610	620
AG3	38	Yes	605	650
AG5	43	No	690	770
AG9	50	Yes	635	655
AG11	34	Yes	610	670
AG12	30	Yes	600	690
AG13	60	No	695	730
AG14	55	No	630	660
AG18	49	No	680	705
AG20	40	No	650	710
AG21	30	No	665	755

it can be purchased in narrow strip or foil form and is also available ready mixed with flux in a 30 gram syringe so that parts may be assembled then simply heated. For the model engineer, the first purchase Could be a low melting point 55% silver alloy, in the 1.5 mm size, as it is the most useful size for most modelling work.

In **Table 2**, the BS refers to the British Standard which is a reference to specific solder types that are deemed standard types.

The Solidus column shows the temperature at which the solder melts, and the Liquidus column shows the temperature at which the solder runs and will flow freely into the capillary of a joint. For model and general engineering purposes, it is usual to pick a solder where these two temperatures are close together. Many solders where this occurs used to contain Cadmium, which makes the solders more toxic. Cadmium containing silver solders have now been banned in Europe, but we have included data for completeness - please take care and use extra ventilation if using old stock of such solders.

Since the price of silver solder is mainly driven by the silver content, the higher the silver content the more expensive the solder.

Each major supplier gives their own product name to the standard types and for three major suppliers the equivalents are provided in **Table 3**.

Flux

A flux is essential when silver soldering. Do not attempt to do work without it. If you use the powered type, it must be mixed with water to a creamy texture before use. The composition should have the consistency of single cream.

Flux types include:

- Powdered Flux - EasyFlo or Tenacity the flux type must match the type of silver solder, or the metal being soldered)
- Prepared fluxes which are often premixed versions of the powdered flux.
- Liquid fluxes - Jewellery supply houses sell various types of liquid fluxes which are very good but more expensive

Photograph 13 shows two types of stick solder, a 1/16" diameter and 3/16" by 1/16" stick along with the powdered EasyFlo flux and the little jam pot used to keep mixed flux ready for use, plus an example of silver solder in liquid form in the tube.

Table 3 - Manufacturer Equivalents to Standard Types Shown in Table 2

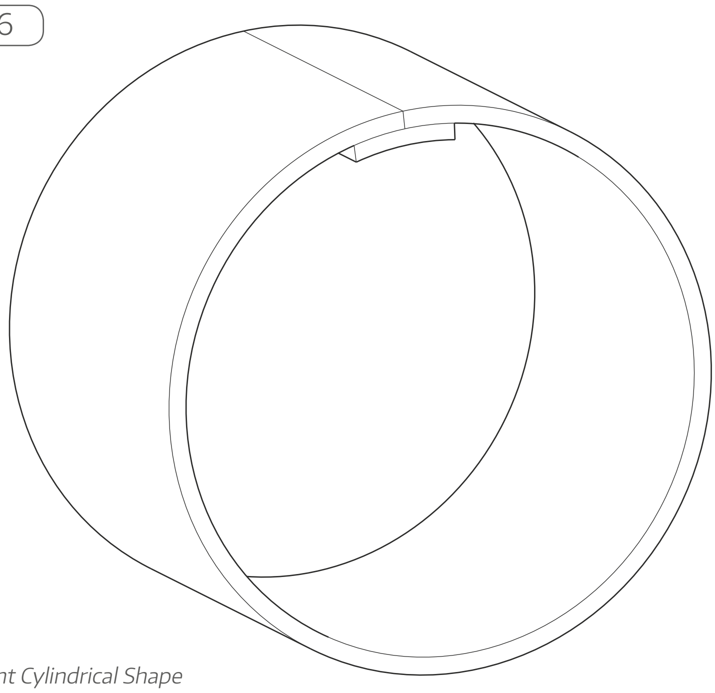
BS Name	Johnson Matthey	Frys	Thessco
AG5	Silverflo No 43	No 5	-
AG13	Silverflo 60	No 4	H0
AG14	Silverflo 55	No 29	M25T
AG18	Argobraze 49H	No 37	M19MN
AG20	Silverflo 40	-	M10T
AG21	Silverflo 302	No 33	MOT

Anti-run for Solder

An anti-run is close to essential for some work, so you may as well develop a technique for stopping solder from running where you do not want it. There are several ways of doing this most of which is discussed in the Process section later in the article. Beware that solder will run anywhere that is clean, fluxed, and where capillary action can occur. There are also some products that you can use to assist with this and they are:

- Office White-out / Tippex typist correcting fluid - small container with integral brush in lid, getting hard to find (note that 'solvent free' versions aren't suitable).
- Never Seez R lubricating compound by Bostik
- Marking out ink (this was recommended by George Thomas)
- Jewellery supply houses supply proprietary products
- Jewellers yellow ochre in a paste form
- Indian ink – used for protecting hinges in jewellery work, and can be applied with a brush
- Ordinary soft lead pencil (2B through 6B) is reported to be used by orthodontist technicians
- Soot from the flame of an acetylene torch with no oxygen being used, although this is a method to be avoided as it is messy and getting the soot just where you want it, is difficult.

Fig.6



Lap Joint Cylindrical Shape

Binding Wire

Binding wire is an essential component for joint preparation in some situations. Joints can often be easily held in place by wire. The best type is black (not bright drawn) binding wire which is available in all sorts of sizes. The larger sizes are found on building sites, and used for installing concrete re-bar (re-enforcing steel bar). Generally, the sizes of more use to model engineers are those less than 3/64" (0.050") diameter, and iron binding wire is available in various diameters down to 0.008". The jewellery supply houses supply wire from 0.020" down to 0.005".

Pins and Screws

Bright brass or steel wire can be used as a pin to secure components made of brass or steel. You will require wire that is very small diameter, generally 1/16" or less, and is bright and drawn hard (does not bend easily). Holes are drilled through the assembled component and the wire is inserted as a pin to hold the components together. I do not recommend that you use small diameter drill rod or silver steel.

Small screws can be used to hold parts together while they are soldered. The heads can be filed or machined away after soldering. These pinning and screwing methods should be mastered if you are making complicated, multi-part components.

What Can Be Soldered?

The list below describes some of metals that can be silver soldered along with comments and notes.

- Brass - Easily soldered
- Mild Steel - Easily soldered.
- Tool Steel - Easily soldered.
- Stainless Steel - More difficult.
- Cast Iron - More difficult.
- Copper - Easily soldered.

- Silver - Easily soldered.
- Bronze - Easily soldered.
- Carbide tool inserts to steel tool holders - Moderately difficult
- Gold - Easily soldered but normally soldered with gold, rather than silver solder.

The following points should be noted regarding what can be soldered.

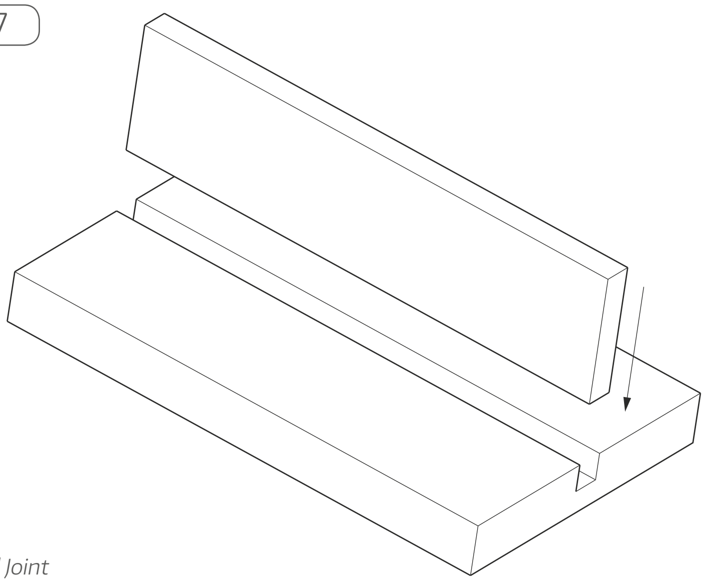
1. Stainless Steel - requires appropriate flux, Johnson Matthey make a Stainless Steel grade flux called 'Tenacity' which is also good for large assemblies needing a lot of heat. Test run a joint, before using for serious work.
2. Cast Iron - To solder, ensure the cast iron is clean and free from surface graphite. Clean with a degreasing solution. SSQ-6 is a silver solder in a tube which MuggyWeld claim solders cast iron easily (muggyweld.com/cast-iron-repair). This tube contains premixed solder and flux, apply from tube, assemble and heat. Note that a tube of the product has a shelf life of about one year.
3. Mild steels containing lead to aid machining will not solder as well as regular carbon steels.
4. Drill rod (silver steel) solders beautifully.
5. For Carbide or other small tool inserts use AG14, although special foil is available for large inserts which use AG18 solder. Test run a joint, before using for serious work.
6. Silver soldering of aluminium will not work – the aluminium will melt before the filler rod! Consider a special soft solder.

Planning

As with any process planning is important. Some decisions which need to be made prior to starting any silver soldering process are:

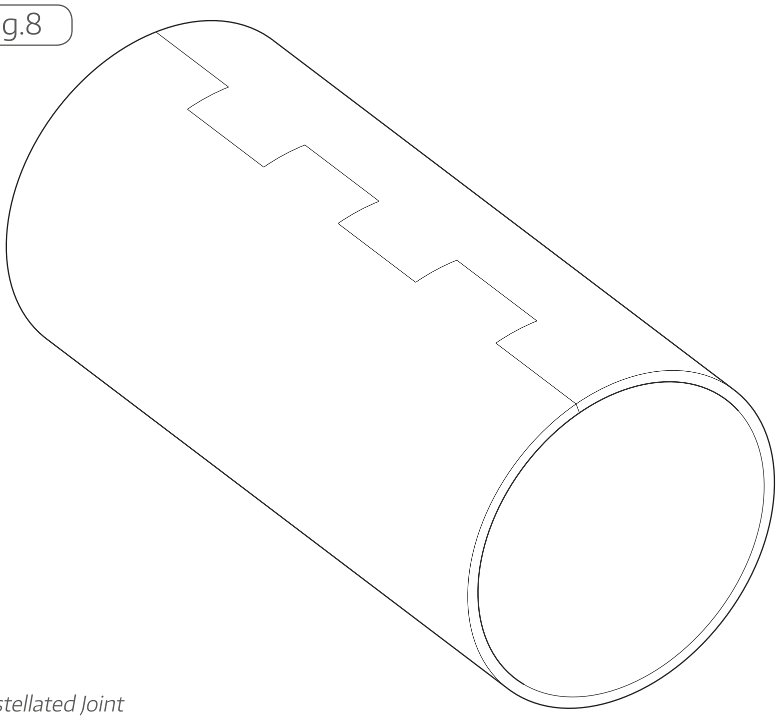
- What gap is required between the components?
- Will the gap make the components hard to position? If this is the case, then how will the parts be held in position? Consider part holding options discussed later in the article.
- As the flux is heated, parts may move if they are not secure, plan how to stop the movement.
- How will the part be supported on the brazing hearth, and how will the flame get to each joint? Some support structures may impede heating enough to make them impractical. If part of the joint will be hidden what material can be used to reflect heat at that part of the joint?
- What type of torch will be used and with which tip, nozzle, or burner?
- Do you need a support for the torch? If a support is required how will it be secured?
- What type of silver solder and flux will be used?
- How will you apply the silver solder?
- How will you apply the flux?
- Have you an appropriate piece of solder to apply, or are you going to risk using a full rod of solder?
- How will you move the part from the brazing hearth to the pickle?
- What pickle will you use?
- How are you going to clean up the part after pickling? Does the part need special treatment prior to final finish such as painting?

Fig.7



Slotted Joint

Fig.8



Castellated Joint

Joint Design

An overlap of the metals is usually required. Four times the thickness of the thinnest component is a minimum overlap as a design criterion for joints under pressure.

Plain butt joints, as shown in **fig. 4**, are generally to be avoided unless absolutely necessary. Where a butt joint must be used, use a silver solder that provides fillets as this will help with joint strength.

Over-lapped joints are shown in **figs 5** and **6**, both joints show the large areas provided over which the solder can flow.

Joint gaps are described below, but machining two parts with a little play is required. For successful soldering, joints require a surface area, and the ability for the solder to flow through the joint, by capillary action. The capillary action of the solder, when in molten form, is the reason for the gap, and why the gap is so important.

Figure 7 shows the advantage of a slotted joint over a butt joint. There is three times the area available in the slotted joint for solder compared to the butt joint shown in Fig. 4.

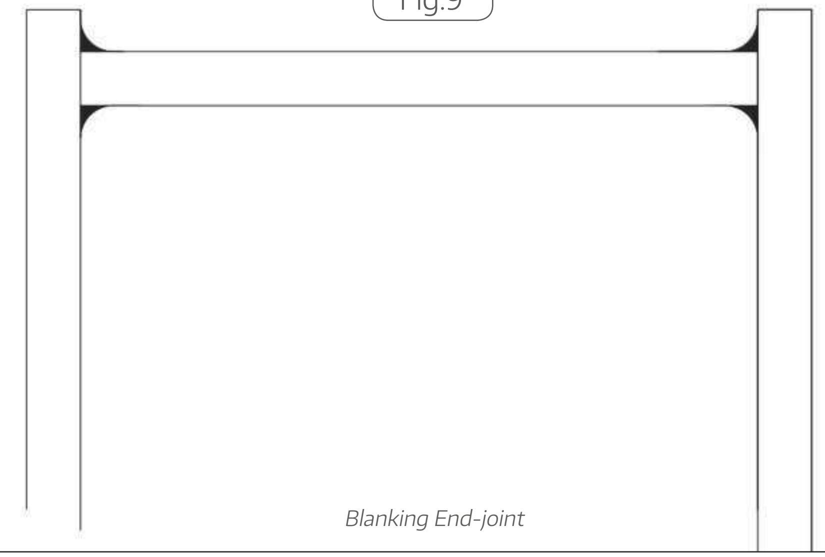
The joint in **fig. 8** is a castellated joint which is a modified coppersmith's joint. It provides additional solder contact area. For boilers, the castellated dimensions are usually about ½ by 1 to 1 ½''. The joint can be further strengthened by using a plate under the castellated joint.

A blanking joint, in the end of a tube-like structure, can be strengthened by allowing fillets on either side, as shown in **fig. 9**. A second solution is to create a flange or shoulder which can give additional area to the joint.

If you want solder to run in a certain direction score the components by scratching lines with a scriber in the direction the solder is to flow. These score lines need only be a thousandth of an inch or so deep, but seem to make a vast difference to the capillary flow.

A different technique for joining two flat surfaces is by sweating a joint. This involves depositing the solder on one surface in the first operation, and in a second operation placing the second face on the deposited solder, and reheating and allowing the two parts to join. This is a common operation when soft soldering, but also works for silver soldering.

Fig.9



Blanking End-joint

Small Fittings and Fabrications

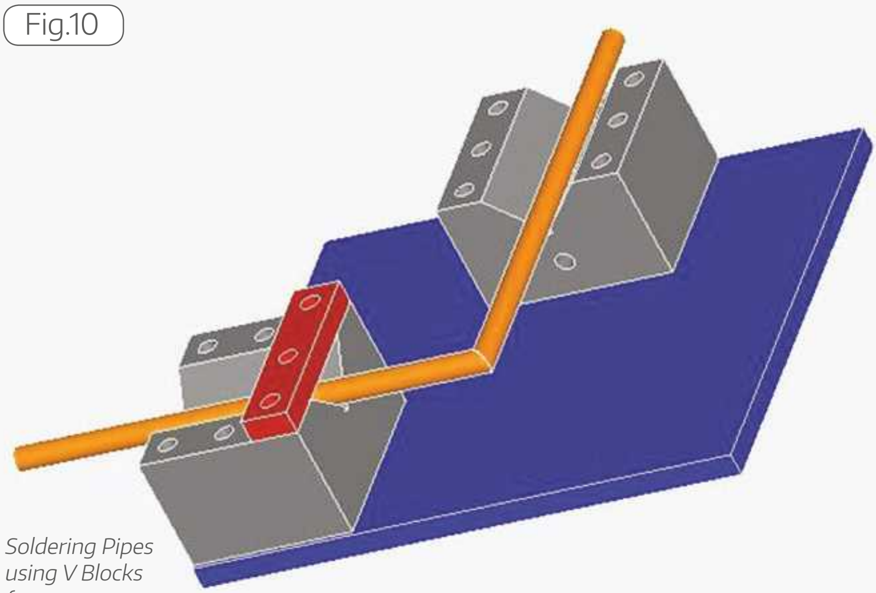
Connecting pipe work components involving cylindrical shapes such as pipes, and pipe fittings requires proper planning and design, especially if when in use, these components are under pressure. Components such as pipes into unions and sockets should slip into the receiving socket about the same amount as the pipe diameter. This ensures a good area for solder to flow.

Sometimes when assembling fittings, it may be better to thread the male and female components as this secures them in place and then silver solder the threads to seal and complete the joint. There must be enough space between the threads for the silver solder capillary action to flow and fill the joint.

If the components to be joined, can be chamfered (say 0.010 to 0.050") where the solder is to be applied, this can be very effective in aiding penetration. When you are machining your own parts this is an easy operation to add to the machining sequence.

Supporting pipes and fittings during soldering can be quite a problem, however there are a couple of solutions. One way of using 'V' blocks is shown in **fig. 10**, where the blocks are attached from underneath to a base plate (blue), straps (red) are used to hold pipes in position on the v-block. The two v-blocks (grey) can be positioned so that any pipe shape can be silver soldered accurately, in this case an elbow joint with the elbow formed by cutting the pipe at 45°.

Fig.10



Soldering Pipes using V Blocks for support

A second solution, if it is a short pipe, is to insert an iron wire support inside the pipe to support the pipe, and pull the iron wire out after soldering.

Joint Gap

Table 4, provides for each type of silver solder, minimum, and maximum gaps for that solder type. The distance between components allows the solder to flow through the joint, if there is no gap, then there will be no solder. A minimum gap is therefore required for capillary action to occur.

AG18, marked with an asterisk in Table 4, is used for carbide tip attachment and are usually used with silver solder in foil form places in the joint.

The gap specified by suppliers is the best gap necessary to get a maximum strength joint. A typical strength of the joint versus the gap is shown in fig. 10. Each solder type will follow a similar curve.

From fig. 10, for most joints not under high pressure or tension/compression conditions, one can see that as long as the gap is big enough for capillary flow to happen, and is not excessively wide, for most solders there is plenty of latitude for a successful joint. Therefore, the best advice is ensure there is a gap for capillary action, and after that don't worry too much.

To be continued

Table 4 - Optimum Gap Size for Standard Silver Solders

BS Name	Min Gap mm	Max Gap mm	Min Gap in	Max Gap in
AG5	0.075	0.20	0.003	0.008
AG13	0.05	0.20	0.002	0.008
AG14	0.05	0.15	0.002	0.006
AG18	*	*	*	*
AG20	0.025	0.15	0.001	0.006
AG21	0.075	0.20	0.003	0.008

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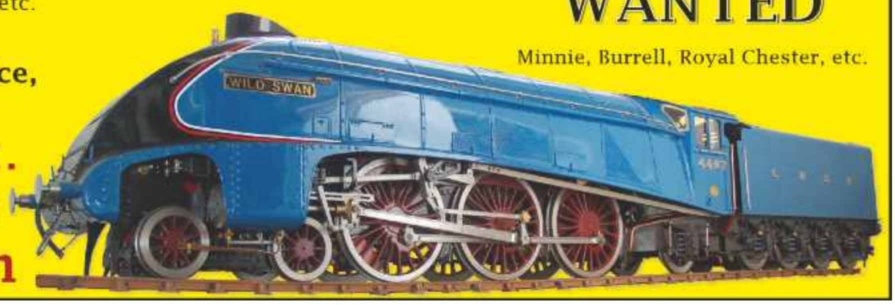

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