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NOVEMBER 2015

MODEL ENGINEER EXHIBITION 2016 ANNOUNCED

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On the Editor's Bench

THE 2016 MODEL ENGINEER EXHIBITION

I'm pleased to repeat the official announcement made by Diane Carney in the latest issue of *Model Engineer*.

We are delighted to announce that the 2016 Model Engineer Exhibition will take place on 16, 17 and 18 September at Brooklands Museum, Weybridge, Surrey.

The event will, as always, be sponsored by the publishers of Model Engineer, My Time Media and will feature the World Class Competition, individual loan models, stimulating displays by Clubs and Societies, a cross section of traders and suppliers and all this against the backdrop of one of the best museums of historic transport and engineering in the country. Without doubt the exhibition promises to be something completely new, refreshing and invigorating as well as thought-provoking and inspiring.

The organisers took the decision to move away from the tried and tested format of the MEX, sensing that, successful as it was, times have changed and exhibitors and visitors alike would welcome something original and, perhaps, a little unconventional. It is the hope, therefore, that all those who have enjoyed the Model Engineer Exhibition in the past will embrace the new concept and that everyone will look forward to a great weekend of pure indulgence in this wonderful hobby, surrounded by engineering history! We believe that, more than ever, it will be worthwhile making a weekend of it and taking extra time to enjoy all that this fantastic new venue has to offer. The decision to change the date was also made in the hope that a September weekend will be rather more pleasant for outdoor activities (if it's anything like this year it will be glorious - but it's probably best not to tempt fate!)

In future issues of *Model Engineer* we shall be bringing you more about Brooklands Museum, the Birthplace of British Motorsports and Aviation; of the tremendous history of flight and flight testing since the very early 20th Century; of the world's first purpose-built motor racing circuit; of world speed record attempts and pioneering flying clubs and flight training. The museum also incorporates the London Bus Museum within the purpose built Cobham Hall on site - a quite spectacular exhibition in its own right - and there will be an opportunity to take a tour of the first British production Concorde. And there is so much more…

There is just under a year for you to prepare your models for exhibition! We are currently in the process of writing to the clubs that have traditionally supported us and we shall be putting together a programme of events and activities in the coming months. More information, including details of how to enter your work into the exhibition or the competition and how and where to purchase tickets (there will be discounted 'early bird' tickets available) will soon be published through the pages of this magazine and on the Model Engineer website: www.model-engineer.co.uk For now, though, mark the date on your calendar - you won't want to miss MEX 2016.

My congratulations and thanks go to Diane and everyone else who has put in a huge amount of effort to secure such a fantastic venue.

Fifteen Minutes of Fame

Believe it or not there is a (tenuous) link between regular contributor Mike Cox and avant-garde artist Andy Warhol – soup tins!

A number of readers got in touch to say that the light bulb fitted to his demagnetiser is rather vulnerable to breakage, and that in such an event this would expose the live wires inside the bulb. I checked with mike and he reassured me that the bulb was well protected with a soup tin, and that he didn't submit a photo because it looks rather crude! Now some readers can be a little sceptical of photos annotated 'guards removed for clarity', but in this case I am pleased to say that Mike has sent me the accompanying image of the demagnetiser, resplendent with its shiny soup-tin. Naturally, it is advisable to earth the said tin.

A few other comments were made, one of which is that the switch should be placed in the live supply (this wasn't obvious from the accompanying diagram). The other was a query about whether or not the aluminium disk had a significant impact on the effectiveness of the demagnetiser, due to eddy currents? The disk is solely there to show the demagnetiser's 'hot spot', so Mike has tested it with and without the disk and is unable to detect any difference in its performance.

I've already had a few reports of readers successfully making their own versions. A few have used smaller transformers without adding the bulb, so there is scope for experimentation, but please take care when working with electricity.

MODEL ENGINEERS' WORKSHOP

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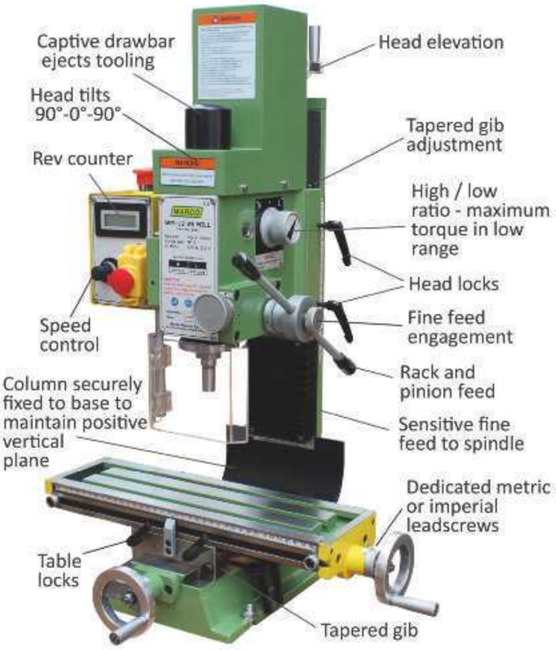

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Contents

See page 23 for details.

Coming up...

in the December issue

HEAVY METAL

Will Doggett introduces his heavy duty rollers.

PLUS Mike Checkley describes a micrometer end stop for his CNC vice, Keith Wraight constructs a power cross feed for Myford lathes and Andy Clark shares his experience of a Maker Faire in New York.

Regulars

ON THE COVER

Welding is a useful skill, allowing us to fabricate large and complex shapes. This month we explore the advantages of MIG welding.

HOME FEATURES WORKSHOP EVENTS FORUMS ALBUMS

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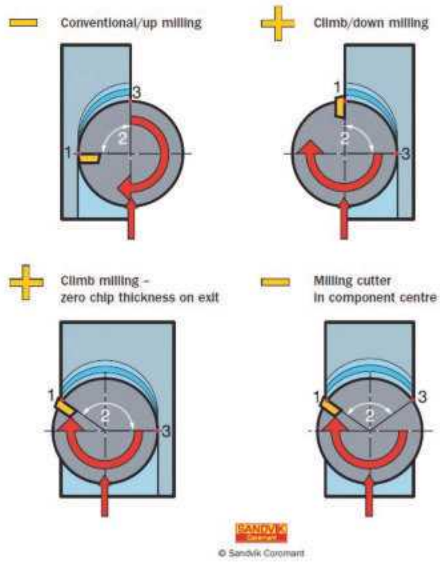
Why Climb Mill?

In the past climb milling was seen as bad practice, leading to broken cutters and spoiled work, but the advent of CNC and minimal backlash machines has seen it become a preferred approached under these circumstances. Thanks to Sandvik Coromant we bring you their guide 'why climb mill'.



Other hot topics on the forum include:

› **Engineers' Blue**
Fed up of blue fingers? What are the alternatives?

› **Clarkson Autolock vs ER Collets?**
It's a face –off between the old industry standard and the new kid on the block.

› **Groove for Round Belt Pulleys**
Struggling to get a grip? We can help…

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Feedscrew Nuts for an Alpine Mill

Ian Priest restores accuracy to an Alpine Minor Milling Machine.

About twenty years or so ago, my wife bought for me an 'Alpine Minor' bench mounted milling machine (**photo 1**). This machine, despite its shortcomings, has performed sterling service completing the majority of all milling tasks required to complete two 5 inch gauge steam locomotives. The major problem with this machine that has all too often been pointed out, is the build quality, especially one of a vintage like the one I have.

On the plus side the Minor does have a reasonable size table with four tee slots and for the size of machine a decent quill travel being 4 inches. It also has a fair range of speeds, all from a single 1½ HP single phase motor. It is also fairly compact. By far its biggest downfall in my opinion is the lack of a rising table.

1

The Alpine Minor machine.

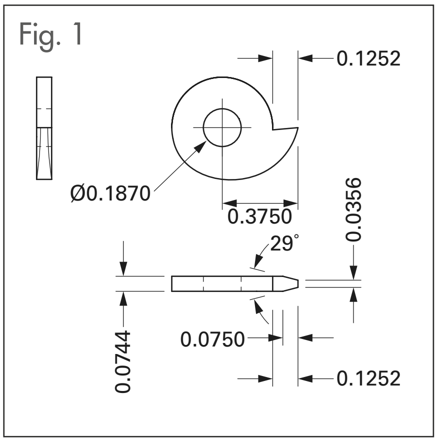
Over the years my machine has, as stated, performed all of the tasks asked of it and a 'good workman never blames his tools' but with use wear and poor build quality took its toll, and this mill took second place to a Tom Senior, which fitted with a DRO performs the majority of my milling operations. The Minor then became a little redundant and saw little work except where its slow bottom speed found use for large diameter fly cutters and the like. It did for some time reside with a 6 inch rotary table fitted to the table and saw use profiling various locomotive parts.

Little wonder then that the grey matter churning over one evening urged me to convert it to CNC. A logical choice really given the table size, the tee slots and the fact that not too often do I need to use the full 4 inch quill travel when milling.

Let me state that, to date, my knowledge of CNC could be written on the back of the proverbial postage stamp. I do know that no matter how good any electronic attachments may be, or how powerful a CNC programme, the machine, be it lathe or mill, does need to be in reasonable condition. The re-conditioning of my Minor became the priority and the basis of this article.

Close examination of the mill determined that basically it wasn't too bad, that is until the feedscrews on both the x-and y-axis were looked at. The x-axis was exhibiting 0.020 inch of backlash and the y-axis about 0.015 inch, far too much for my liking.

Initially I toyed with the idea of fitting ball screws offering a zero, or pretty near to it, backlash installation depending, I guess, on how much you want to pay. I



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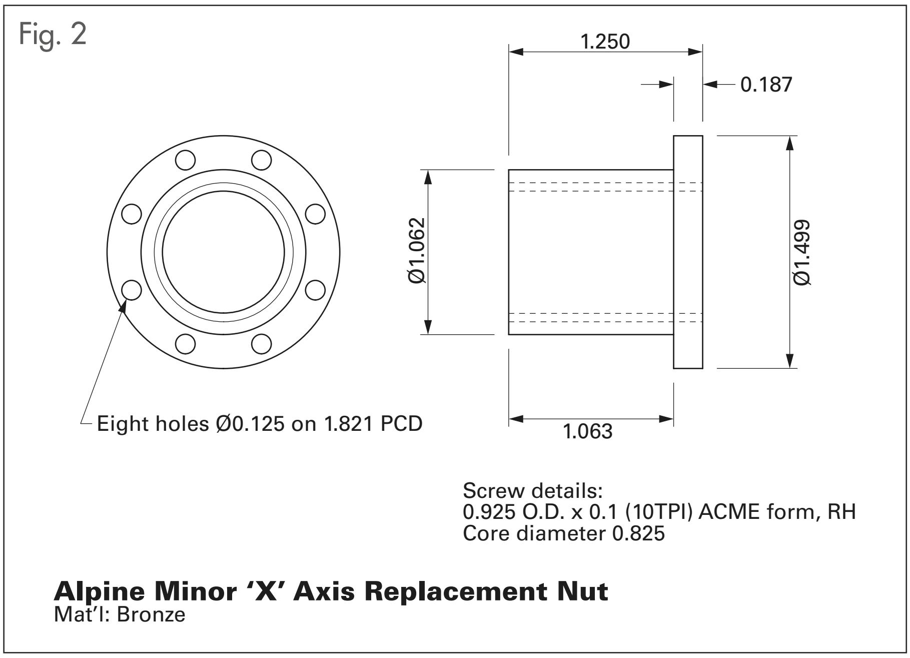
discarded this idea not because of the cost but because I am not fully decided yet on how far I want to travel down the CNC route and the cost of commercial ball screws would have made a considerable dent in my wallet. Maybe if all goes well I might invest in such items at a future date depending on how I get on.

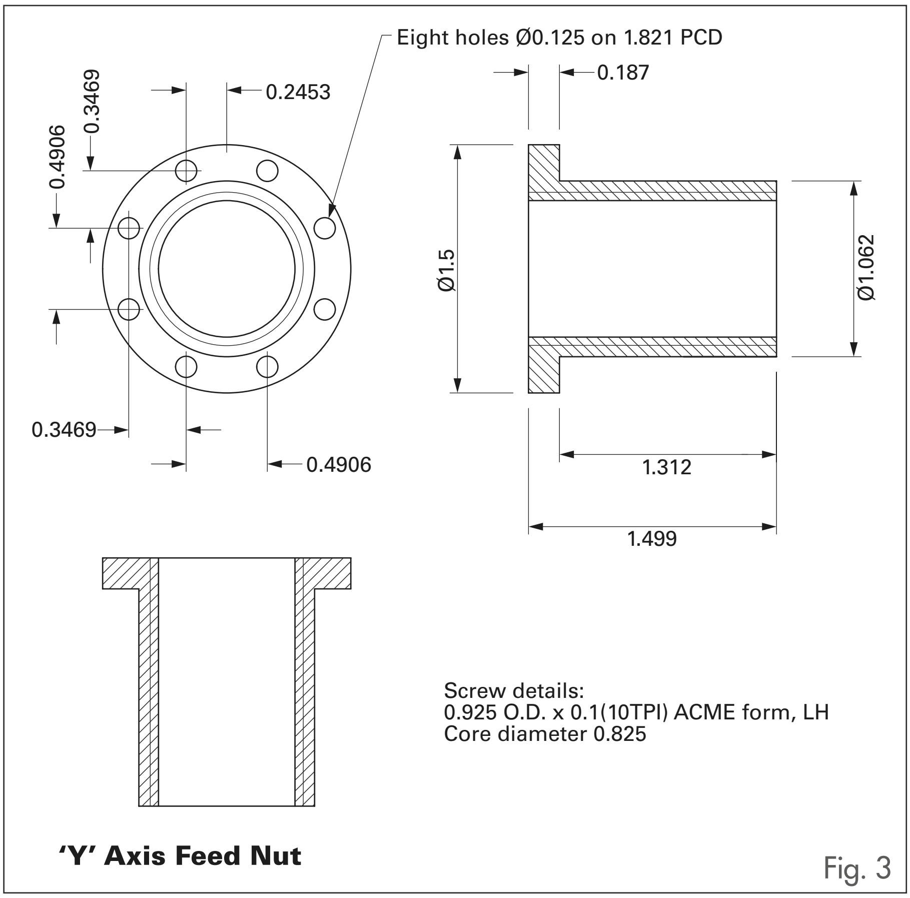
My only option then was to remake two feedscrew nuts for both the x-and y-axis (axes or is it axis's – not sure!)

The original feedscrew nuts on my machine were, I would like to believe, bronze castings, although they do look a little yellow to me and might even be brass, in any case they were worn so as to be useless, more use as ornaments than feedscrew nuts. On a positive side the actual feedscrews were in good order and on balance I'd rather re-make the nuts than the screws. **Figures 2** and **3** are drawings of the actual nuts.

The actual screws were a little strange, I knew the pitch was 10 TPI because of the graduations on the feedscrew collars but the outside diameter when measured turned out to be 0.925 inch. The thread form is Acme, and I believe the original screws were rolled as opposed to being of the better quality ground.

Readers will note that the included angle for an Acme Thread is 29 degrees and that the thread height is 0.5 inch x the pitch which in my case is 0.100 inch giving a thread height of 0.050 inch.



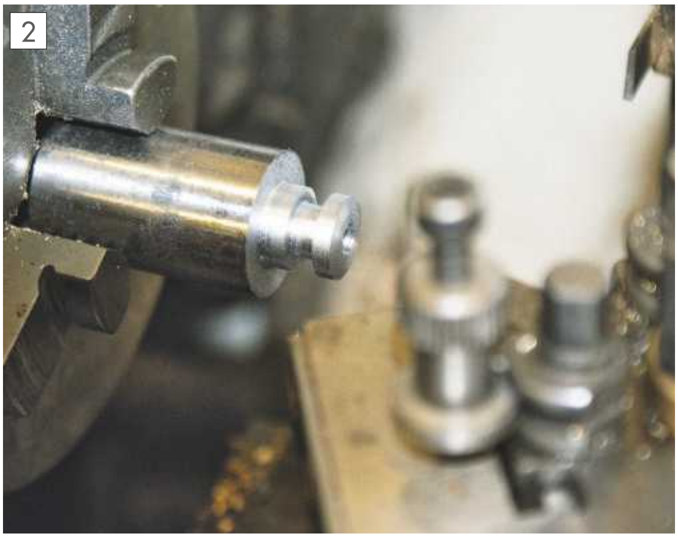


Snail Tool

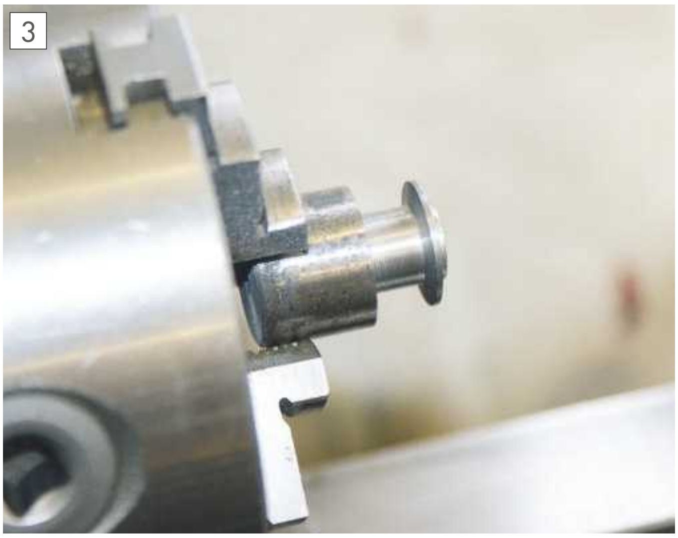
The first task then was to produce a suitable internal screw cutting tool. This was achieved by making what I call a 'snail tool' (**fig 1**) due to its shape made from a 0.875 inch diameter length of silver steel. The cutter bit once made is fastened to the end of a boring bar.

The cutter itself is made from silver steel which was annealed by heating it to the usual bright red and allowing to slow cool, a quick polish with emery cloth ensued just to remove any scale. Mounting the silver steel slug in a three jaw chuck, face off and turn the outside diameter down to 0.750 inch diameter using a medium speed and a sharp tool. Many amateur engineers shun the use of suds or coolant in the home workshop, I don't but have through experience found for a really fine finish use a sharp tool stoned to a good finish, use a slow speed and fine feed and the best cutting lubricant is a blob of spit on the end of the tool bit. An added bonus being that it is that it's free! I also use pumped suds for more general use!

Next using a parting tool gap out the blank to 0.500 inch diameter about 0.5



The tool blank.



The tool profile.

The 'snail tool' fitted to a boring bar.

The x-axis nut and carrier.

inch long, the length is not critical The next step is to offset the topslide to half the included angle of 14½ degrees to the left that is facing towards the lathe headstock and, again using the parting tool, machine the left hand face of the embryo screw cutting tool. It is important here to obtain a good finish so stone the cutting edge of the lathe tool and take your time. Once satisfied offset the topslide to machine the other face bringing the tip dimension to just below the required finished width of 0.0365 inch. Make the tool thinner at its tip than it needs to be; the tool tip can later be ground or stoned back to finished dimensions (**photos 2** & **3**).

Once satisfied centre drill the end and drill through 0.187 inch, clearance for a 2 BA mounting screw used to mount it on the end of a suitably taped boring bar. Do not at this stage be tempted to part off the embryo tool but leave it on the parent bar stock, it's much easier to hold and work on that way.

The next stage is to remove the majority of what you've just taken a long time to machine, to give a shape similar to that shown in fig. 1. I used a combination of milling (on the Tom Senior) and filing to finish my tool. Once satisfied return to the lathe and part off.

It is important when quenching not to use water too cold as the thermal shock may cause cracking. Tap water from the cold tap at 'ordinary temperature' will do just fine.

Heat treatment

Hardening and tempering is the next order of the day. We need to heat the tool again to a bright red/orange colour and quench in water. With a tool of this small size it is important not to play the flame on the cutting edge but allow the heat to soak through gradually. I use a block acting as a heat sink to slow the rate of heating down a little. The reason for this is as the tool is thin it is easy to burn the tip away rendering the tool useless for intended purpose.

Equally important is to ensure that when quenched the tool, is agitated to prevent air bubbles forming on the surface reducing the effectiveness of the quench.

Our toolbit is now very hard and like glass, very brittle so clean up and prepare to temper. Again due to the small section size of the tool, the temperature will come up very quickly so pre- heat a steel block and place the tool on top of that, as the required temperature is reached – pale straw in colour quickly remove to the quench and cool off.

The tool can now be mounted on a toolholder and using same as a handle any final adjustment can be made either using the offhand grinder of the oilstone or as will probably be the case a combination of the two. **Photograph 4** shows the finished screwcutting tool mounted on the end of a boring bar ready to start screwcutting.

In the manufacture of my feednuts I decided to have a trial run using a relatively cheaper lump of brass before I committed to an expensive lump of bronze. In any case the first stage is to mount in the lathe three jaw, face off, centre drill, open out and bore to the core size of, in my case, 0.825 being the screw outside diameter minus 2 x thread depth.

This size is close enough to 21mm diameter for readers to be tempted to drill the bore, this should not be done and final size arrived at by boring. The reason for this is that drills seldom produce an accurate hole but we do want our feednuts to be as accurate as possible.

Once complete we are now ready to start screw cutting. My lathe is a Myford Super 7B with gearbox, as such it was easy to set up for this operation. Others may have to set up a gear train to cut the required pitch of 10 TPI. Use a screw gauge to set the cutting tool at the correct angle relative to the work and make sure the thread dial indicator is engaged.

If you do not have such a device don't despair all it will mean is that once the screw cutting process starts you should not disengage the feedscrew.

Zero the cutting tool against the bore and zero the cross slide dial. I had initially intended to cut the thread using a mandrel handle to drive the lathe. After a couple of turns I gave up on this as it was quite hard work, instead I cut under power by engaging the back gear and running the lathe at an indicated speed of 92 RPM.

This proved to be very satisfactory; initial cuts were of 0.005 inch infeed. As final size is approached try the screw in the nut. Here I was fortunate in that although the Alpine mill x-axis screw is quite long compared to the lathe capacity, with the tailstock removed I was able to try the screw in its nut.

I found it necessary to run the cutter down several times at final depth to shave off a few tenths till the screw just fitted in the nut.

At this point I, based on the logic that the extreme end of the feedscrew probably had no wear at all, but that the central portion of the screw where the majority of work takes place probably did, I decided then to remove the nut from the lathe while being a little on the tight side. As it turned out although the first inch or so was tight, close examination revealed that this portion of the screw was rough probably left over from original manufacture. This was addressed by careful polishing with fine emery cloth, a drastic step I know but it did the trick, the screw now runs freely without any backlash that I could detect along the entire length of the screw.

The next stage was to complete the same procedure for the y-axis nut remembering that, for me at least, that this screw is left hand. A similar result was duplicated for this nut.

All that remains is to machine the nut carriers, a simple task which should bear no explanation. **Figures 4** and **5** detail the nut carriers I employed. **Photograph 5** is of the finished x-axis nut carrier and nut mounted to the milling machine.

I also took the opportunity of giving the slides a good de-grease and oil, the gibs were reset and with a degree of patience I now have a vertical milling machine in good order. Yes, it was worth the twenty or so hours of development, research, machining and fitting time. All I have to do now is work out the intricacies of CNC and 'G' code. ■

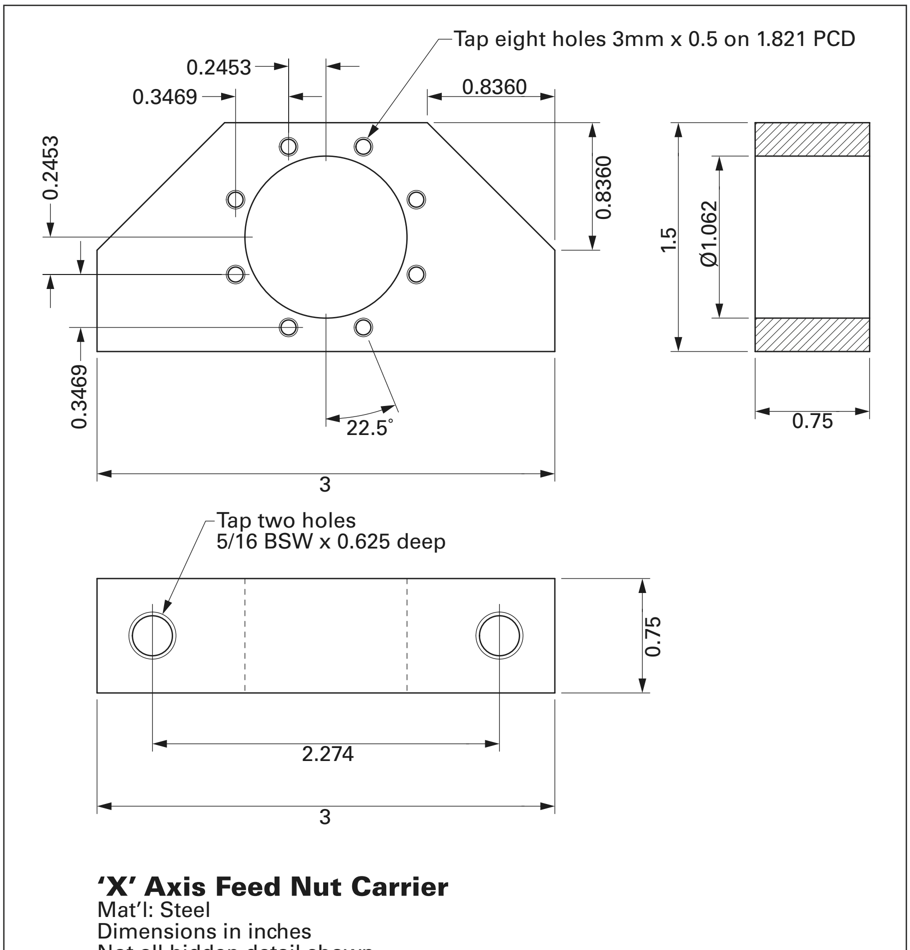
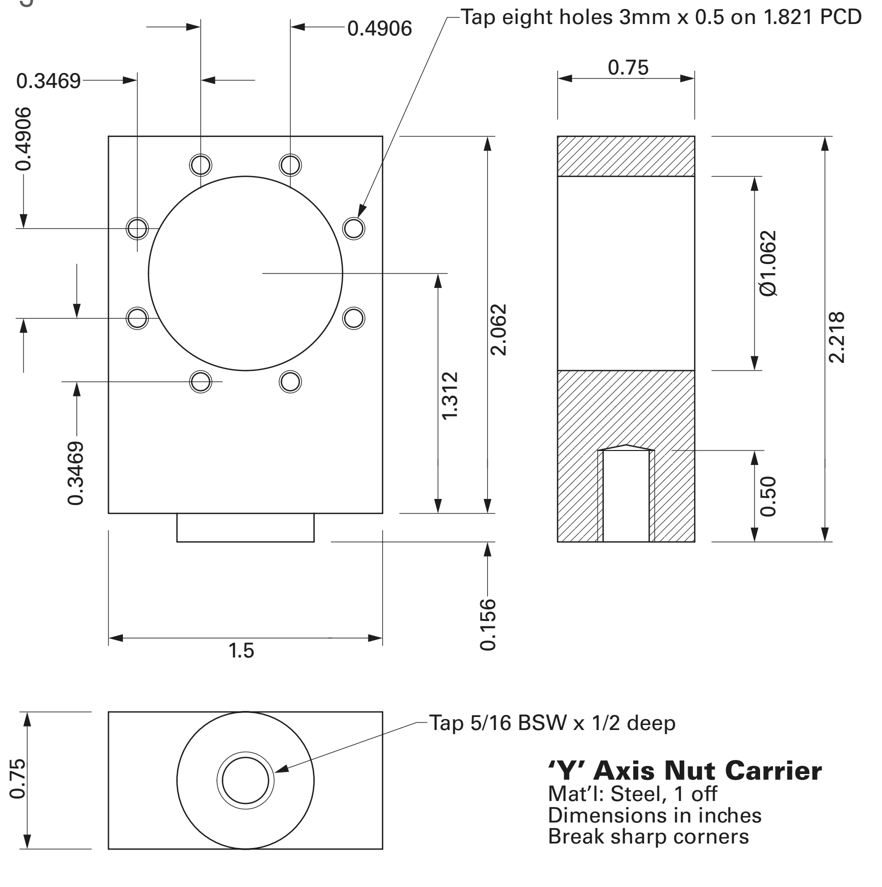


Fig. 4

Fig. 5



Carols, Cappuccinos and Lofted Solids

Bob Reeve tackles an ambitious task using CNC.

A rare Carol.

This project had nothing to do with Christmas, did not involve any singing and there were no fancy coffees; only the instant variety. There was however a certain amount of cussing, which increased as the project proceeded for reasons that will become apparent. It was one of those projects that started in an innocuous sort of way with a request from No 3B nephew (one of twins) and girlfriend Emily, to the effect that a little help would be appreciated with their current car project. The role of kindly uncle precludes a refusal!

It appeared that small Japanese cars have something of a cult status in the UK. I'm told they are known generically as Kei Cars (a contraction of the Japanese for small or light car) and there is a UK club dedicated to them (**ref. 1**). It transpired that said nephew & girlfriend were aficionados and had acquired a few of these cars in conditions varying from new to hauled-out-from-under-a-hedge. In the latter category was the Mazda Autozam Carol (**photo 1**) that was to become the centre of this project. Only 5 are registered in the UK making it fairly rare. The photograph was taken at a rally and the unknown passer-by illustrates why these cars are called 'Kei' cars

Unfortunately this particular Carol had been abused in its early years by being driven with a serious water leak which eventually wrecked the engine. However the body shell was in relatively good condition and worth preserving.

The proposed plan was to take the engine from another Kei car, a Suzuki Cappuccino (**photo 2**), and transplant it into the Carol. The Cappuccino in question was the silver one in the photograph. These are not rare and the body was not in good condition. In fact it was being considered for a move to the scrap yard. Apparently both Carols and Cappuccinos (and some others) have similar 3-cylinder 660 cc engines with a common cylinder block. They can all trace their lineage back to the Suzuki Alto, so minimising the difficulties of an engine transplant. It was intended to use the original Carol inlet manifold and what was required was an adaptor plate to marry up the fixing holes of the manifold to the cylinder head. The ports were likely to be on the same centres and all that was required was a flat aluminium plate with a few holes. I was provided with an approximate outline, some dimensions for the fixing hole centres and three circular ports. Some inch-thick aluminium plate of a suitable size was provided for the purpose. What could be difficult about that?

A pair of Cappuccinos.

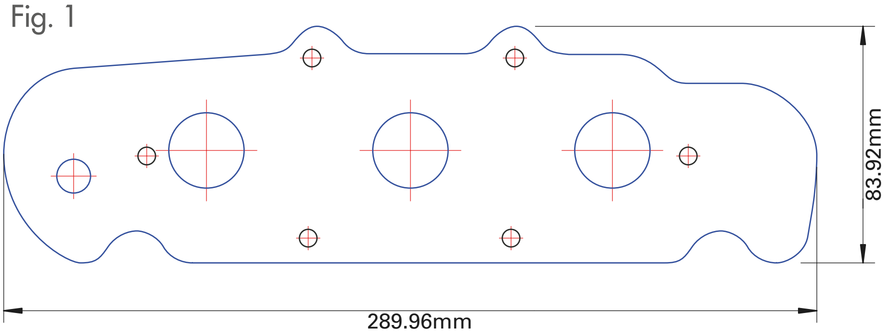
The first task was to draft out the proposed outline which was done in TurboCAD (V20). After a few amendments to radii and such like it was clear that the best way to generate the profile would be to CNC mill it. There were too many linked radii to make it an easy job on a manual mill with a rotary table. At which point I decided that I may as well programme in the fixing holes and the three ports. There were 6 blind holes which would eventually be tapped for the manifold studs and 9 through holes for the head fixings. All 15 could be machined at one setting from the manifold side. Unfortunately, I had drawn it (**fig. 1**) from the engine side! But this turned out to be a very minor problem compared with what was to come.

At this point it was time to introduce some precision, starting with the fixing hole and port centres. As a check on the information provided, I produced the profile in 8mm MDF by transferring the 2D data into Dolphin Partmaster (**ref. 4**) to produce the CNC programme complete with all the relevant holes; 3 ports, 6 holes for the cylinder head studs and 9 holes for the manifold fixing boles. I know from past experience how difficult it is to get 6 studs to go through six holes unless you can spot through. The profile with all the holes was duly presented to my nephew for a check on the fit to the cylinder head. Needless to say it didn't fit!

After a bit of back and forth communication a week or so had gone by without a satisfactory fit so I requested the Cappuccino cylinder head and the Carol manifold to take my own measurements. When they arrived, straightening a few bent studs made the measuring task easier and a satisfactory fit for all the studs was achieved, but there were a few surprises:

1. Similar engines does not mean identical. The Cappuccino head was a twin cam (**photo 3**) and the Carol was not.
2. The proposed profile would not fit as a flat plate due to interference from the cam-box fixing studs. There would need to be some relief machined into the plate.
3. The Cappuccino's inlet ports in the cylinder head were not circular – more a tri-lobed shamrock leaf sort of shape.
4. The Carol inlet ports were also nowhere near circular – more a tear drop sort of shape, presumably to accommodate the fuel injectors which can just be seen in **photo 4**.
5. There was an additional connection to the head for coolant (right in photo 3) which would need to accommodate a ¼-inch BSP pipe and the unused port (left) would need to be blanked off.
6. Water passages in the Cappuccino manifold (**photo 5**) meant that two of the head studs should be replaced by cap heads as shown in photo 3, which would need to be in counter bores.

Fig. 1



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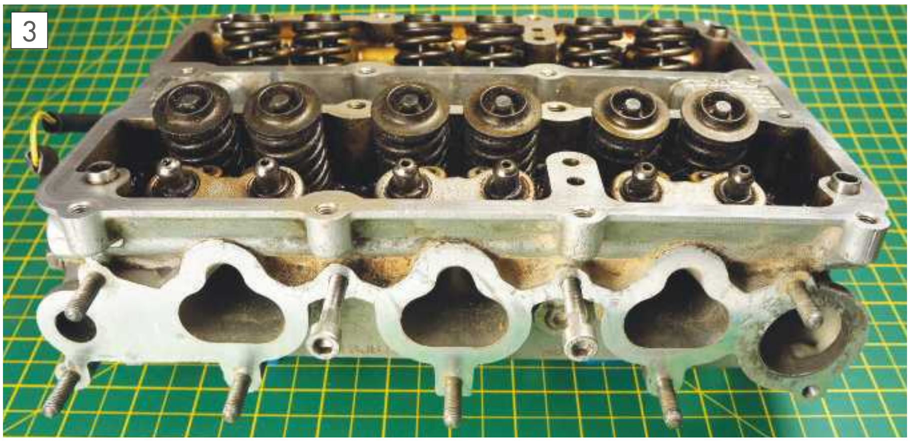


Cappuccino cylinder head.

4

Carol inlet and injector.

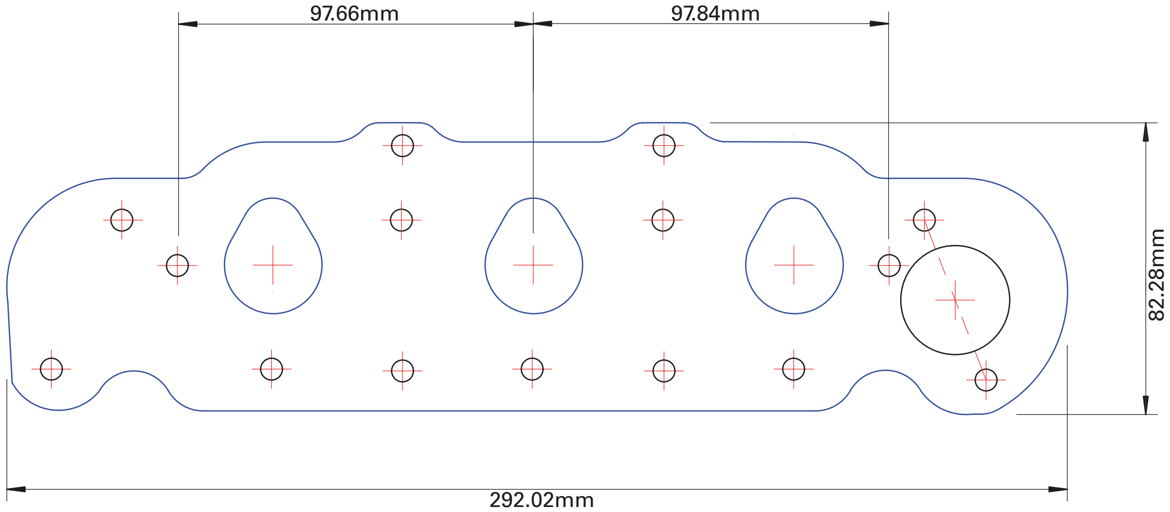
5

Carol inlet manifold.

By now a couple of weeks had passed and this was beginning to look like it was going to be less-than easy.

The only redeeming feature, so far, was that the ports actually were on the same centres (if a tear drop has a centre) for both engines. It was clear that some major revisions would be necessary. Revisions to the profile could avoid all but two of the cambox fixing studs and those could be

Fig. 2



accommodated within the plate thickness. The profile would need extending a little to provide sufficient material round the newly identified cooling water connection. These modifications can be seen in **fig. 2**, this time drawn from the inlet manifold side with the correct port profile. However, the differing port shapes was not an easy problem to fix and another week went by.

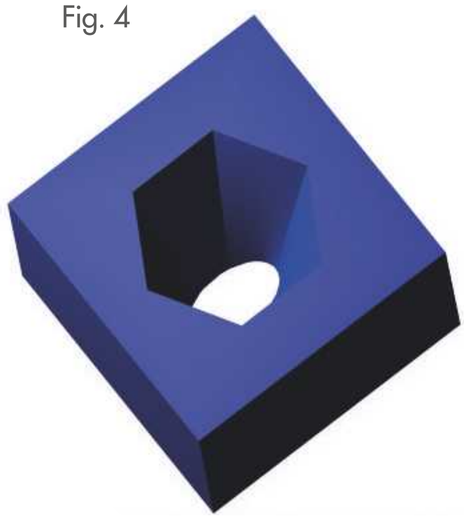
My search for a solution centred on milling a port which would make the transition from one shape to the other within the 1 inch thickness of the plate. The solid modelling facilities of TurboCAD were brought to bear on the problem and I began to explore the use of lofted solids to achieve the required geometry. Lofted solids are constructed by joining two different 2D profiles in different planes by straight lines. **Figure 3** demonstrates a simple lofted solid using a hexagonal base and an elliptical top. For the ports a lofted solid 'hole' is required. This is achieved by subtracting the lofted solid from another solid, such as a cube in **fig. 4**.

Even with this approach it was not going to be easy, the lofted solid for the ports had undercuts from both sides and I had no idea how to mill such a complex shape on my X3 CNC Mill.

At this point I had two strokes of luck, one technical and one more of a psychological boost. The latter was the article in *MEW* by Andrew Johnston (**ref. 2**). In it was a description of the use of lofted solids to generate bevel gear teeth.

Fig. 3

Fig. 4



For the first trial, the port was milled in a small square of 1 inch thick mahogany that happened to be to hand. It machines nicely and is more forgiving if the cutter doesn't follow the expected path.

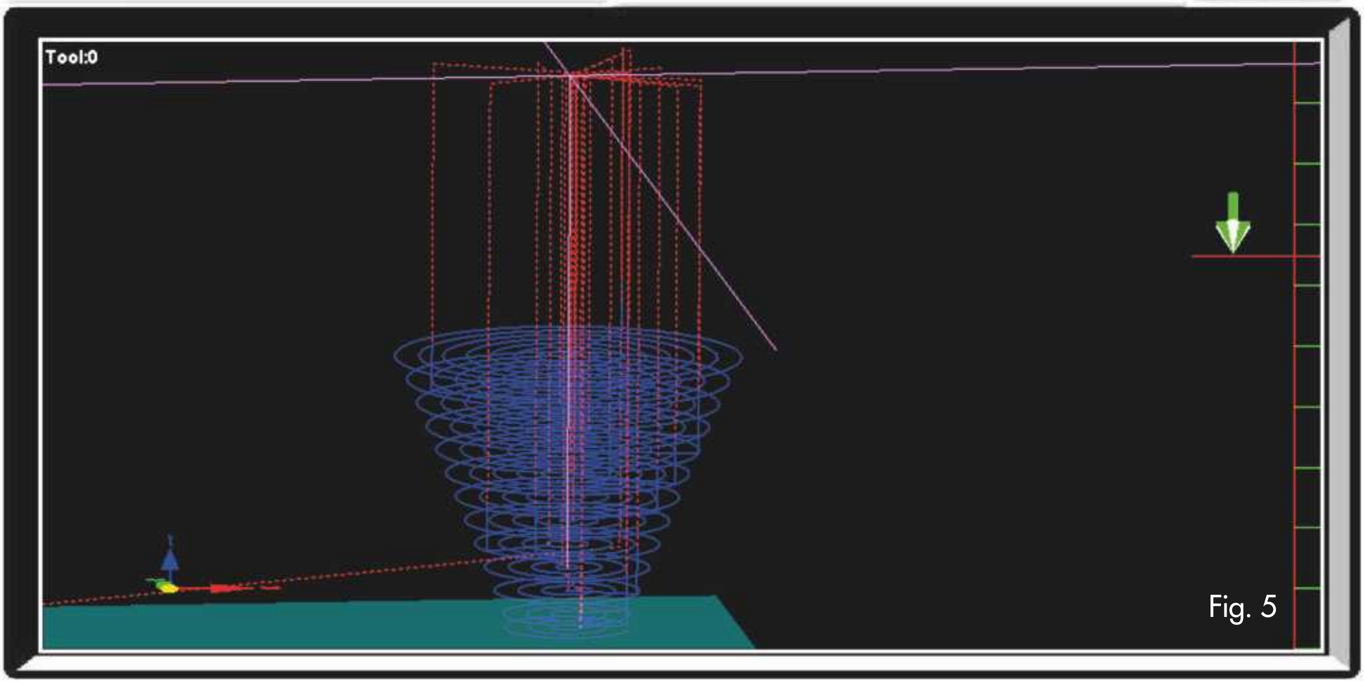


Fig. 5

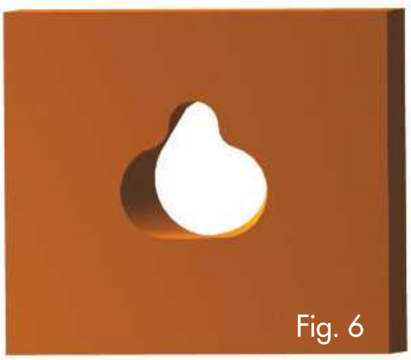
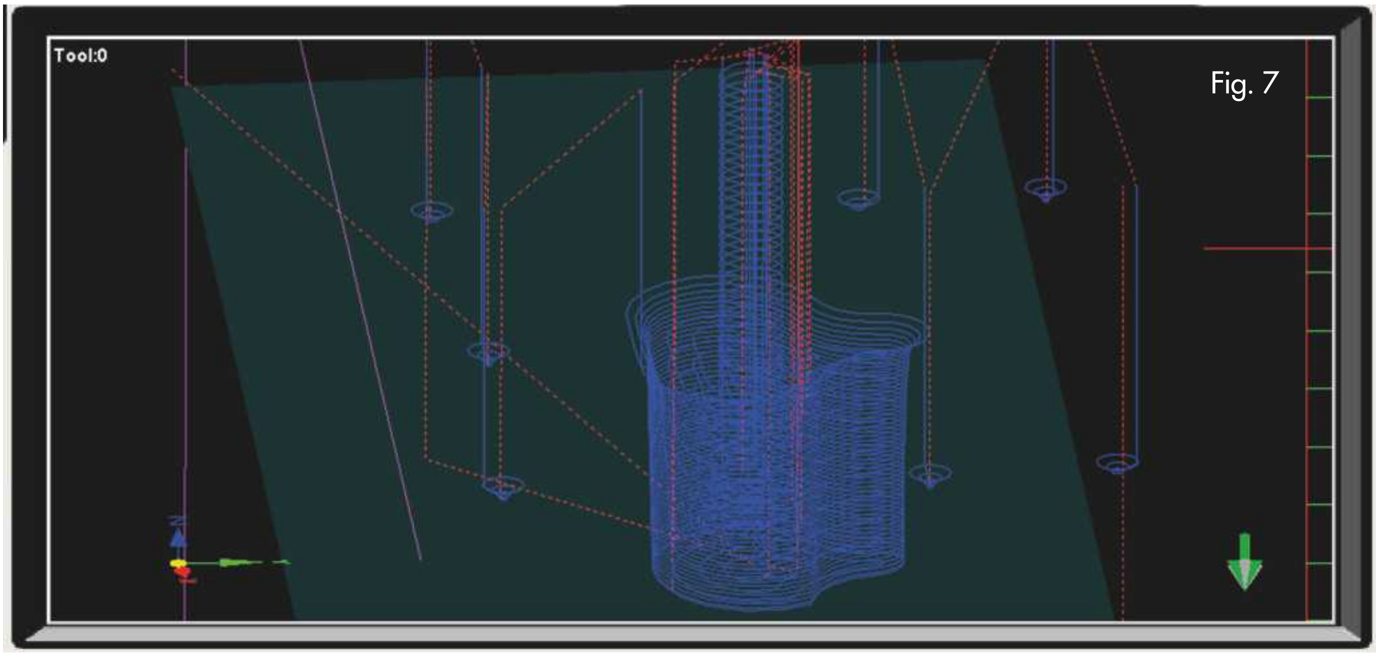


Fig. 6

It was very reassuring to know that there were other model engineers exploring this rather obscure geometric construction and having some success, just when I was thinking this was all getting too difficult. Thanks Andrew.

The technical luck came in the form of an e-mail to Pete, my long time friend and co-conspirator, about the capabilities of BobCAD (**ref. 3**) in programming a Z-slice approach to the lofted solid. The immediate response was that he didn't know, but would investigate. The following day a reply with a trial programme demonstrating how a conical pocket could be milled arrived. The tool path from Mach 3 is shown in **fig. 5**. By way of a trial, I milled the pocket into a scrap of wood that happened to be to hand. It worked much better than I expected.

There was, however, still the problem of the under cuts. We suspected that if BobCAD could do Z-slicing, it probably had enough inbuilt intelligence to detect the undercuts and avoid them. Unfortunately, this would necessitate milling each port from both sides. Using the same approach as in figs 2 & 3, I produced a solid model for a single port (**fig. 6**). This was forwarded to Pete and I



sat back to await the outcome. Back came two programmes. First, a programme for a single tri-lobed (engine port) comprising a spiral approach down the Z axis then Z sliced at 2mm intervals for a roughing cut with a 10mm dia. slot drill, followed by a finishing cut with 1mm steps and using a ball ended cutter to blend in the steps (**fig. 7**). The roughing cut is buried inside the finishing cut and holes for fixing and registration can also be seen. The latter are needed since, the component would have to be machined from both sides, and accurate registration would be required.

The second programme was for the tear drop shaped inlet port and consisted of only a finishing cut. Most of the material would have already been milled from the port on the other side of the component so it was thought that no roughing cut would be needed.

For the first trial, the port was milled in a small square of 1 inch thick mahogany that happened to be to hand. It machines nicely and is more forgiving if the cutter doesn't follow the expected path. Especially since, in this case, the ability of BobCAD to deal with the undercuts was as yet unproven.

I was delighted to find that not only did BobCAD avoid the undercuts but the feeds and speeds were near enough to get a good finish. The result can be seen in **photo 6**. There were two locating pins in the red holes; headless woodscrews turned to fit the holes and screwed into a sacrificial substrate. The fixing screws were located in the blue holes. The red holes are equi-distance from the centre line of the port so the component can be rotated (about the Y-axis) to machine the other side. Note the relief for the cam-box fixing studs had also been machined in as a second (manual) operation.

For machining all the holes and three ports in aluminium, a more substantial jig was required. A sort though the 'might come in useful one day' pile, yielded a substantial steel plate which was flat enough and already chemically blacked. There were a number of holes already in it, but they could be avoided and holes for silver steel locating pins were drilled and reamed. The design was such that it would accommodate both single port test pieces and the full size component (**photo 7**). There was also provision of an 8mm sacrificial MDF layer to prevent the cutters breaking through the bottom of the component into steel at aluminium feeds and speeds. Note that the jig was handed, hence the bold identification of the front. The symbol preceding the word 'front' identifies where the jig should be positioned approximately with respect to the centre of the table to avoid tripping the X-limit switches when the full size component was in place. Nothing too difficult, but another week had passed.

By way of an illustration of the complexity of these programmes each cut (i.e., roughing or finishing) on one port is around 6000 lines of code taking about 20 minutes to machine and there are 4 programmes for each port. I was really glad I had not even attempted manual programming. There were still some adjustments to the programming needed because, although the machining trial had been successful in wood, it might have ended in tears if the tear-drop port had been machined in metal. There was just too much material to be removed without a roughing cut. By now I was relieved to find there was some light beginning to show at the end of the tunnel.

To be continued...

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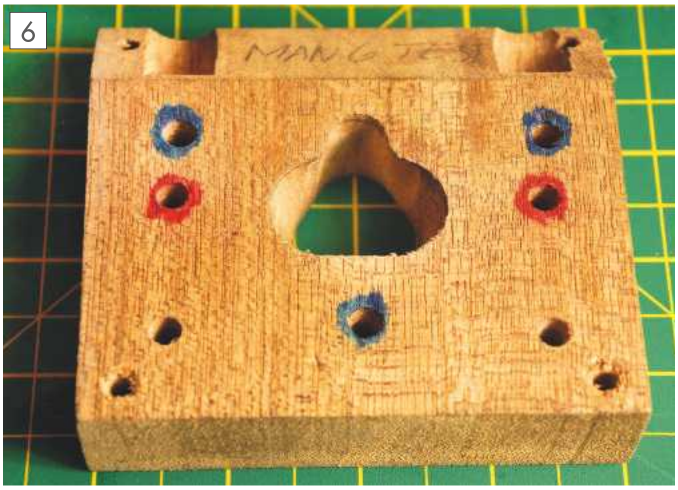

Single port trial.

Jig mounted on X3 table.


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PRODUCT REVIEW

The Antex TCS 50W

In last month's issue we briefly announced a new soldering iron from the UK specialist, Antex. The Antex TCS 50W is claimed to be the first soldering iron with Temperature Control buttons and an LCD display built into the handle.

1

Now temperature controlled irons are not a new thing at all. There are many available, but the usual approach to temperature controlled irons depends on a remote sensor in the iron linked to a soldering station on the bench. The problem with this approach is that the soldering station typically takes up a considerable amount of bench space. An alternative that takes up just a small area is an iron with a preset thermostat inside the tip, but restricted to a single temperature.

I must admit I was surprised to realise that a soldering iron with built in variable thermostat and digital display was not already available! My daughter and wife have been using hair straighteners that benefit from such luxuries for several years! Perhaps the small dimensions of a soldering iron element have created some special challenges, but in any case I was keen to try out the TCS 50W.

I learnt to solder with Antex – my dad used to run a small TV rental business and he had a pair of lovely delicate Antex irons for 'electronic use'. I was about 14 when I finally got my hands on my own one - a CS18, which lasted about 30 years! I upgraded to a new pattern CS18 about ten years ago, because I wanted a nice floppy silicone lead, **photo 1** compares the TCS50W with a modern CS18. Without temperature control, my strategy has been to use different sized bits from a pointed 0.2mm one for surface mount to a small 'hoof' about 4mm in diameter for heftier connections. The simple push-fit Antex system makes changing bits easy.

Advantages of a temperature controlled iron are manifold. Naturally it can be more powerful, in this case 50 watts instead of 20 watts. This means it heats up faster and it can also push a lot more power into a small bit when tackling a larger joint, naturally the thermostat lets it do this without overheating. The other advantage is that you can match the temperature to the job – less for delicate items and even lower if you are using low temperature solders for tasks like joining white metal parts that could melt in contact with a normal iron. This makes a temperature controlled iron ideal for model makers as well as electronics buffs.

The benefit of the digital temperature control is that you can set the temperature accurately, the range of the TCS 50W runs from 200° to 450°C (392°– 842°F). It is very clearly displayed on a (suitably hi-tech blue) backlit LCD screen (**photo 2**). Around 350°C is ideal for general;

2

electronic work, but the beauty of this system is you can tweak the exact temperature to suit your style of working.

In practice, what was it like using the new iron? In truth, it was excellent. Although the iron is a bit bulkier, it is no larger than some ordinary irons, and there is very little extra weight. The slightly floppy silicone lead means it is easy to guide around delicate jobs and the digital control is easy to use and responsive. Trials on a delicate Arduino board (**photo 3**) and a medium sized connector (**photo 4**) showed the iron works well. I have used it on a few other jobs, and the extra power was very welcome when soldering some relatively large section copper cable.

The TCS 50W cost £69.99 and is available from **www.antex.co.uk** ■

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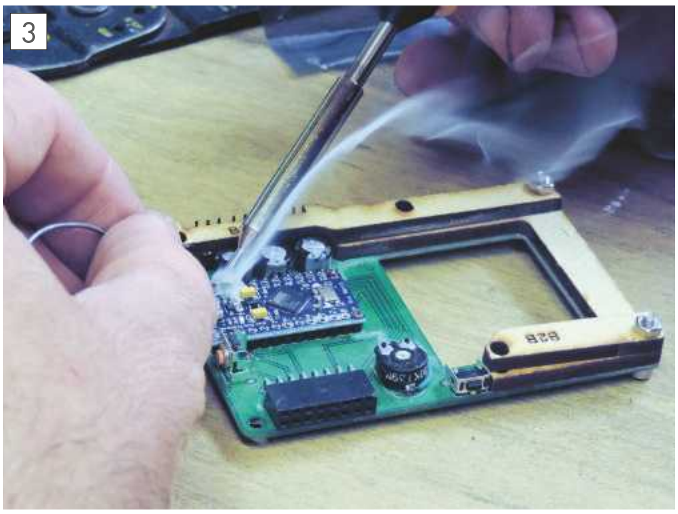

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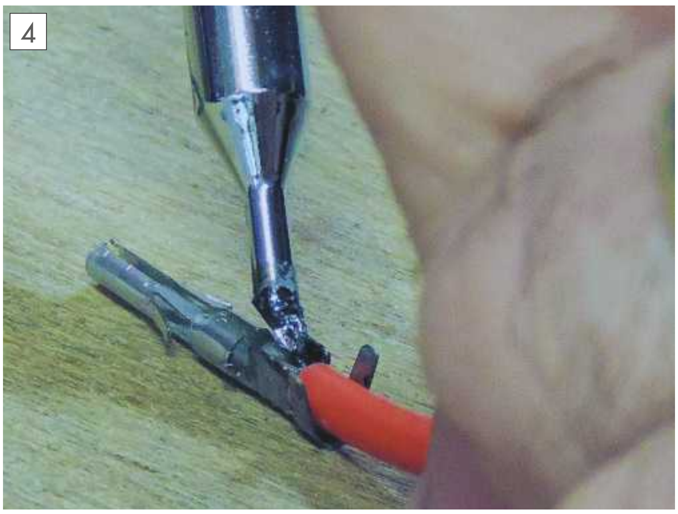
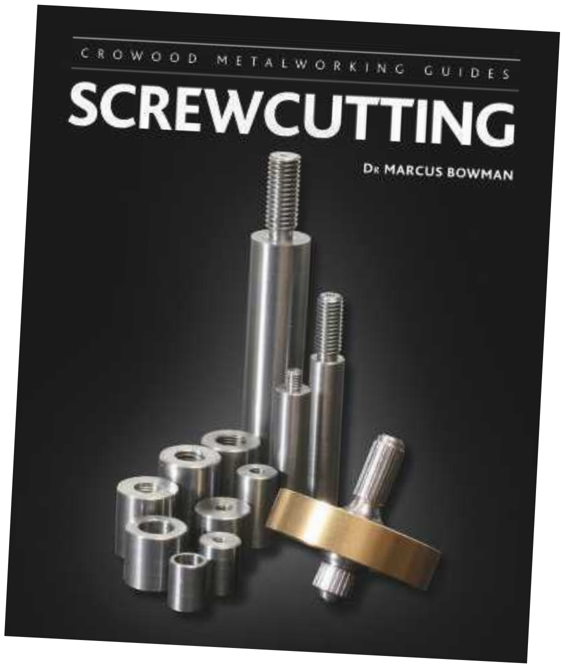


On the Wire NEWS from the World of Hobby Engineering

SCREWCUTTING by Dr Marcus Bowman



The latest title in the Crowood Metalworking Guide series addresses the huge topic of screwcutting.

As well as containing a wealth of technical information of different types of screw threads, the book covers both manual and machine threading in great detail. Screwcutting in the lathe using changewheels is addressed in detail, providing a useful guide to a subject that is the cause of much head-scratching in our workshops.

The book also addresses the issue of measuring threads. A particularly useful aspect of the book is that it addresses the appropriate tolerances for mating screw threads. Hopefully, this information will provide some solace to those who despair that their lathe cannot cut exact metric or imperial threads to the nearest micron, as working to the required tolerance is rather less demanding.

Written by regular *MEW* contributor, Marcus Bowman, the book is his third for Crowood. It is presented in his usual clear style with many crisp images, clear diagrams and a number of practical examples of what can be achieved using the methods described.

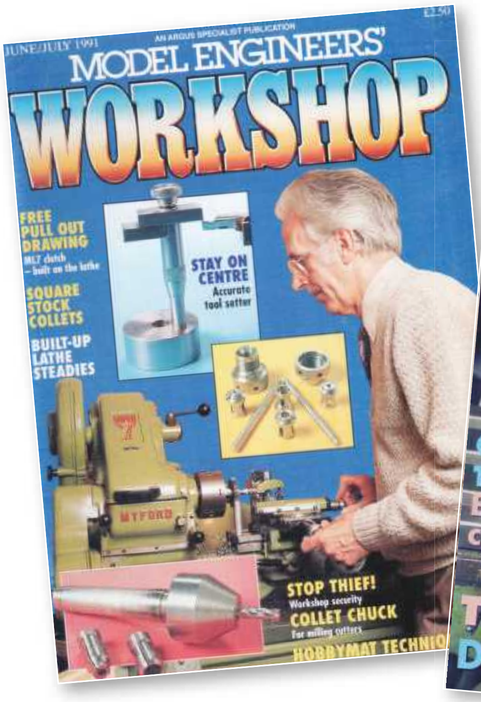
The CAHW Index

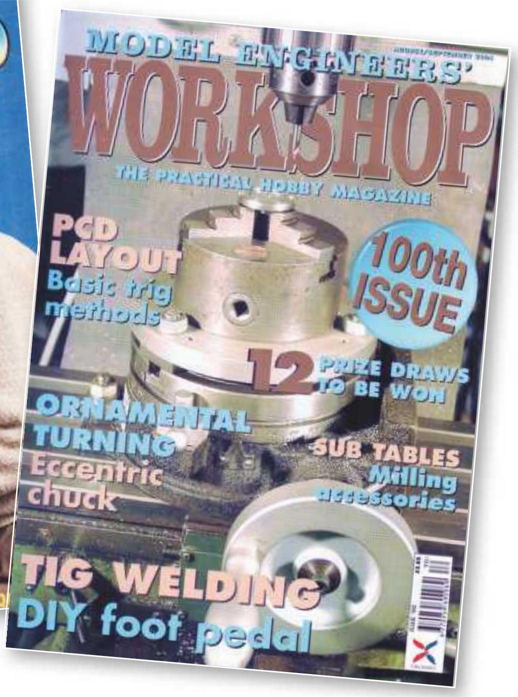
Barry Chamberlain, who produces the indexes published in *MEW* has contacted me to say that in the future he will not be producing any further CD-ROM copies of the CAHW index. Unfortunately with the advent of tablets and the like so fewer folk have access to a CD-ROM drive, sales of the *MEW* Index on CD-ROM have fallen below an economic level.

Barry has updated the CAHW.co.uk web site to announce an 'End of Line' sale of remaining stock priced at £5.00 for UK sales and £6.00 for non-UK sales.

He has reassured me that he will continue to produce the annual *MEW* magazine Index updates.

As a user of the CAHW index myself, I can recommend picking up a copy while you can.





Midlands Garden Rail Show

This year The Midlands Garden Rail Show returns for its 15th year. This popular exhibition, dedicated to Large Scale Model Rail, continues to grow from strength to strength and is regarded as one of the leading garden rail exhibitions in the UK.

The exhibition, which will take place at the Warwickshire Exhibition Centre near Leamington Spa, attracts over 2,000 enthusiasts from all over the UK and Europe. Visitors will see live steam model locomotives hauling coaches and wagons - the real thing in miniature.

Amongst the fabulous layouts confirmed to attend is **The End of the Line 7mm Scale - O / O14 Gauge**. This layout represents the distribution point of a very small coal mining operation in the early 1960's. The output of the mine is divided between distant industry, transported away by rail and local demand which is handled by road haulage.

For further details on the exhibition and suppliers attending please see www.largescalemodelrail.co.uk

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How (not) to paint a locomotive
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A book for model engineers. There are many beautifully made miniature locomotives, but very few are well painted. This book tells you how (and how not) to do the job to the highest standard.

This is the book which was written by Chris Vine after he had struggled for nearly two years to paint his locomotive Bongo, an LNER B1. He made a lot of mistakes along the way and found that there was almost nothing written which was of use to model engineers.

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After winning a gold medal at the model engineer exhibition in 2004 and also the Charles Kennion Memorial cup for the best finished model in the show, Chris was encouraged by the chief judge to write down what he had found out along the way; this book is the result. It covers choice of equipment, making a spray booth, paint, preparation, spray painting, hand painting, lining, transfers, a list of suppliers and more...

It gives chapter and verse on how to get a great finish on your model. How often have we seen super models spoilt by a poor paint job? It is quite simply the best practical book for model engineers we have seen for decades.

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Readers' Tips

TIP OF THE MONTH WINNER!

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This month's winning tip is another one for readers whose lathes with bolt-on chucks. This comes from Richard Hawkins in Reading, who wins £30 of Chester gift vouchers.

Myford 254S Gearbox Tips

On my lathe the chuck is held in place by three M8 cap screws. When I want to change the chuck for another, I find it very difficult and slow to do so! The gap between the lathe head stock and the chuck mounting flange is 13⁄16 inch. I struggle to get my index finger and thumb between the gap to undo the screws after I have unlocked them with the Allen key and moved them far enough out to get a grip of them with my fingers.

My solution to this problem:- I have taken an old small broken spanner 3.25mm thick and 4 inches long, ground off the broken end drilled a hole and soldered a pin into it. Into the three cap screws I have drilled holes to locate the pin. I now loosen the screws with the Allen key and then with the modified spanner am able to undo them quite quickly and only need to use my fingers to withdraw the screws when undone. Conversely, I place the screw in position give a couple of turns, and then use the modified spanner to screw them in and then lock them up tight with the Allen key.

The size of the pin is 1.4mm, material I fortunately had in stock. You could get away with a slightly larger pin, perhaps a 1.7mm.

I hope this may be helpful to readers that have smaller lathes.

Richard Hawkins

This month's runner up is a nice simple one from David Piddington in Brum. He wins a copy of a Marine Chronometers book.

An Old Saw

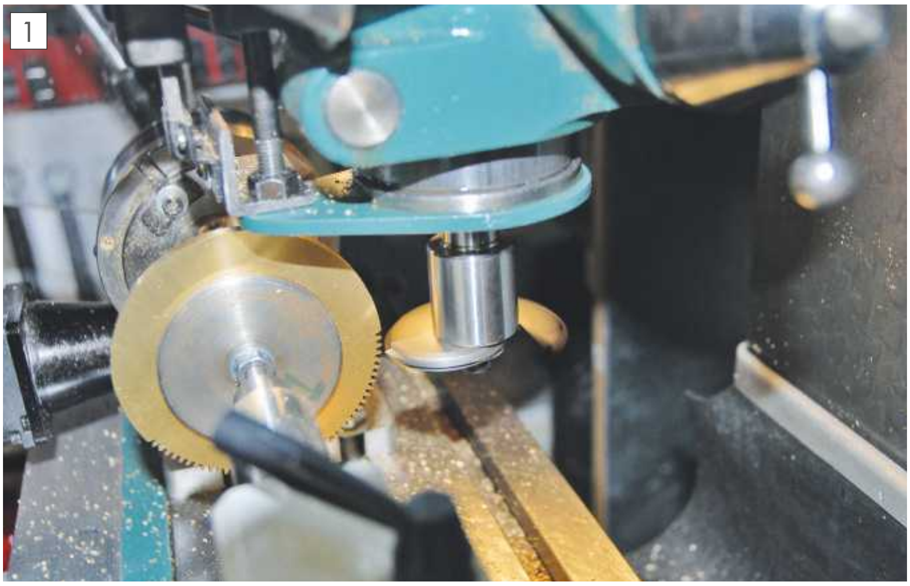
Not sure if anyone else has done this to a 'Junior' hacksaw, but I modified one of mine many years ago and I find it preferable to the standard model. Obviously this is the 'cheapo' type, but it's not difficult to bend other shapes using standard ¼ inch mild steel bar. For 'cack handers' simply bend the other way.

David Piddington

Adventures in Clock Wheel Cutting

Glenn Bunt relates his experiences in making clock wheels, with some advice for beginners.

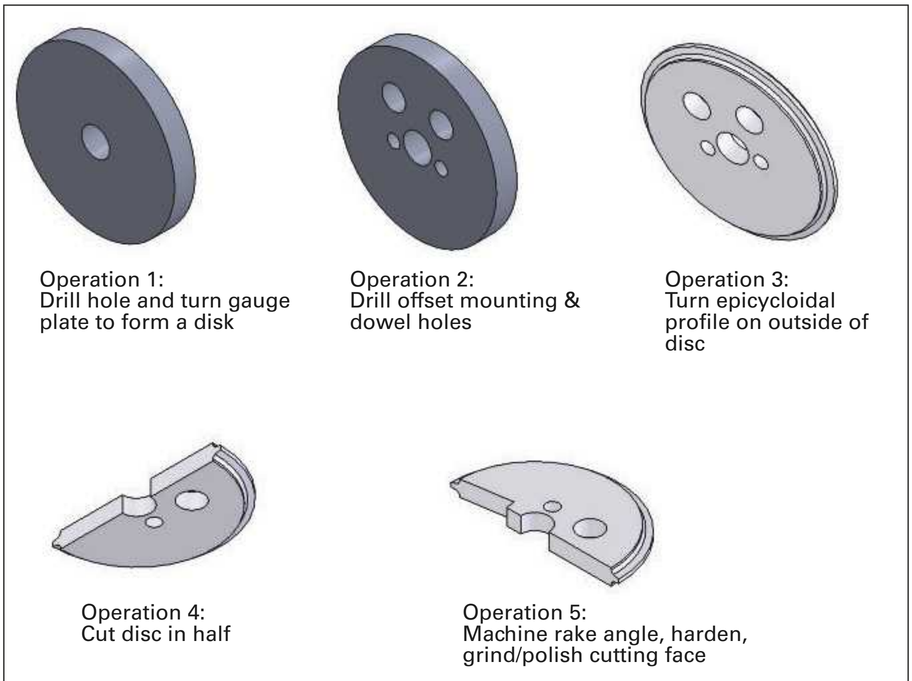
I have just finished making a three train musical longcase clock. The project took nearly two years from the design stage to completion. But my first challenge was to make the cutters that would cut the epicycloidal form on the gear wheels and pinions. In this article I describe my adventures in making the clock gear and pinion cutters.



Cutting a clock gear tooth profile using the fly cutter I made.

The Epicycloidal tooth form

For those new to the subject of clock gears and pinions the epicycloidal tooth form used on clocks represents a classic gothic arch shape on the gear tooth, this is similar for the pinion but it tapers in towards its root so being wider at the top and thinner at the bottom thus creating a relief when the gear and pinion mesh together. In the past these tooth forms were often hand made or cut on crude machinery, there are many variations on the tooth geometry and this makes it very difficult to repair or replace old gears or pinions. An extruded form of pinion also used to be available called pinion wire, it was not unknown for clock makers to modify this to suit their needs by removing a tooth and then re-arranging the other teeth so that they were evenly distributed around the centre. I needed to make some .8 module clock gear wheels and several eight, seven and six tooth pinions. One gear cutter would suffice for the gear wheels but the pinions would require a cutter for each configuration.



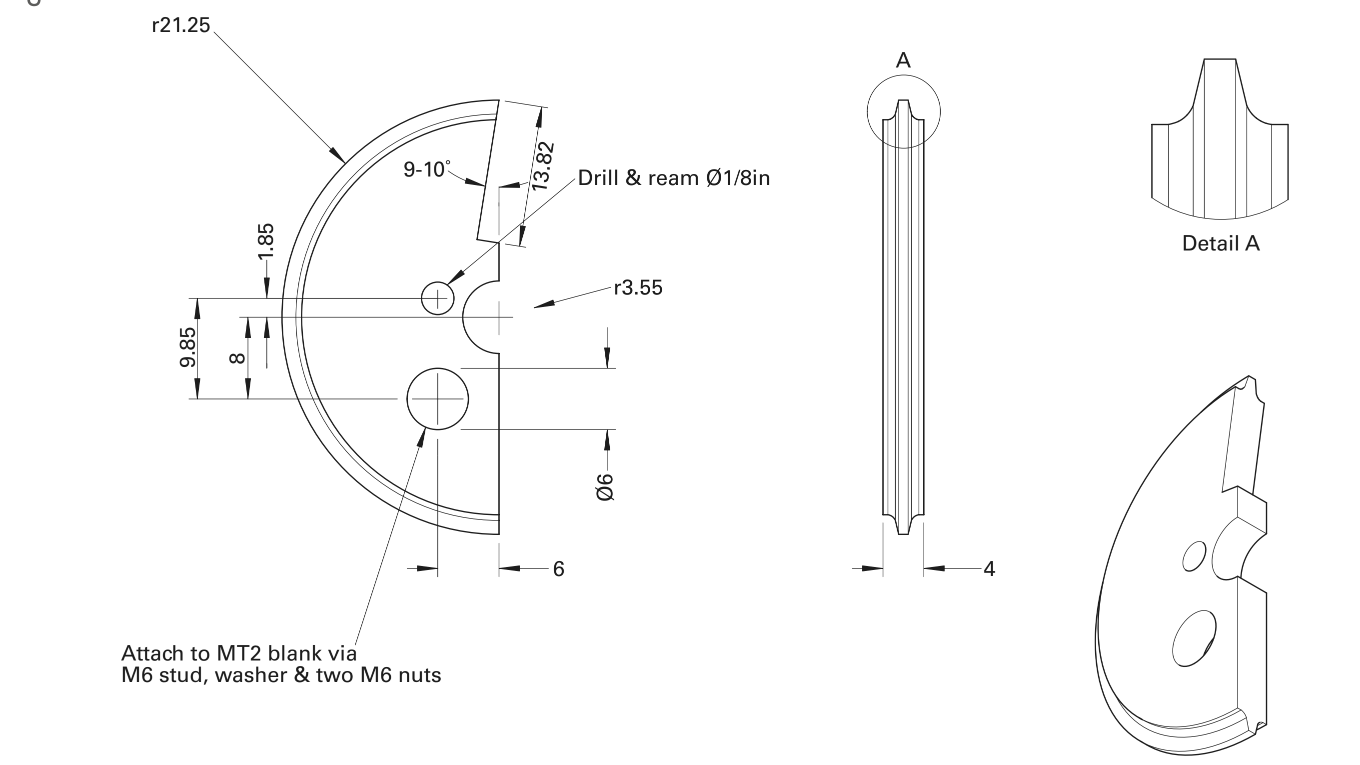
.8 Module Circular Disc Gear Cutter Fig. 1

Where to get the information

Of course, I could have purchased the .8 module cutters required for my clock but that would have been too easy and lets face it they're not exactly cheap! No, I was going to make my own but how was I going to make them? There have been a number of excellent articles written in both *Model Engineer* and *Model Engineers Workshop* over the years. The internet is also a good place to look for inspiration.

I would also recommend two books which make interesting reading. *Making an Eight Day Longcase Clock* by Alan Timmins and *Wheel and pinion Cutting in Horology* by J Malcolm Wild. Alan`s book describes how to make a longcase clock using both traditional and some slightly more modern techniques, more importantly; at the back of the book there is an appendix on clock gearing theory

Fig. 2



.8 Module Circular Fly Cutter

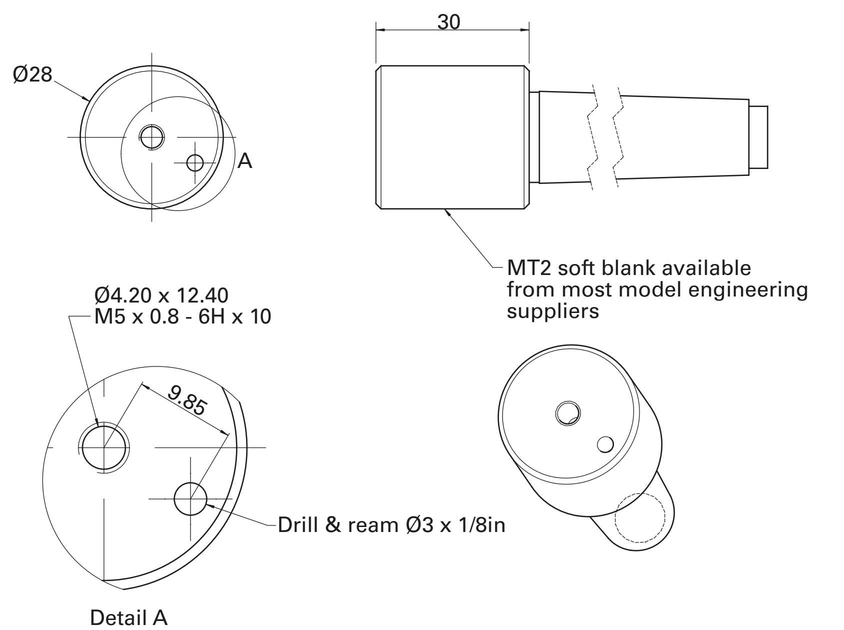
Dimensions in mm unless otherwise stated

and how to make your own fly cutters to generate the epicycloidal tooth form.

Malcolm`s book focuses on how clock gear and pinions have been machined throughout history, discussing gearing theory and the equipment but there are also chapters on machining clock gears and pinions using home made cutters.

I don't intend to discuss clock gearing theory in this article as the reader can reference any of the above mentioned sources for that; here I discuss the techniques I used for making and using home made cutters.

The easiest cutters to make are gear cutters for generating tooth profiles on clock gear wheels, this is where I started:



Gear Cutting Spindle MT2 Shaft Blank

Fig. 3

The clock gear cutter

After doing my research I found that the general consensus of opinion for cutting the tooth form into brass and making gears was to use a single blade type cutter. This was the easiest form of cutter to make and produced results which were comparable to multi blade cutters available commercially.

I found details on a number of different designs. A single blade fly cutter, the type and size that would fit into a lathe boring bar but used in a milling machine spindle and disc shaped cutters of various configurations (**photo 1**). These are formed from profiled discs and then cut up to make a number of cutter blanks. My choice was for the latter.

How I made the cutter

Figure 1 shows the steps in making a gear clock cutter, and **fig. 2** gives details of a 0.8 module circular fly cutter. I started off with 4mm thick gauge plate, roughly marking out 42 mm diameter with a scribe and then using a punch to mark where I would drill a 7mm hole. The hole size is not important, mine was 7mm because this was the arbour size I had available on the lathe.

The gauge plate blank is clamped onto an arbour in the lathe ready to clean up the outside diameter until it's completely cleaned up. Ideal diameter is between 40 & 50mm.

I produced a number of circular blanks so that I could have different profiles turned on the outside for various tooth forms and as backup in case I made any mistakes. It often takes less time cutting a component than it does to set it up. So it makes sense to manufacture some spares ensuring the dooaagh moment is not followed by many expletives!

At this stage it's an ideal opportunity to remove the circular blank from the lathe

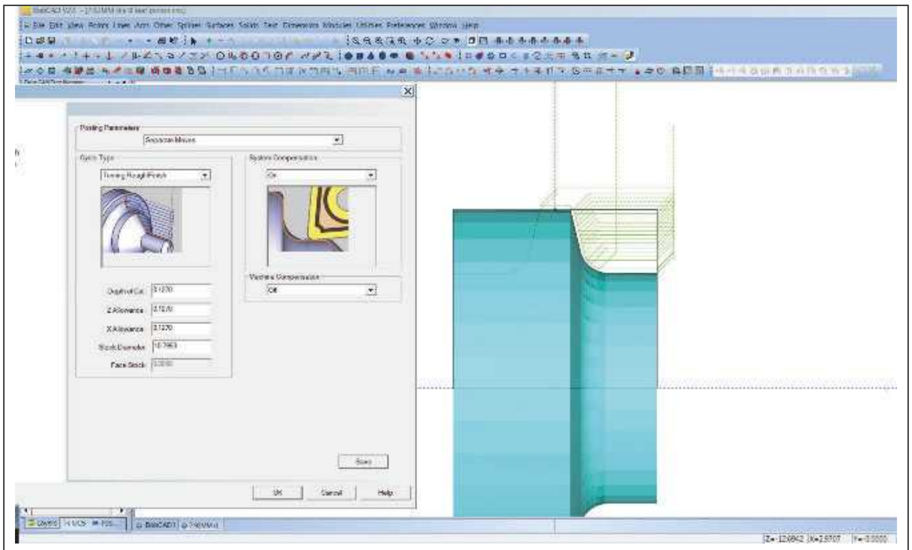


Fig. 4

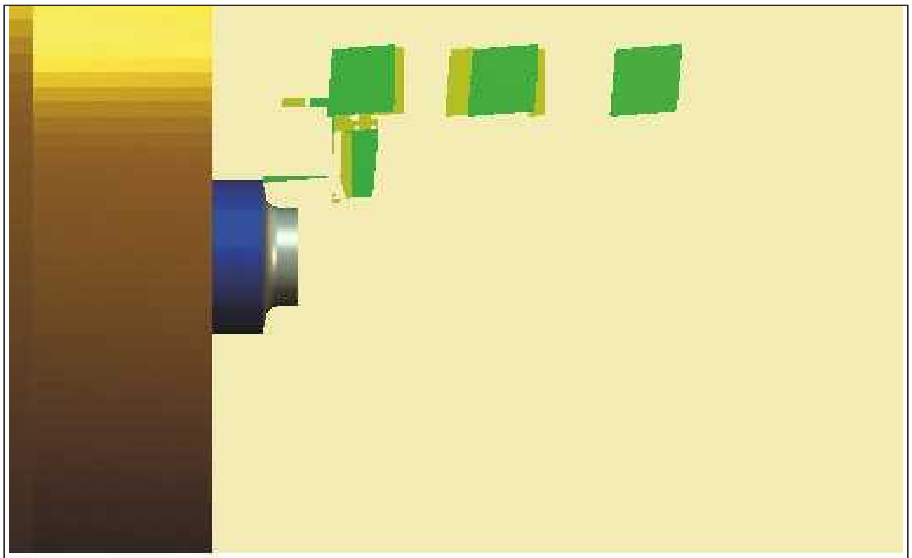


Fig. 5

and drill the additional holes but before we do this it is worthwhile marking the centreline of the blank. I did this by resting a scribe block on the cross slide, setting it to centre height and gently marked the centreline either side of the retaining nut. The line will be used later to help set up a saw when cutting the blank in half.

There are four holes, two offset 6mm diameter holes which will be used too clamp the cutter to the spindle (via a Morse Taper 2 soft blank) and two ⅛ inch diameter holes which will locate on a dowel to stop the cutter from rotating. These holes need to drilled and reamed. A gear cutting spindle made form an MT2 blank arbour is shown in **fig. 3**.

Now, there are various ways of achieving the next step; which is profiling the outside of the circular blank. You could choose the more conventional way of making a form tool and use this to generate the required profile on the circular disc. Either one side at a time or both profiles in one go. The alternative way and the method I chose was to use my CNC adapted Myford lathe and profile turn the geometry one side at a time.

How I created the cutter form

First I created a drawing of the form I wanted to machine using a CAD package (I used Draftsight). The drawing differed slightly from the actual profile I wanted to achieve because I extended the lines from the side of the geometry and off the top part of the profile - replicating the tool path.

I use Bobcad to generate the CNC toolpaths for both milling and turning. The milling module in the program is excellent whilst the turning module is good but it can be a bit quirky at times. Using the software and getting to know its foibles is time well spent. **Figure 4** shows the template drawing loaded into Bobcad and using the turning module I was able to create the toolpaths required.

Figure 5 shows the Bobcad Verify process of simulating the CNC part program that was generated.

Using my homemade Tangential HSS cutting tool (my favourite tool) a toolpath was programmed to approach from the side of the blank remove .005 inch and then retract away after completing the move along the top profile. This would be repeated until a stock envelop of .002 inch was reached on the generated profile and then a finishing cut at a slower feedrate would complete the profile.

The lathe set up

Before machining the gauge plate profile I ran another CNC program. I cut the face and diameter on a mild steel bar using the tangential cutter.

This allowed me to check the tool settings within Mach3 (the CNC controller used to run my Myford adapted lathe) and adjust the tool compensation in X and Z.

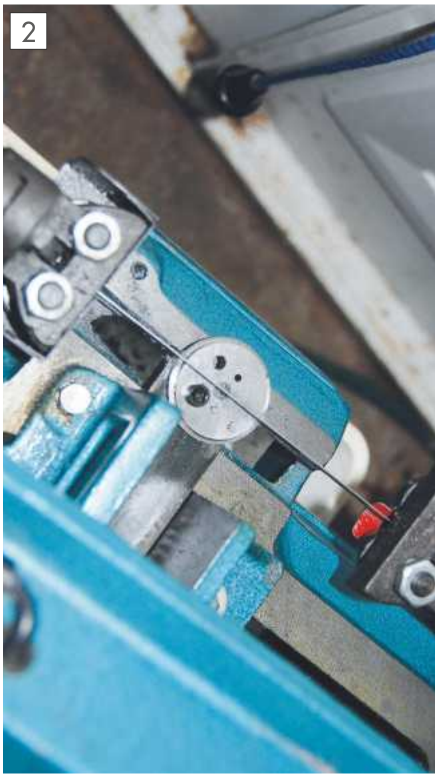
This would confirm that the lathe tool and Mach3 were set up correctly. As it would be very difficult to measure the width and depth of the generated tooth form after it had been cut.

Machining the profile

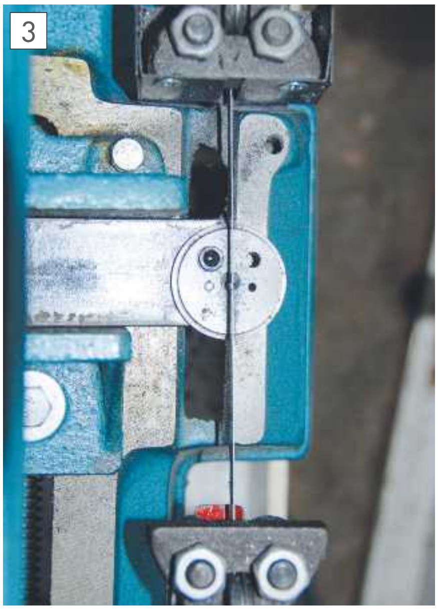
The mild steel bar was replaced with an arbor and the gauge plate disc to be profile turned. I positioned the lathe tool on the side and top of the blank and set the faces as the X and Z datums. First I cut one side of the blank and it was then turned over on the arbour the for the second side to be cut. Whilst cutting I liberally applied oil with a brush making sure any tool wear was minimised and I got the best finish possible.

Cutting the circular blank in half

I used the scribed line on the circular blank as a guide to help cut it in half – this can be done by hand but I chose to use my Clarke 6 inch horizontal bandsaw. My hacksaw cutting skills aren't good and I would have probably ended up with a very uneven cut line. **Photograph 2** Shows the circular blank being cut.



My Clarke bandsaw cutting the circular blank.



A view of the bandsaw set up.

Work holding for the circular blank

Holding the circular blank whilst cutting it in half presents a challenge!

I made up a jig from a scrap piece of rectangular bar stock. I drilled and tapped a M6 hole in the bar to secure the circular blank and then bolted the two together. Using the side of the rectangular bar stock as a guide I used a square and ensured the scribe line on the circular blank was perpendicular the bar edge. Now all I had to do was position the line on the circular blank directly under the band saw blade and ensure both sides of the blank were equal. As the rectangular bar is held in the band saw vice it would be clamped tight and perpendicular to the saw. shows the work holding setup on my clarke 6 inch bandsaw.

Milling the rake angle

Once the circular blank has been cut into two halves the next requirement is to clean up the sawn face on the milling machine. You can do this by hand on a linishing belt but it is better to machine it flat, as you will need to use this face in order to set the correct orientation for milling the rake angle.

The rake angle needs to be cut at about 9-10 degrees.

The blank can be mounted in a vice by placing a 6mm dowel through the offset hole and resting it on top of the vice jaws. The blank can now be tapped around to the correct angle using a protractor whilst being held lightly between the jaws. Alternatively, the blank can be mounted on its cutting arbour in a three jaw chuck mounted in a rotary table. The cut face should be levelled by running across it with a dial test indicator and then adjusted it to the correct angle. I used the latter method and I cut the rake angle on my blanks to a depth of 14mm, machining the face until it cleaned up.

Before heat treatment of the cutter it is worth considering identifying the cutter type for future reference, so make sure you stamp or mark your blanks with some identification i.e. module number etc.

Heat treatment

The heat treatment of my blanks was completed by a friend, he had access to a vacuum furnace and offered to get them hardened for me, now I couldn't turn that down could I? To harden gauge plate heat with a gas torch until cherry red and then quench in oil. To temper the blank we need to see its colour change so its important to clean up all the faces before re-heating. Use emery paper or wire wool to restore a clean shiny surface and then repeat the heating above with a gas torch but this time looking to achieve a light straw colour. It may help heating the blank up in a small tin of sand, this will slow the process down ensuring the colour change is more gradual and less localised. For more information consult the books described earlier in the article or previous articles in the *MEW* magazine.

Grinding the rake angle

After heat treatment the cutters will require a little bit of cleaning up to remove scale etc and this can be done using fine emery paper or wire wool. I used a high speed spindle and diamond cutting wheel to grind a sharp edge on my cutters.

I mounted a high speed kress spindle onto the quill on my Tom Senior milling machine using an auxiliary plate. A 1 inch diameter diamond disc cutting wheel as supplied with dremmel type spindles was used to grind a finish on the rake angle. I used a Kansas stone for final finishing and removed any burrs created when grinding the rake angle with an aluminium oxide stone.

The clock pinion cutters

As the material used to make pinions is generally tougher steel (I used EN8M) we can forget about using single blade fly cutters to generate the tooth form. The cutting speeds used when machining pinions are a significantly slower (feed rate and spindle speed) than for brass gear wheels. A single blade fly cutter would burn out well before completing a pinion and the flank finish would be very poor. Let me tell you from my own experience, after spending hours polishing the tooth flanks of my cut pinions you do not want to start with a surface chatter or poor finish.

There is plenty of information on the internet about making your own multiple blade cutters and the two books I discussed earlier also have information about cutter designs. I chose to make a pinion cutter design with four blades (**photo 4**).

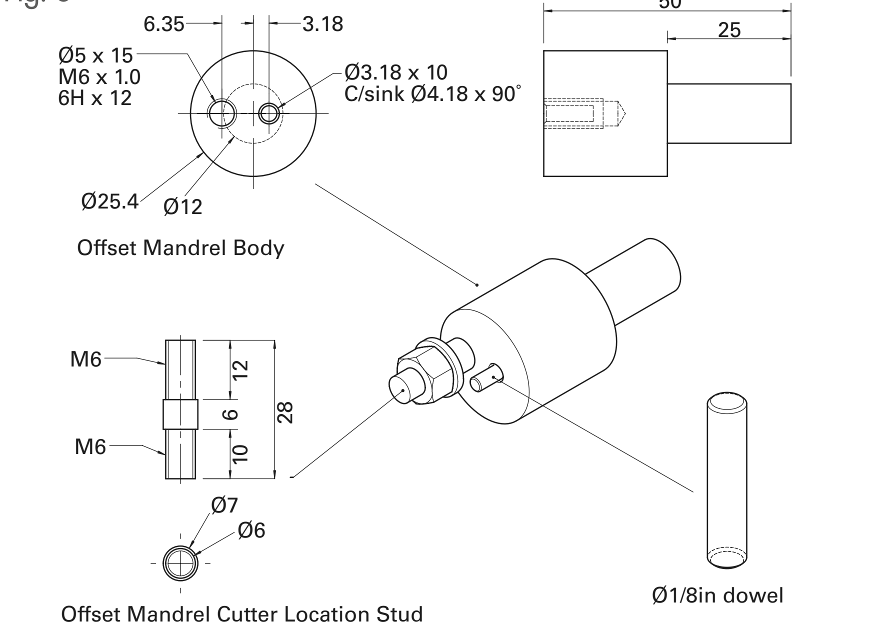
Four tooth pinion cutter.

The offset mandrel

In preparation, before making a pinion cutter we need to make a offset mandrel. This will be used to generate the relieved form on the cutter.

It is made from inch diameter steel bar. There are two holes drilled into the end face, one drilled and tapped M6 and the other drilled and reamed for ⅛ inch diameter. In the M6 threaded hole is located a stud used to clamp the cutter blank in place and the other hole has a dowel pin inserted into it for locating the cutter and for indexing the blank. **Figures 6** and **7** show the design of the offset mandrel.

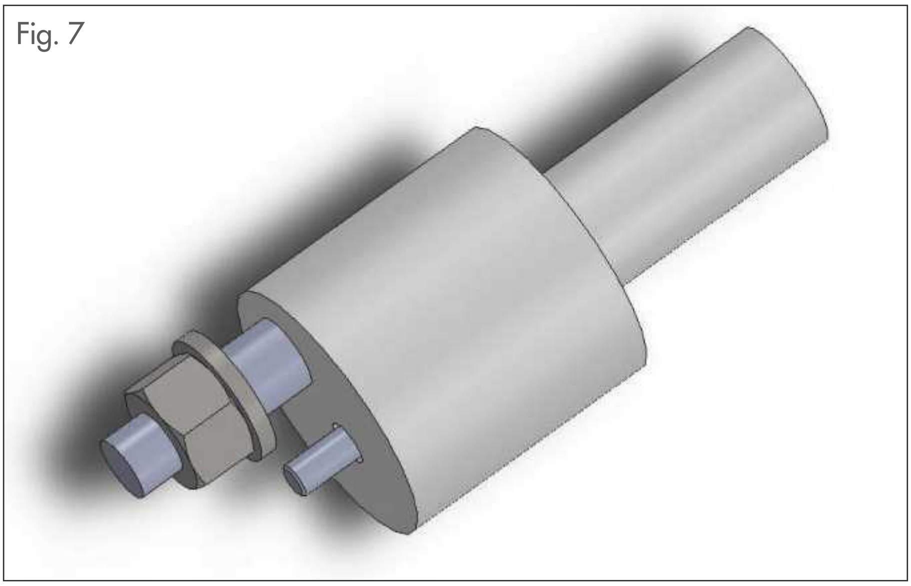
Fig. 6



Offset Mandrel Assembly

Dimensions in mm unless otherwise stated

Indexing holes for the pinion cutter.



Making the cutter

Figure 8 details a four point 0.8 module pinion cutter, and **fig. 9** the stages in its manufacture. I used 30mm diameter Silver steel for my pinion cutter blanks, facing off the end of the bar and then drilling & reaming a hole 7mm diameter. This was then parted off and the faces cleaned up. Some ¼ inch gauge plate will do equally as well.

Photograph 5 shows the next operation which is to drill ream four equally spaced ⅛ inch diameter holes into the cutter blanks. As you can see from the photograph I drilled the holes using my CNC rotary table mounted vertically on my Tom Senior mill and used a Centre drill to start off each hole. Drawing 4 shows the dimensions for the indexing holes. **Photograph 6** shows the pinion cutter blanks after drilling.

Turning the quadrants

Using a pencil or scribe, mark two lines, each line through the centreline of the cutter mounting hole and out through the middle point between each indexing hole (drawing 4), these lines are used as

The completed indexing holes in the pinion cutter blanks.

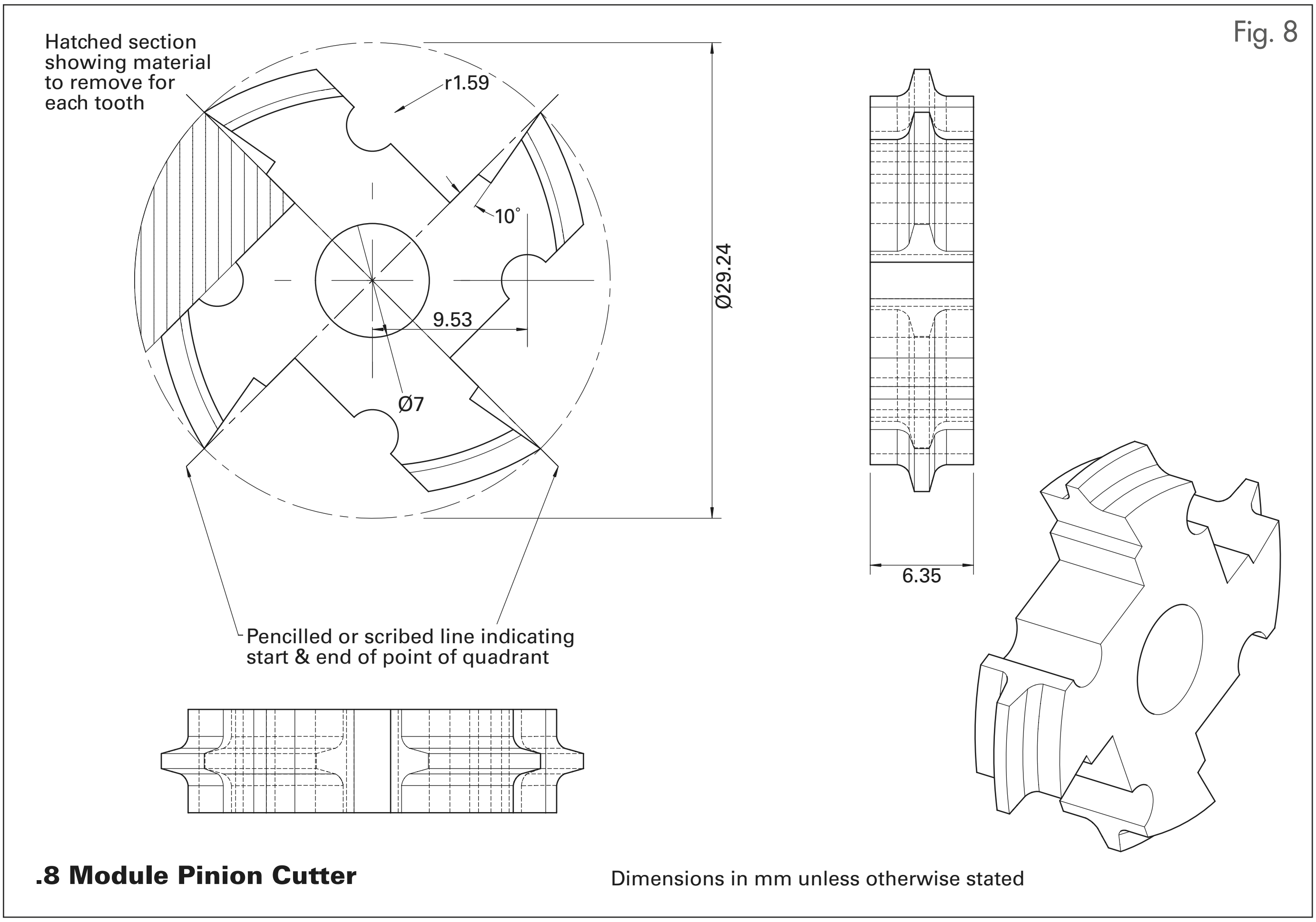
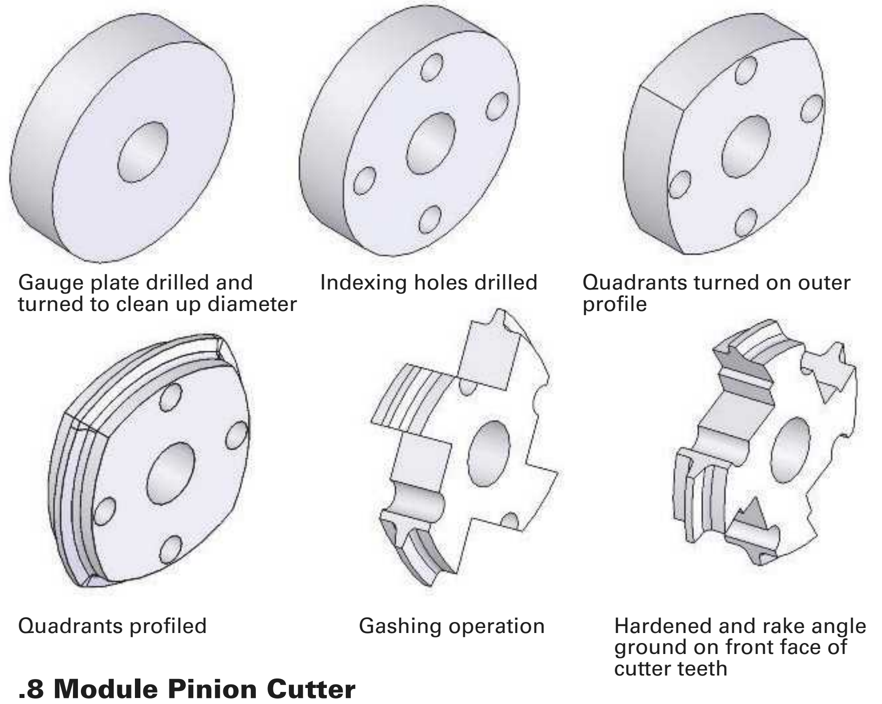


Fig. 9



a guide when turning the quadrant on the pinion cutter.

Mount the offset mandrel into the lathe (I used my ER25 collet system) and place a cutter blank onto the threaded stud locating the indexing hole onto the ⅛ inch dowel.

As per **photo 7**, turn the outside diameter of the blank until the area between the lines marked on the blank has cleaned up. Which should equal one quarter of the blank. Note the position on the lathe cross-slide as the other lobes on the blank need to be turned to the same depth. Repeat the operation for each segment of the blank, photograph 7 shows the last cutter blank quadrant being turned.

Turning the profile

For the cutter blank profiling I again used the CNC adaptation on my lathe. Using a similar technique as on the gear cutter I turned the profile on the blank but this time it was broken down into eight operations. One quadrant would be profiled at a time, the blank would be indexed on the offset mandrel and the operation repeated. Next the blank would be turned over on the mandrel and the four profiles on the other side machined.

Removing material for the cutter teeth

I have described the machining steps up to point four in which we have a cutter blank with all the quadrants profiled. The next stage is to remove material so that we can see the cutter teeth starting to emerge from the blank.

Photograph 8 shows how I approached this work. I mounted a rotary table on my Tom Senior Milling machine in a horizontal orientation aligned with the main slide. I rotated the table until the periphery of the milling cutter was positioned to cut the front face of a tooth and set to a depth to cut halfway through the indexing hole.

This was repeated for each quadrant. The operation could equally be achieved by cutting down through marked lines on the cutter blank with a hacksaw and filing the rest of the material out.

Clean up the face of each tooth with an end mill by orientating the front face of each tooth so that it is horizontal, the cutter blank is then rotated anticlockwise 10 degrees and the rake angle is machined on the front face. **Photograph 9** shows the rake angle being milled.

Heat treatment

The pinion cutter blank will require heat treatment but before you contemplate this don't forget to mark you blanks with the module number, diameter and how many teeth the cutter was designed for. I heated the blanks with a map gas torch until cherry red and then dunked the cutter blank in water. My forge comprises of a number of Vermiculite Fire bricks placed strategically on my bench to ensure the heat remains localised on the component. After thorough cleaning with wire wool and fine emery paper the pinion cutter blanks are re-heated (tempered) to a light straw colour and again dipped in water.

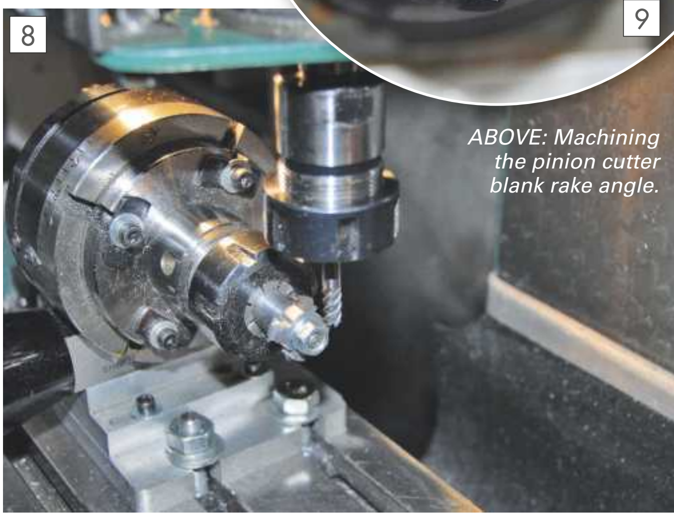
Grinding the rake angle

After heat treatment the cutters will require a little bit of cleaning up and sharpening - this is as I described earlier in the article for the gear cutter but of course here a rotary table will be of greater assistance due the number or teeth.

To be continued...

ABOVE: Machining the pinion cutter blank rake angle.

Turning the four lobes onto the pinion cutter blank.



Removing material from the profiled cutter blank.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Taps & Dies
Silver Solder
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Gauge Glass
Graphite Yarn
Jointing
Steam Oil
Cutting Oils

One Man and his Lathe

Andrew Johnston and his Britan Repetition Lathe

Can a machine made for mass production find a useful home in a hobby workshop?...

There was never any doubt that I was going to be an engineer, the only question being which discipline. My professional background is in electronics and signal processing, varying from academia doing post doctoral research into pulse compression radar signal design and processing to more practical areas including active noise control, high end motor racing and automotive power electronics. However, I have always been interested in machining and metalwork, buying my first lathe (a Logan) while at school. After I moved into a property with a garage 15 years ago I was able to start collecting machine tools seriously.

Britan lathe with bar feeder.

Britan repetition lathe

This article describes the Britan repetition lathe (**photo 1**) probably not a machine found in many home workshops. As the name suggests it is intended for repetitive production of turned parts. It is more versatile than a capstan lathe, but less so than a cam auto lathe. The Britan came in two versions, parts up to ¾ inch and up to 1¼ inches; the larger size being more popular.

The Britan lathe was made by Britcam Tools based in Gloucester Street in Cambridge. Manufacture started in the 1940s and ended late in the 1970s, or early 1980s, so the Britan is now only available secondhand. While the Britan was largely superseded by CNC lathes, some commercial machine shops still have one tucked away, as simple parts can be made more economically on the Britan rather than tying up an expensive CNC lathe.

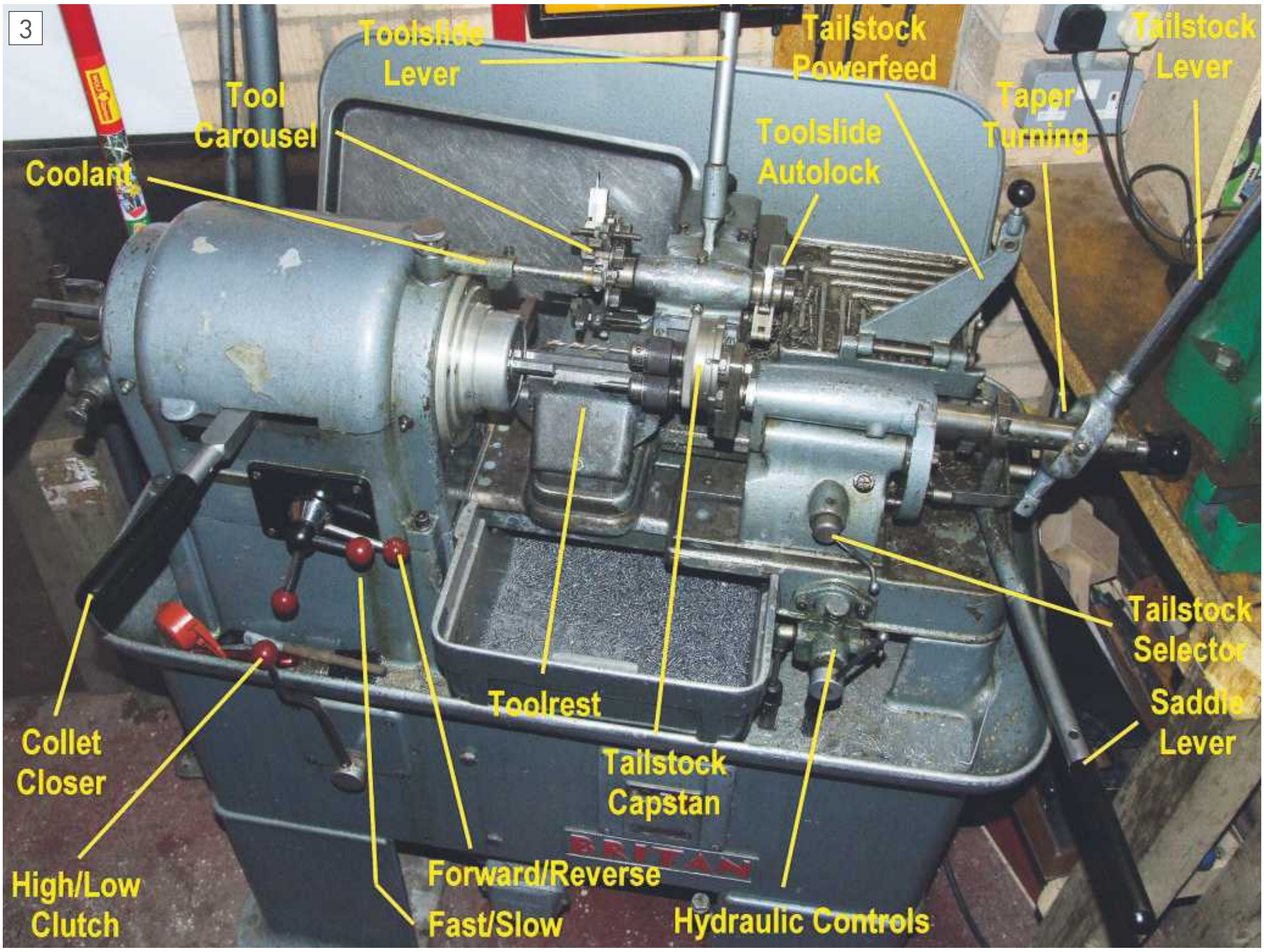
Acquiring the lathe

I first saw a Britan lathe some years ago while visiting an eBay seller to collect items I had bought. The seller was manufacturing automated cat feeders, and as well as a manual lathe and mill he had a couple of Britan lathes set up to make small parts for the feeders. I was impressed by his demonstration of the Britan, read up about them and bought a copy of the manual on DVD. Although the lathes come up fairly regularly on Ebay they often have parts missing or have little associated tooling. Over time the idea of acquiring a Britan faded, driven as it was by curiosity rather than need.

By chance in 2012 I received an email from one of the companies I work with, saying that the proprietors of the machine shop they used were retiring and if I was interested in the machine tools I should contact them. The company had two locations, one in a village north of Cambridge and one in Cambridge itself. I bought two large V-blocks, an angle plate, some Morse taper drills, a double-ended Wolf grinder and a nice 1 - 2 inch Moore and Wright internal micrometer. Of the machine tools the only one that caught my eye was a 1¼ inch Britan lathe. It had a good range of collets and many accessories. So I bought it!

The Britan has a small footprint (approximately 40 by 24 inches, excluding the bar feeder and operating handles) but is heavily built, as befits a lathe intended for production work with operators on piece rates. I cannot find a weight, but reckon it is at least 600lbs. However, moving the lathe was straightforward using a pallet truck and a hired trailer (**photo 2**).

Moving the Britan lathe.



Britan lathe - annotated.

Although the lathe came with a good assortment of collets and tooling, by chance two lots of Britan tooling came up on Ebay shortly after I bought the lathe. I made sure I bought both lots. Both sellers were close together and less than an hours drive away, so collection was not an issue. Duplicated collets and tools were sold, and some dead length collets intended for the ¾ inch machine were sold to a member of the ME forum.

Tour of the Britan

The Britan is quite different to conventional centre lathes, so a tour of the main parts and features may be useful. For a start there are no leadscrews and no dials or conventional handles. The lathe, with key parts annotated, is shown in (**photo 3**).

The headstock spindle is belt driven (left of the headstock in photo 1) with 3 speeds for this model. The number, and range, of speeds available varied according to model. Normal rotation of the spindle is clockwise as seen from the tailstock. The headstock spindle only takes dead length collets; there are no chucks or faceplates available. Unlike draw-in collets the work does not move when a dead length collet is closed. So if the end of the work is positioned against a stop and then the collet is closed the length set by the stop is not lost. The collets were available in round, hexagon and square, both metric and imperial. Other shapes could be made; I have seen a collet to hold a rectangular section. The workholding collets are similar to DIN6343 but do not appear to be a standard size. The collets are closed by the 'Collet Closer' lever at the headstock. On the Britan this lever is between the drive belt and the collet, rather than the more usual position outside left of the headstock. This means it is closer to the operator, and hence faster to operate. The lathe can be fitted with a pneumatic bar feeder, on the left and through the door in photo 1.

The main power switch is just above 'Britan' name. This provides power to a 1/3hp auxiliary motor that drives a coolant pump, a hydraulic pump and an air compressor for the bar feeder. Control of the main drive motor is by two levers on the headstock. The rear lever ('Forward/Reverse') is up for reverse, or anti-clockwise, rotation, centre neutral and down for normal, or clockwise rotation. Remember that normal spindle rotation is 'backwards' compared to most centre lathes. The front lever ('Fast/Slow') is up for half speed, centre neutral and down for full speed. These levers operate electrical contactors and hence control the main motor directly; speed by changing the number of poles and direction by swapping two phases. The levers can be moved separately or together. The lathe can thus be moved from full speed normal rotation to half speed reverse rotation in one operation simply by moving both levers with no need to stop the lathe first. This saves time in a production environment. In order to benefit from this type of control, and run both the main and auxiliary motors, a proper 3 phase supply is ideally needed. The overall speed range can be changed by moving the drive belt position, but this is less than straightforward involving moving a heavy motor buried under the lathe, between the stand pillars.

More than many machine tools a repetition lathe is reliant on a range of accessories. These fall into three categories; collets, tool carousel and tailstock.

Bottom left on the cabinet is another lever ('High/Low Clutch') for controlling

4

Collets.

5

Tool carousel accessories.

spindle speed. This selects a high or low range. It operates by moving from one clutch to another, one driving the headstock spindle via one belt the other via two belts and an intermediate speed reduction shaft. Both belt sets are running at the same time, it is just a case of which clutch is selected. Again the lever can be operated with the lathe running or stopped. It is much easier to operate with the lathe running. So, for each main drive belt position there are four speeds available covering a wide range.

In normal operation the lathe runs 'backwards' so the tools for turning are held behind the work, labelled 'Tool Carousel'. This has positions for 6 tools, each of which can be independently tilted so as to get the tool point on centre. When cutting each tool rests on a block with a hardened steel blade, 'Toolrest'. This provides a rigid location for the tool enabling heavy cuts to be taken while giving an excellent finish. The clamps are designed to take 5⁄16 inch square HSS blanks, as well as 5⁄16 by ½ inch, and by ⅝ inch, for special tools. Holders are available for 1⁄16 by 5⁄16 inch parting off blades, large and small boring bars and roller boxes for slender shafts. Each tool position has two stops controlled by screws and locknuts. One controls how far the tool is fed radially, operated by the vertical lever labelled 'Toolslide Lever', which also indexes the carousel to the next tool. The other screw bears on a block at the rear of the headstock and determines how far towards the headstock the tools moves, controlled by the lever labelled 'Saddle Lever'. The radial toolslide also has a 'Toolslide Autolock' feature so that the tool can be locked against the toolrest while turning a long diameter without having to hold the toolslide lever. The saddle can be operated manually or by hydraulic feed. This is controlled by the lever and valves bottom right, labelled 'Hydraulic Controls'. The lever has three positions, in that shown there is no hydraulic drive, vertical is hydraulic feed 1 and left is hydraulic feed 2, which are independently controlled by small knurled knobs. By means of two screws and a lever at the back right the saddle can be set to turn parallel, parallel and one taper, or two different tapers.

Coolant is available from a spray bar on top of the headstock, labelled 'Coolant', the length of which can be adjusted.

The tailstock has its own short slideways and can be locked by means of a bolt at the back of the tailstock. The tailstock has two positions which are selected by releasing the lever labelled 'Tailstock Selector', rotating the tailstock parallel to the lathe axis and re-engaging the tailstock selector. Each position can contain a hardened steel shaft which can hold a variety of tooling. As shown the 'front' shaft normally holds a capstan unit, labelled 'Tailstock Capstan' which can hold up to 8 tools in collets or in drill chucks mounted in the collets. The collets are similar to those used on clock and watchmakers lathes, but special to Britan. This shaft is lever operated via the 'Tailstock Lever' and has three adjustable, and independent, stops. The rear shaft can hold larger drills, and the plate on the saddle labelled 'Tailstock Powerfeed' can be attached to the shaft to drill using the hydraulic saddle feed. The rear shaft can also hold other tooling such as tap and die holders, knurling boxes and Coventry dieheads. The tailstock shafts are used with clamps that provide both stops and prevent rotation of the shaft during operation.

Accessories

More than many machine tools a repetition lathe is reliant on a range of accessories. These fall into three categories; collets, tool carousel and tailstock.

There are three types of collet for the Britan (**photo 4**). On the left are a selection of dead length collets for workholding. In the middle are larger collets for direct use in the tailstock shafts, and on the right the smaller collets for use in the tailstock capstan. The tool carousel primarily holds tool bits, but some accessories are available (**photo 5**). On the left are toolbit clamps and holders for parting blades, in the centre holders for boring bars and right roller boxes for turning slender shafts. For the tailstock there are Coventry dieheads and tap and die holders, with dog clutches, and centres.

Shown in **photo 6** is a view of the accessories draw. The long shaft at the bottom right is a backstop that screws onto the headstock spindle for second operation work. Since the lathe normally runs 'backwards' left hand drills and centre drills are required. These are readily

6

Accessories draw.

Radiused toolbit.

Studs and jig.

Jigs for making nuts.

available commercially and for new jobs I often buy left hand stub drills to build up my collection.

Using the lathe

The repetition lathe requires considerable setting up before use. Since there are no dials or feedscrews sizing is done by trial cut, measurement and adjustment as required. The quality of the turned work is also directly related to the grinding of tools. So it is essential to have mastered the art of grinding HSS toolbits. Despite the myths it isn't that difficult.

It may be thought that a lathe such as the Britan has no place in the model engineers' workshop. However, many models have repetitive parts, some of which of are quite simple, but add considerably to the visual appeal. To illustrate the use of the Britan I have made all the $\frac{1}{4}$ and $\frac{5}{16}$ inch BSF studs, nuts and locknuts for my 4 inch scale traction engines.

The studs are formed in two operations. Starting with a parted off end, a HSS toolbit ground to the correct radius and with a flat section (**photo 7**) is used to face off to length and form the curve on the end of the stud. Then the stud is moved forward in the collet to a set length. A Coventry diehead is used to cut the thread and the embryo stud parted off. A Coventry diehead cuts very clean threads (**photo 8**) but is relatively slow. The recommended SFM for low carbon steel is about 20fpm compared to 100fpm for turning. Running too fast results in torn threads. Once all the studs have been made the second operation can be done. This threads the other end of the stud. Since this will be permanently hidden once the stud is installed we only need to cut the thread. There is no need to clean up the parting off 'pip'. However the studs cannot be held in the collet as the plain length of the stud is not long enough. So a simple jig is needed, also shown in photo 8. This is simply a threaded block with an adjustable brass stop. Brass is used so that the rounded end of the stud, which will be visible is not damaged.

The nuts are also made in two operations. The first sequence uses a blank toolbit to set the length of material, a knife tool to face off the end and a tool ground to a 30 degree angle to add the chamfer. The tapping hole is then drilled using a centre drill and a stub drill, both left hand. The embryo nut is then parted off. For the second operation the spindle backstop is used with a special hollow stop on the end giving room for the tap to extend beyond the nut. The nut is placed in the collet and a countersink used to clean up the drilled end and reduce burrs from tapping. The hole is then tapped. The tapping unit has two driving dogs that allow the tap to drive into the work until a stop is reached, when the tapping head pulls forward and starts spinning. Reversing the spindle rotation picks up a second dog and the tap backs out. I use spiral flute taps, even on through holes, as the swarf tends to be ejected rather than pushed into the work collet. Tapping is done at the same speed as turning, in this case 500rpm. The locknuts needed a second chamfer and this was done on the centre lathe, screwing each locknut onto a threaded mandrel. The jigs for making the nuts are shown in **photo 9**. A selection of the studs and nuts are shown in **photo 10** and the complete batch shown in **photo 11**.

Conclusion

While the Britan repetition lathe is not an essential machine tool in the home workshop I am very pleased with mine. It doesn't require much room and once owned widens the machining options. Even a simple operation like machining pillars to a consistent length is easy compared to using my centre lathe where the collet system is not dead length. There are two caveats; to make full use of the Britan it needs to be well equipped and requires a three phase supply. ■

Nuts and studs.

Complete batch of parts.

Rebuilding a Warco Major Mill/Drill Part 2

When Richard Smith brought an eighties mill-drill out of storage, he found that it needed a bit of work to get it up and running.

I bought my Warco Major Mill/Drill about thirty years ago and it has been used quite a lot. It was dismantled when we moved house and remained so for some time. When I reassembled it, I found the motor had died. Space is tight in my new workshop and with the pulley drive and motor hanging out the back I had problems finding a space to put it. I decided that rather than just replace the motor I would fit a new inverter based drive with the motor located in front of the column allowing the machine to go back against the wall. The new motor would have a simple timing belt drive to the spindle. All the bearings were well worn and needed replacing. The final result is shown in the photo, right.

The restored machine.

Taper boring the drive pulley

The next challenge was to taperbore the new drive pulley to match the taper on the drive shaft so that it located at the position planned. I decided that if I could set the topslide angle to match the taper on the driveshaft I could simply keep boring until the entering diameter matched the design value. I had an old clock gauge available so decided to mount this in the toolholder at centre height. If not at the exact centre height the taper would be wrong. I clamped a piece of scrap MS in the toolholder and gripped a big enough end mill in the three jaw chuck and using the power crossfeed milled a flat edge to act as a seat. I then remounted the steel in the toolholder sitting on the seat and gripping the drills in the three jaw drilled it out to match the dial gauge mounting. I was fortunate to be able to achieve a tight fit after finishing with a reamer and loctited the gauge in (**photo 16**). This ensured that the gauge was at centre height.

I then remounted this assembly sitting on its machined face to run along the lathe axis and roughly in line with the topslide travel. The aim was to align the topslide travel with the driveshaft taper. The drive shaft was mounted between a dead centre in the tailstock and a drill chuck acting as a centre in the headstock. Both of these picked up on the original centring faces in the drive shaft and in fact the drive shaft clocked to run pretty true. I then set the topslide over until it tracked true down the taper and locked it (**photo 17**).

The new pulley was mounted in the four jaw chuck and the pilot bore located on the tailstock centre. I also checked that the face was square to the axis (**photo 18**). The pulley was bored with many hand fed passes until the entering bore diameter was correct. I must admit I also checked progress by trying the drive shaft frequently for depth and was pleased to find drawing and practice in agreement! Being hand fed the finish in the pulley

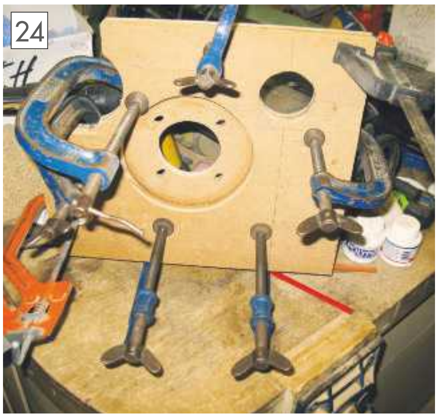
Mount for dial gauge.

Aligning with the taper.

Preparing to bore the taper.

Checking the taper with blue.


Fitting the pulley.


Doubling up mounting plate.

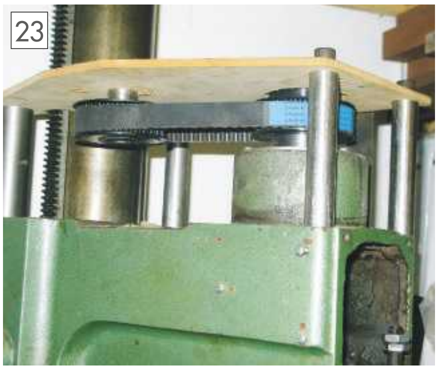
wasn't perfect but I did smear some marking blue in a line in the pulley and pushed the drive shaft in and rotated it by hand which showed pretty good contact (**photo 19**).

Replacing the drive shaft bearings

The drive shaft runs in two bearings separated by a spacer (parts shown in **photo 20**) and which are a press fit on the drive shaft. One bearing sits against a shoulder and the other end has a circlip. To press the bearings on I used the quill as a press (**photo 21**) supporting the bearings on a modified scaffolding fitting that had been lying around for years. I faced the base then bolted it to the faceplate to face and bore the other end to suit the bearings.

This arrangement worked fine and the whole assembly was then mounted in the head and the retaining plate fitted. The drive pulley sat on top and was tightened down with the original nut using a spanner through the slot in the end of the spindle to stop rotation (**photo 22**).


Spindle parts.


Checking mounting plate geometry.

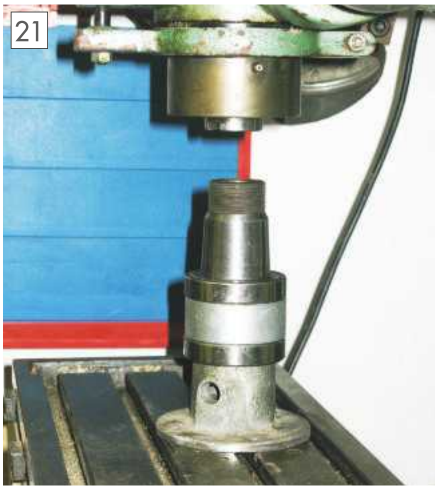

Motor on temporary MDF plate.

MDF Drive plate

The next step was to print off a copy of the drawing for the motor mounting plate and to cut it out from 6mm MDF. I made a stud to simulate the motor shaft so I could mount the complete timing belt drive and check it all fitted. The mounting holes tied up pretty well, which was a relief as I had had to measure them as they were (**photo 23**).

I had some 12mm MDF and used the 6mm MDF plate as a template to cut it out. To be on the safe side I decided to reinforce this with more MDF cut to clear the motor and glued it on (**photo 24**).

This was then mounted on the pillars ready for the drive. I ordered the motor off the internet together with a cable which I wired to the terminals before mounting on the mill along with the rest of the drive (**photo 25**).


Pressing the bearing in place.

I mounted the inverter on the wall close by and completed the wiring and plugged it into a socket. Nervously I turned it on – and nothing happened.

I mounted the inverter on the wall close by and completed the wiring and plugged it into a socket. Nervously I turned it on – and nothing happened. Fortunately I had managed to keep the manual all these years and even more fortunately was able to find it. It turned out the unit had been setup for remote operation. Once reset to run from its own panel the motor turned and I could wind the speed up and down. Joy.

Aluminium Drive plate and spacer

For the 'proper job' I ordered cut to size pieces of aluminium from the internet. I had decided to increase the plate thickness to 15mm. The 15mm plate was sawn so the first job was to clean up two edges. I was relieved to find the MDF plate showed no signs of strain doing this (**photo 26**).

The motor has a raised locating face so I needed to make a spacer to surround this so that the motor sits on the face with the tapped holes. I made this before continuing with the drive plate as I could


Machining the alloy plate.

MDF used as faceplate spacer.

Holesaw locked against rotation.

Finished ring.

check it against the motor and then use it to check the motor mounting slots in the drive plate. This was to be from 4mm thick aluminium. I marked it out and drilled the four clearance holes for the motor mounting bolts. Then MDF to the rescue again! I bolted it to a piece and then bolted the MDF to the faceplate (**photo 27**).

To make the two large diameter holes in the motor mounting plate I had bought two holesaws, one 76mm and one 114mm diameter. I used the larger to start the hole in the spacer. I soon found that the drill chuck couldn't hold it so ended up with an allen key through a convenient hole and resting on the holesaw drill one end and a tool in the toolpost at the other (**photo 28**). This worked fine and I carried on and then bored out to size. The outside diameter was then turned (**photo 29**).

A print of the motor mounting plate drawing was then attached to the plate with photo mount spray adhesive, locating it along the two machined edges. The Warco saw in bandsaw mode trimmed off the surplus and the remaining three edges were milled to the lines on the drawing, reclamping the plate for each cut. I drilled holes at each end of the motor mounting slots and then milled them out with a smaller slot drill. You will notice the plate is set with the slots aligned with the X axis (**photo 30**). The spacing of these slots is relatively critical so I had bought one of the digital scales with a remote readout and fitted it to the Y axis. This made milling the slots to width dead easy. I must get more of these scales. I drilled holes at the ends of the slots first then milled out to width.

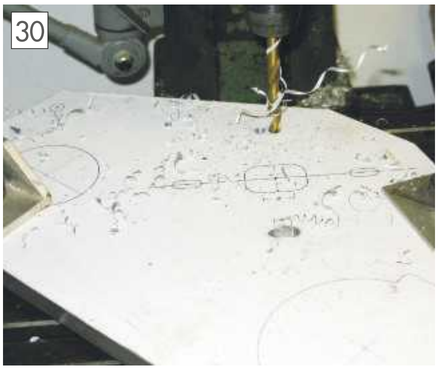


Plate marked out for slots.

The smaller hole...

... and the larger one

Finished mounting plate.

Now for the two large holes. These were obviously going to put the greatest strain on my MDF mounting plate so I was particularly nervous about the largest. I started with the smaller using plenty of cutting compound and clearing the swarf frequently. The finish on the hole was rough (**photo 31**) so I used a cheap trepanning tool from a market stall to just clean it up . This worked surprisingly well.

Now for the big one! I knew from the lathe that a drill chuck wouldn't hold it. I found an old face milling cutter that had come with the mill when it was new. The cutter head was bolted to the arbor and after some persuasion came off. A bit of turning and the holesaw had a new heavy duty arbor. Drilling the hole was not a pleasant experience. The noise was horrible but I persevered. Plenty of thread cutting compound and lifting off. The finish was a bit rough (**photo 32**) but I didn't try the trepanning trick and cleaned it by hand with emery. Anyway, it runs close by the mill column and you can't see it . A bit more milling to the lines and a few holes and the plate was finished (**photo 33**).

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.

Seeing the Light

Dear Neil, I have a compact fluorescent lamp close to my lathe chuck so I can see what I'm doing.

While using a digital caliper of the type on the cover of this month's MEW, it came near the lamp and I found that 10 mm bar had grown to 68 cm! A little experimentation showed that the lamp interfered with the caliper reading within a distance of 3 to 4 cm.

Measurers beware! A little light can go a long way......

Les Kettle, Chelmsford

Thanks Les, that may explain some extreme readings in my own shop!

Cheap as Chips

Dear Neil, I read with great interest your article about removing rust using Evapo-Rust, but I wondered if you had ever tried Distilled Malt Vinegar? I found it to be incredibly effective over the years for renovating old rusty tools, particularly old machine tools that were made in the days when 'proper' steel was still made in Sheffield.

Even in the 'posh' supermarkets, the cost is negligible, (about £1.25 a pint) and it can re-used over and over again. I keep a large plastic container with a fitted lid in my workshop (shed). Then if I pick up anything that needs de-rusting, it simply goes in the pot, with the lid on, for a couple of days. When it comes out, all the rust has softened and turned into a grey film that comes off very easily with steel wool or a soft wire brush. As an illustration see the attached photo.

I bought this neglected 24 inch Record Stillson at a boot fair and as you can see it was originally covered in very thick rust. The jaws and the adjustment ring went in the pot for a couple of days and came out like new. I plan to treat the rest of it the same, I just need to find a bigger pot!

I don't know if it's the fact that the vinegar is distilled or whether it's specifically malt as opposed to some other form of vinegar (cooking has never been my strong point). However I know it works and it works surprisingly well.

The only disadvantage I have found is every time I take the lid off and something either goes into the pot, or comes out again, I get this overwhelming urge for fish and chips!

John Wheeler, by email

Evaporate that Rust

Dear Neil, like a lot of people, I have been trying various methods to remove rust and have never been fully satisfied with the results nor, sometimes, the safety of the process. I therefore read with great interest your article and decided to give Evapo-Rust a try (*MEW* 233).

The product is not widely available in Australia, but there are stockists listed on the Evapo-Rust web site. The product is, quite expensive but appears to be cheaper on-line, but I purchased mine over the counter from a local auto paint shop.

I have now used it extensively on a backlog of rusty tools and parts and I am very impressed with the results. The process is simple and relatively quick, but it really does strip the rust off very effectively. Surface rust is gone in a few hours, whilst thick deposits take a few days. I found it better to wire brush the bulk of the rust off before soaking in the solution.

Unfortunately the process seems to take any blueing away with the rust. It also tended to leave most surfaces with a dull grey/black finish. On the other hand, I didn't find it damaged chrome, paint, wooden handles, brass or aluminium. Having said that, no one should claim the result returns the item back to new. Rust can leave permanent stains, and if bad enough, no amount of rust removal will fix the missing metal resulting from pitting.

With caustic or acid processes, you have to wash the item very thoroughly after the treatment. Perhaps old habits die hard, but I also washed the Evapo-Rust off with water as soon as I could, despite the suggestion that this is unnecessary. This means a thin layer of surface rust forms almost immediately after the washed item dries. A bit of a light rub down and an application of oil or paint fixes this.

The part does need to be fully submersed and soaking, this does create something of a challenge when you are trying to remove the rust from larger or in-situ pieces. I'm yet to work out how to soak the sizable worktable on a saw bench I picked up cheaply some years ago.

I enjoy bringing old tools back to life and saving them from the tip, so I always seem to be picking up something at swap meets and sales that needs some TLC. A visitor to my workshop commented that I have 'every tool known to man'. My wife seems to agree with this statement as she often quotes it when I bring another rusty pre-loved item home for restoration. I usually bring up her having too many shoes, and she quietens down a bit.

For the record, I have no connection with Evapo-Rust. The first I heard of it was from your article. Compared to my usual methods, like vinegar or electrolysis, I am now of the view that Evapo-Rust gives superior results, with a simpler, faster and safer process.

Tony Zuiderwyk, Australia

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

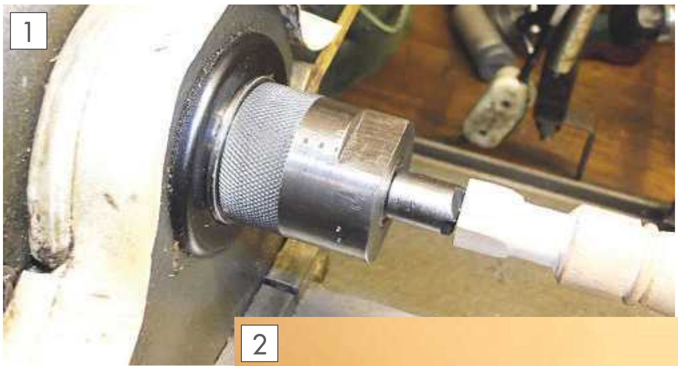
Write to The Editor, Neil Wyatt, Model Engineers' Workshop, MyTimeMedia Ltd., Enterprise House, Enterprise Way, Edenbridge, Kent TN8 6HF. Alternatively, email: neil.wyatt@mytimemedia.com

A High Speed Spindle for a Myford Lathe

I blame the *Model Engineer* editor for starting it. There was an article on the Robert Stirling heat engines and the making of a scale version. Not having a current task in hand I thought a bit of wood turning would be of interest. It did not take too long before I realised that the top speed of the ML10 was too low for spindles of half-inch and less cross-section. A maximum normal speed of 815 rpm needs to be double or more of that so I aimed at 2000 rpm to be sure.

The following Item is my solution to the problem - a high speed spindle for wood turning that fits inside the original spindle. Has it been done before? Probably but I had not seen any designs. My solution was cheap and did not take ages to produce, the bearings and the steel shaft are from scrap printers. I will show some dimensions but it will be the materials to hand dictating most of the sizes. Equally, I am not giving step-by-step instructions, as the method of construction should be largely self-evident from the figures and photographs. The design should be possible to adapt for any lathe with a hollow spindle of adequate size.

Peter Wilton makes a 'revolutionary' accessory for his ML10, the smallest of Myford lathes.



1 *The high speed spindle fitted in the lathe.*

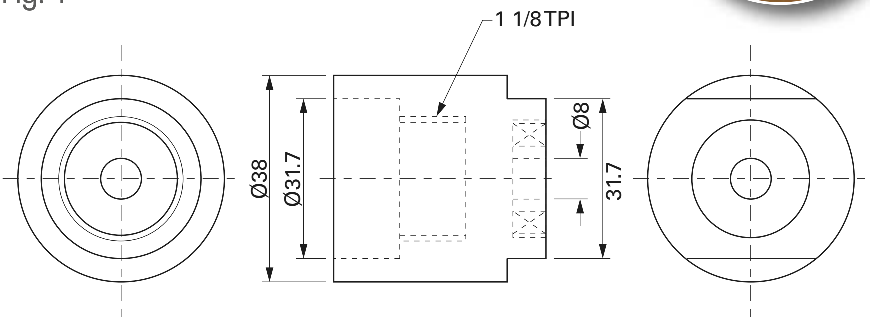
2 *Drive shaft, pulleys and bearings.*

After a good rummage through the bits and pieces boxes enough steel and bearings (19mm O/D, 8mm I/D, 5.56 thick) came to hand so a few sketches just to get the size of things sorted and manufacture started. **Photographs 1** and **2** show the shaft itself. First item up was the head bearing unit (**fig. 1** and **photo 3**) which screws onto the ML10 normal spindle. A space behind the bearing has a felt washer to give a supply of oil (**photo 4**). Nothing too difficult but made easier having a 1⅛ inch x 12 tpi plug tap to clean up the internal thread. Personally I find internal threading very difficult to get a clean cut.

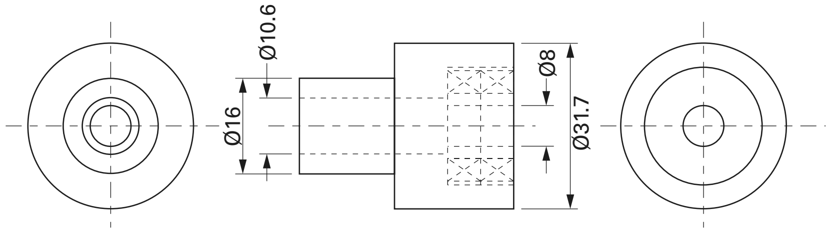
3 *Head bearing.*

4 *Inside head bearing showing felt oiler.*

Fig. 1



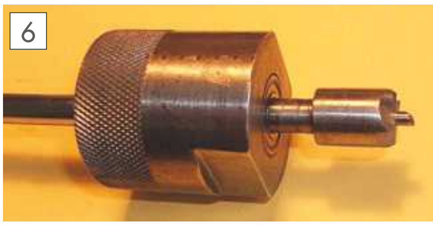
Lathe Head Bearing Unit



Lathe Head Drive Bearing Unit

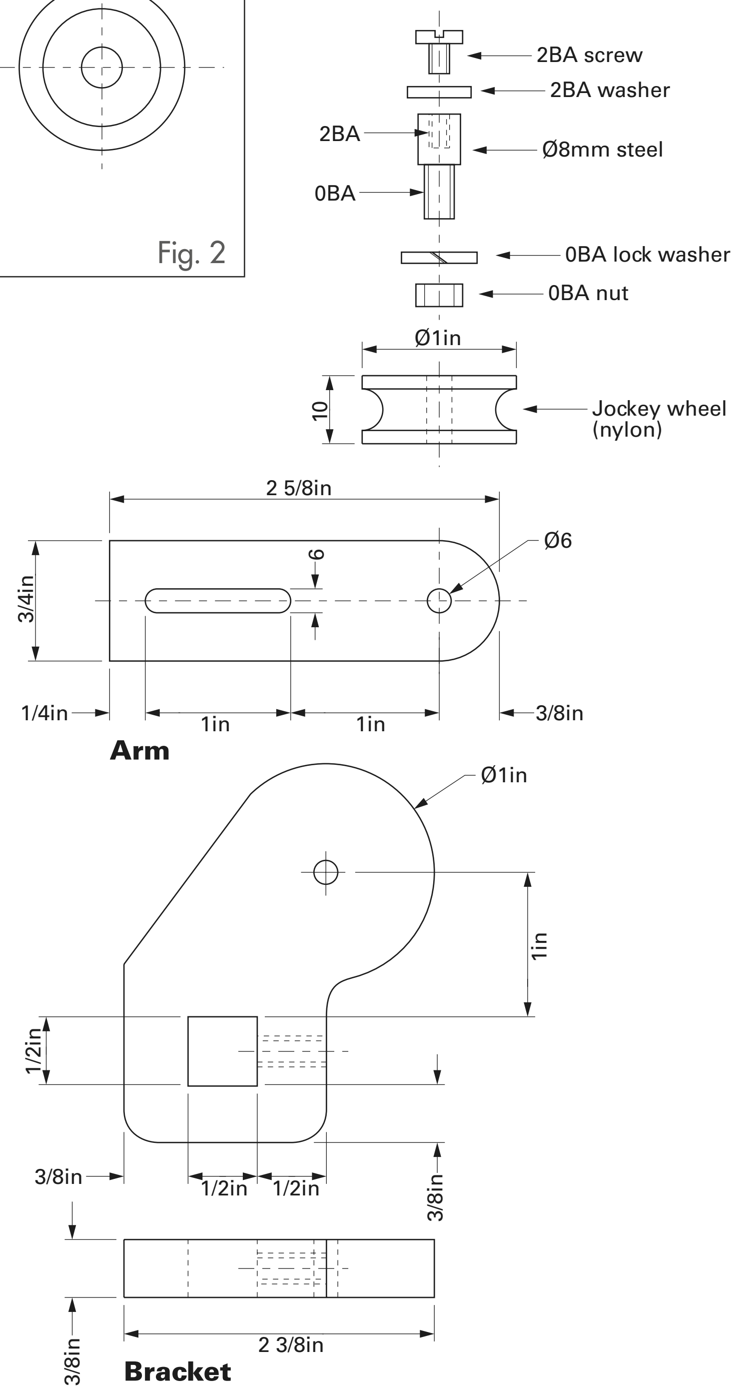
Fig. 2

Driving dog & head bearing.



Lathe drive shaft end bearing.

The two pulleys required.



Drive Belt Tensioning Wheel Components

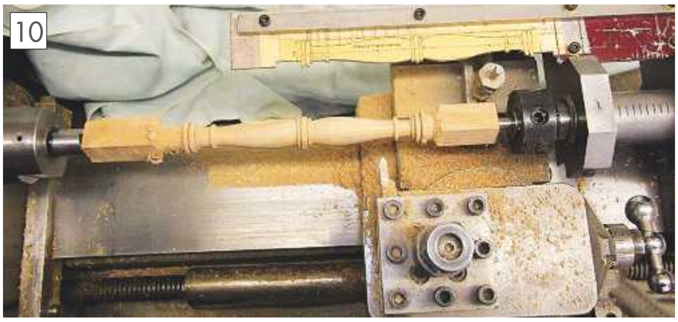
Fig. 3

Figure 2 shows the tail end bearing unit, which is similar but fits in the tail end of the lathe spindle.

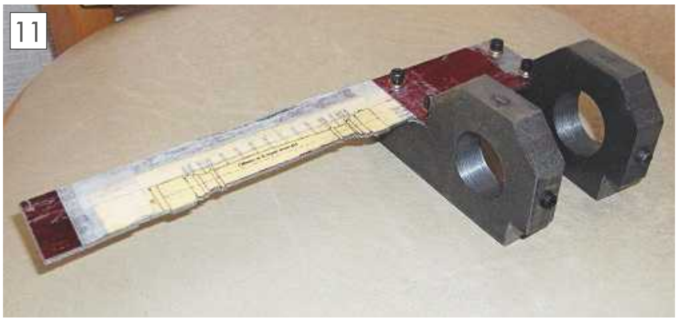
The driving dog, **photo 5** is a fairly easy manufacture if a vertical mill is to hand. Drill the ⅛ inch hole out first, cut the teeth and then fit a ⅛ core plug and trim to length. The rear headstock bearing unit fits snugly into the lathe spindle to take the load from the driving belt (**photos 6** and **7**). Pulley sizes are partly dictated by the presence of the driving belt cover mounting bracket. The belt tensioner (**photos 8** and **9**) serves a dual roll here in

Drive belt and tensioner fitted on the lathe.

Belt tensioner installed.



Profile follower in action.



Profile plate fitted to brackets.

that it holds the belt above the support pin (Myford drawing ref 168).

The belt is 6mm plastic, I was lucky in that there was a yard or so left over from a job done for a neighbour some years ago. I should clean up the belt tension bracket to make it look like **fig. 3** but as it works ok and also will only get occasional use, why bother. The model needs my attention!

Profiling attachment

The purpose of the spindle was to allow me to produce small diameter wooden profiles. This was facilitated by making a profiling attachment comprising custom profile plates and a profile follower (**photo 10**).

The profile plates (**fig. 4** and **photo 11**) were generated from an original printed article but the final print size was experimented with until the size was true to the scale I was building the model in (half size). The profile follower mounting bracket (**fig. 5** and **photo 12**) gave me more flexibility to position the follower

Profile follower and bracket.

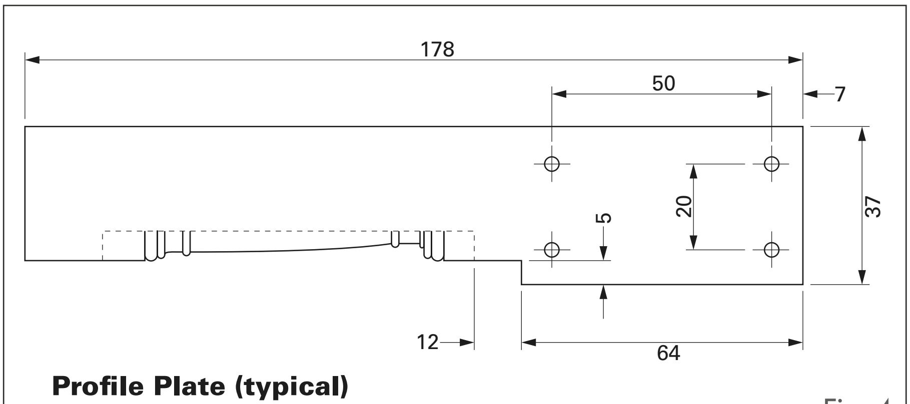


Fig. 4

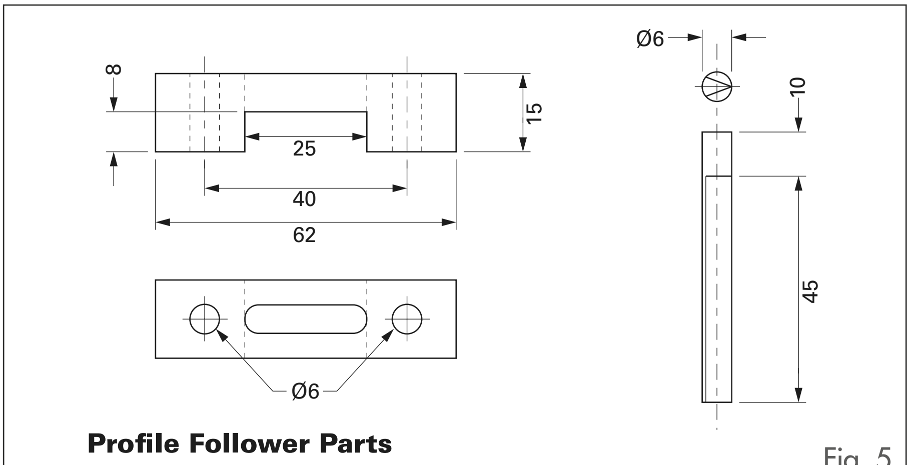
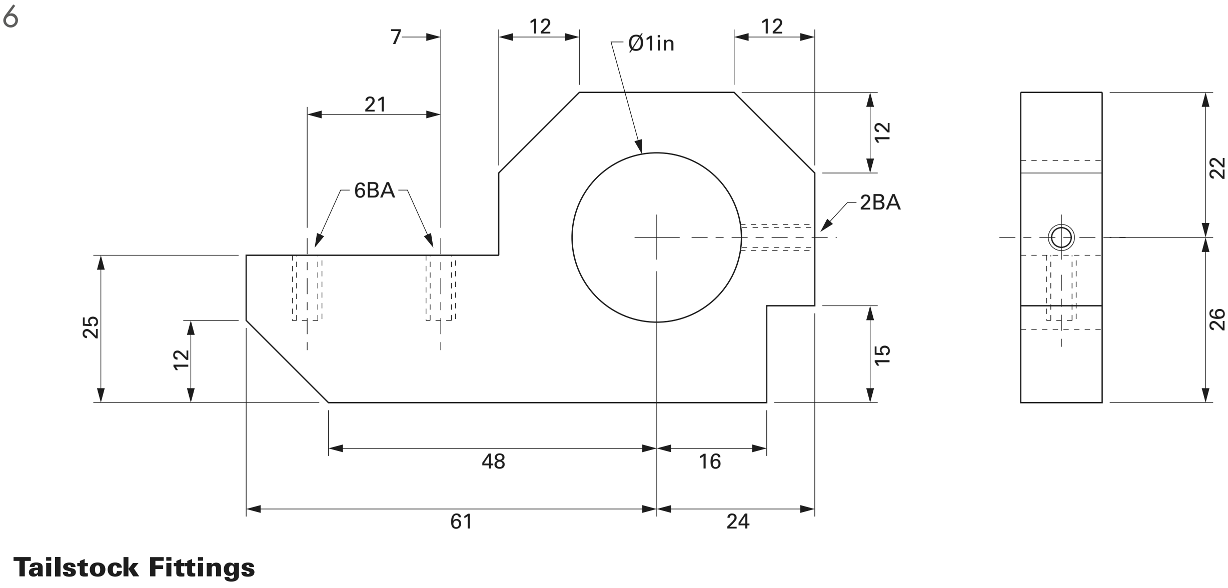


Fig. 5

Fig. 6



with regard to the lathe tool. Mounting brackets on the tail stock barrel (**photo 13** and **fig. 6**) proved to be a good firm fixture, just test the beginning and end of the profile plate with the Follower to ensure that they are equal before final tightening of the mounting screws.

The small rotating tailstock (**photo 14**) was simply an ex printer double bearing unit which happened to be the right diameter to push in a MT2 taper with a socket and grip screw fitted. It just needed a short length of 6mm steel turned to a 60 degree point inserted to complete.

I have omitted dimensions where I think that the source can make the decision for you. My apologies for the mix of metric and imperial dimensions, also that I failed to master CAD process so my drawings may only be classed as sketches! (*We have hand sketches redrawn*, Ed.)To be honest I had moved on from the wood turning task before deciding that there might be something of interest in my ideas.

Coda

As an after-thought I have included a couple of photos and sketches of the Honing process of a cylinder. This was prompted by the realisation that the Drive Shaft End Bearing would fit the non-tapered end of the tailstock shaft. A quick production of a tailstock taper bearing (**fig. 7**) and we were in business (**photos 15** and **16**). I used the offset tailstock design by Michael Cox to make the taper (*MEW* 184, December 2011). It is easy to adapt to an ML10 and takes only a few minutes to set up for MT2 tapers. I can highly recommend it. ■

13

Tailstock fittings.

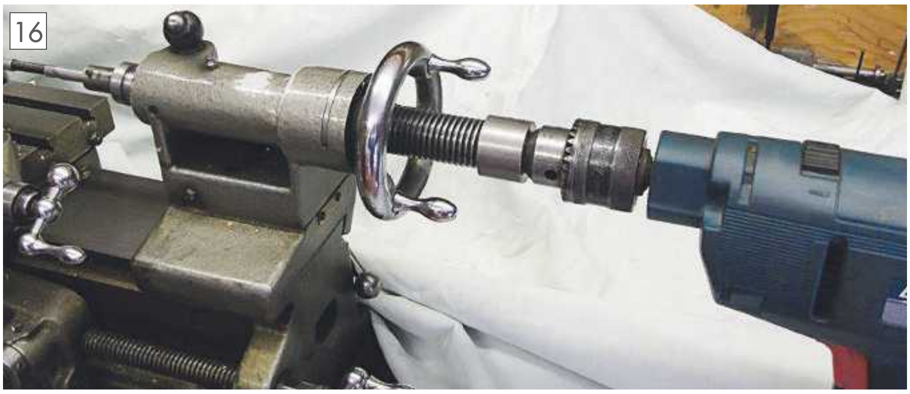
14

Miniature rotating tailstock.

15

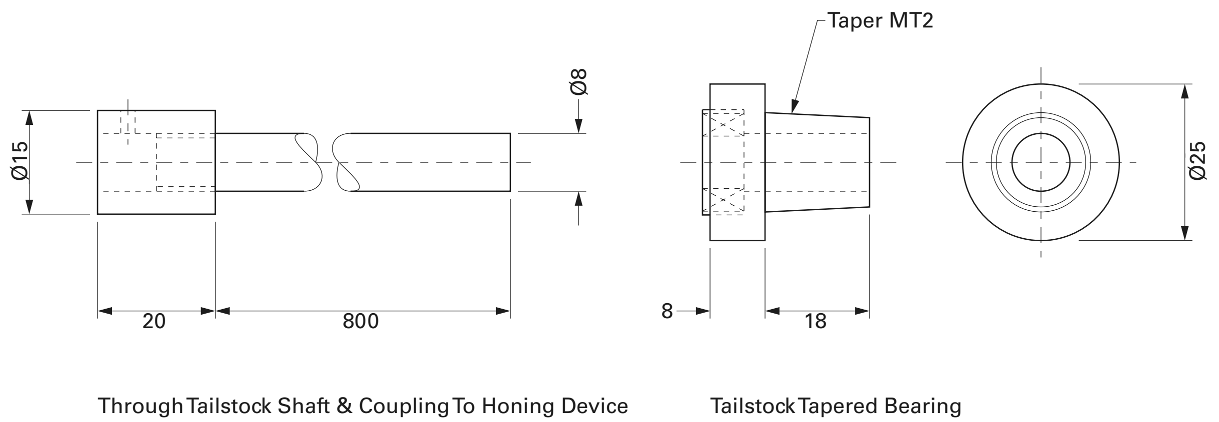
Cylinder honing.

16



Using a hand drill to provide power for honing.

Fig. 7



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From ARC to MIG

In the first half of a two part series, Neil Wyatt explains just what MIG welding is.

Like many *MEW* readers, I have had a basic arc welder for several years (**photo 1**). I don't claim any great proficiency with this technique but I have managed to patch up a few vehicles, make some basic constructions, including my loco driving car (**photo 2**), and do a few other jobs that would have been impractical with almost any other approach.

My Kende basic arc welder.

A stick welder is basically just a big transformer. It drops mains voltage down to a low value, but allows lots of current to flow into a continuous spark, and the heat generated melts the filler metal rod, which forms a seamless joint with the work. Molten flux shields the metal and protects the weld as it forms. The big problems with arc, stick or MMA (manual metal arc) welding are two fold – first the sticks leave behind a thick layer of flux, and even if you continually chip the work clean, it is very hard for a beginner to be sure they are laying down a clean and effective bead of weld. The second problem is welding thin metal, especially sheet steel. It's so easy to blow holes in the metal rather than join itn together, and if you use small sticks and drop the amps, it just becomes even harder to strike and maintain the arc.

My stick welder is a Kende BXI-130B, and it has proven reliable and striahtforward to use – and has just one control for the welding current. I can even manage to make a half-decent weld with it (**photo 3**). My stepson was fortunate enough to take a proper, extended course in welding as part of an apprenticeship, and not only did his guidance help me to improve my arc welding, it made me even keener to try MIG welding.

The MIG welder is the same but different. Add a rectifier, wire feed, special torch and a regulated gas supply to the equation and suddenly things are a lot more complicated with speed, current and gasflow to get right. So the MIG welder is bigger (and heavier) (**photo 4**) costs more and requires more consumables.

Foot rests for my driving car, welded up from mild steel and angle.

So why MIG welding?

MIG (metal inert gas) welding has been around since the second world war, it uses a filler wire continuously fed into the workpiece that strikes a welding arc and forms the bead/weld pool. All this

A delicate job – extension pieces for a valve spring compressor.

Stick welder dwarfed by MIG welder!

The Clarke MIG145 is Machine Mart's best selling MIG welder.

I had the safety gear already but had to stock up on a few other items.

happenes under a continuous stream of a gas such as CO2 or argon that prevents the hot metal corroding, and removing the need for flux. Although unsuitable for joining heavy work, it is ideally suited to sheet metal and the smaller tasks met in the workshop, and has the advantage that the welds are very clean. There is no flux to chip off or make inclusions that weaken the weld.

MIG has some other advantages compared to stick welding – anyone who has tried to arc weld upside down under a car will find MIG much better at awkward angles. It can be used on different thicknesses and types of metal,. Although you need to change the wire and gas used to suit the work.

I should mention no-gas or 'gasless MIG'. This uses a special wire with flux inside it that vapourises on contact with the arc. It doesn't give as clean a weld as gas-MIG, but has the advantage that you can use it outdoors in a breeze – making it popular for car repairs.

The price to pay for these advantages is complexity.

The MIG145

I was determined to try MIG welding without breaking the bank. I went along to Machine Mart to look at the various options they had and get some advice. There is plenty of choice – but I was happy to discount the larger professional machines, as I will not be welding for a living! The first question I was asked was gas or no-gas? My answer was I would prefer a machine that could do both, as no-gas can be a lifesaver for on-the-drive car work but I want to enjoy all the benefits and flexibility of gas MIG. The second question was would I be running it from a 13-amp socket? Not so easy to answer – my workshop is wired with a dedicated 20-amp spur ready for heavier equipment, however, working outside on a car would mean using a 13 amp outlet.

The recommendation was the Clarke MIG145 (**photo 5**) which is apparently the most popular welder sold by Machine Mart, and a particular favourite with hobby car restorers. It retails for just under £180, including VAT, rather more than a cheap stick welder, but you get a lot more machine. It can be used as both a gasless and gas MIG welder and is also a 'turbo' welder. This simply means it has a powerful fan that reduces cool-down time and improves the 'duty cycle' so you can spend more time welding and less time waiting for the welder to cool. Although my arc welder is a fan cooled, the fan is smaller and it has a poorer duty cycle than the MIG.

The MIG145 comes with a basic headshield, tools and a starter spool of wire, but no gas or regulator. You need some other essentials to weld safely, but I already had the safety gear - an auto-darkening welding helmet, several pairs of gauntlets, a leather apron, and anti-spatter spray. I just purchased a CO2 bottle, an extra spool of wire and a regulator and was ready to make a start (**photo 6**).

Out of the box

As supplied, the MIG145 comes in a large cardboard box, and it is surprisingly heavy compared to an arc welder of similar capacity. In the box were also some spare tips, a mini-spool of mild steel welding wire, a chipping hammer/brush and a basic face-shield welding mask. Assembly is pretty straightforward – fitting an axle and wheels to one end and assembling and screwing the handle in place.

Safety equipment

Although electrical welding uses big sparks, the voltages involved are relatively modest, the real dangers come from two sources- the very intense arc and the hot metal. Just seeing the arc of a welder can temporarily blind you, and any length of exposure can cause permanent eye damage, called arc-eye. Although the light from the arc dazzles, it is the intense ultra-violet radiation that causes the real damage, so you need a welding mask or helmet which serves two purposes: it reduces the light level so that you can comfortably view the work and it completely blocks the ultraviolet radiation.

As mentioned, the MIG145 comes with a basic hand-held face shield. I learnt to arc weld using one of these simple masks, but their chief disadvantage is that, until the arc strikes, you can't see what you are doing! Because it is much easier to strike the MIG arc, it isn't impossible to use the supplied mask. I already had a Clark auto-darkening helmet (**photo 7**) which

An auto-darkening helmet is the best welding accessory you can buy.

transformed my arc welding (from failing to adequate as OFSTED might say), so I naturally used this. The response of the auto-darkening helmets is truly instant, and they can be adjusted to give less darkening when the arc is small. Some people worry about what will happen if the helmet fails to darken – the answer is that you will get badly dazzled, but don't worry about arc-eye – the helmet's filters will block the UV anyway as the auto-darkening only affects visible light.

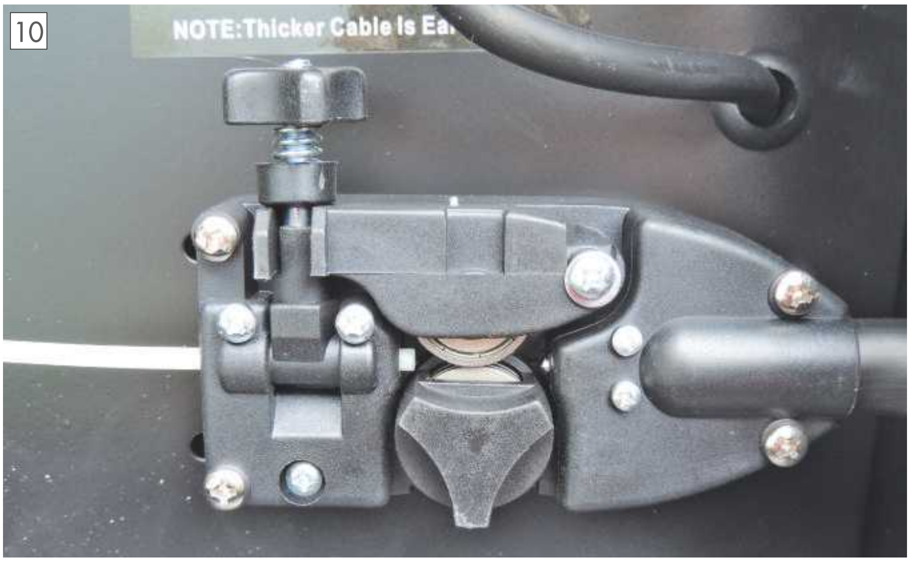
The UV can have other unpleasant effects – notably sunburn, and even the risk of skin-cancer for full-time welders. The answer, is of course to cover up any bare skin, typically this means wearing gloves, a long-sleeved top and long trousers.

Hot metal

When you are welding from time to time there will be sparks and spatters of hot metal. It's essential to wear a decent pair of welding gauntlets and I also recommend getting a full-length leather welders apron. These items are cheap, and come in handy for all sorts of other jobs, including brazing and angle-grinding. Make sure the clothes you wear are cotton – hot sparks may burn holes but are unlikely to set cotton on fire, plus if man-made fibres do catch fire they will stick to your skin. Do I even need to mention that open-toed sandals (or crocs!) are not suitable footwear for welding?

Inside the side panel of the welder.

The cable connections.



Wire drive arrangements.

Anti-spatter

On the subject of hot metal, it's worth mentioning anti-spatter spray. I have no idea how this works, but it does. Spray it on parts of the work where you don't want bits of hot metal sticking, and even on the tip of the welding torch, and it will help make sure you can just get rid of any spatter with a quick rub of the welding brush.

Inside the MIG

I've already mentioned that the MIG welder is not as simple as a stick welder. Instead of just having a big transformer inside, there are a few differences. Most of these can be found by opening a large a hatch on the side of the welder (**photo 8**). This reveals the space for the spool of welding wire, wire drive arrangements and the cable connections.

Unlike simple arc welders, for MIGs the power is rectified so you get a DC arc. For gas welding the polarity of the torch and earth clamp need to be reversed compared to when you are using no-gas flux-cored wire. This means there are + and – terminals inside with heavy duty cables that may need switching over (**photo 9**).

For gas welding the earth cable should be connected to the negative terminal and the torch connected to the positive terminal. For no-gas welding the leads should be reversed. The MIG 145 came set for no-gas welding so I had to swap the cables over.

There are three sizes of spool, mini, midi and large. The MIG145 is supplied with a 100mm mini-spool with rather less than a kilo of wire. The manual only mentions 100mm spools, but if you reverse the spool bobbin it also takes larger 200mm spools which hold around 5kg of wire. There is not sufficient space for 300mm spools inside the machine. A sprung nut provides a little drag to stop the spool spinning freely.

As you would expect there are different types of wire for different types of metal. Mild steel welding wire is available in plain and flux-cored (for no-gas welding). Aluminium and stainless steel wires are also available.

Wire from the spool is fed along the centre of the torch lead. It is pulled off the spool and pushed up a liner in the centre of the torch lead by a drive roller and a tensioned pinch roller (**photo 10**). The wire should feed off the bottom of the spool. There are a number of sizes of wire, the MIG145 takes 0.6mm and 0.8mm plain wire or 0.9mm flux cored wire. The drive roller has two grooves in it and can be reversed to suit the smaller or larger sizes of wire, but be careful not lose the tiny metal key!

The pinch roller can be disengaged to facilitate threading the wire. Fitting the wire is a little fiddly, especially as it is important not to let it uncoil from the spool, but is made easier by making a neat cut across the end of the wire and straightening a short length.

Once the wire is fitted, the side panel can be flipped up and attention now moves to the torch.

Threading the torch

The most obvious difference between MIG and arc is the torch (**photo 11**). Unlike the stick welder's simple insulated clamp (**photo 12**) MIG demands a more complex nozzle arrangement which has a removable insulated shroud (that directs the welding gas at the work) and a copper tip that supports the wire as it exits the torch. The MIG torch also has a trigger that activates the wire feed. On some units, like the Clarke MIG145, it also switches on the current, some welding torches are permanently live.

It's interesting to compare the torches and earth clamps side by side; a large, effective earth clamp is particularly important for sound MIG welding (**photo 13**).

Before threading the wire to the torch, you should pull off the shroud and remove the contact tip. Lay the torch lead out more or less straight and with no kinks. On the front panel, turn the wire feed up to a fairly high value. Keeping the earth clamp well out of the way, switch on and squeeze the trigger until the wire merges from the end of the torch. This can take a surprisingly long time!

Switch off and check the tip is the right size for the wire in use. Fit the tip over the wire and leave around 6mm of wire poking out (**photo 14**). If too long, just clip it short, then refit the shroud. Contacts and shrouds are inexpensive consumable items, so if they are in poor condition, discard and replace them.

The MIG torch with its prominent shroud and trigger.

In contrast, the simple 'torch' of a stick welder.

Gas or no-gas

If you want to use the welder in gasless-MIG mode with flux-cored wire, then the machine is now ready to use and you can prepare to do some welding. If you want to use it with gas, then there are a few more things to do around the back of the machine.

The MIG145 is not supplied with a gas bottle. You need to choose a type of gas to suit the metal you intend to weld. For mild steel the economic choice is carbon dioxide, but argon/carbon-dioxide mix is a general purpose mix for thin sheet, mild steel and stainless steel. Pure argon can be used for stainless steel and aluminium welding. Welding stainless and aluminium requires more skill. As a beginner I got a large capacity bottle of carbon dioxide to have a try at welding mild steel, although some sources recommend the argon/CO2 mix for beginners.

The welder comes with a pair of circular clips and small metal support bracket. These are screwed onto the back of the machine, and hold the cylinder very securely (**photo 15**).

Stick and MIG torches and earth clamps side by side.

Ready to start with 6mm of wire protruding.

As well as a gas bottle you need a regulator, this simply screws on top of the bottle (**photo 16**) and can be set to allow a gentle, low pressure flow of gas into the torch lead where it runs to the shroud. I bought a simple basic regulator, but you can get ones with pressure readouts. The pressure is so low that a small clear plastic tube is all that is used to link the regulator to a small inlet on the back of the welder (**photo 17**).

To be continued...

The optional gas bottle mounts on the back of the welder.

The regulator simply screws to the bottle.

Low pressure gas is fed into the welder by this plastic tube.

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Designing Springs ~ Visually
Part 2

Linton Wedlock continues his series by showing how to calculate spring rates.

In the second part of this series on designing springs by graphical methods, a chart to find the rate (the load-deflection characteristic) of compression and tension springs is described. This part also shows how the results obtained from the four charts in the series can be checked by calculation.

In some applications, the **rate** (or **scale**) of a spring is just as important as the maximum load value. The rate is the amount of force (load) needed to compress or extend the end of a compression or tension spring by a specified distance (**fig. 5**) and the units for the rate are pounds-force per inch of deflection (lbf/inch) or, in the metric system, newtons/millimetre.

The three parameters in a spring which affect its rate are the **wire diameter** and **mean coil diameter**, both in inches (or millimetres), and the **number of active coils**. In most applications, the length, and with it the coil pitch, are also important, but these parameters don't affect the rate. The number of active (or working) coils is not always the same as the total number of coils in a spring. In a compression spring with flat ground ends, for instance, the number of active coils equals the total coils minus 1.5. Although the mathematics which governs the rate is slightly complex, the relationship between the three spring parameters and the rate can be seen easily when plotted in graphical form, as has been done in **Chart 2** (overleaf).

The rate chart

This chart has a generally similar appearance to the maximum load chart described last month, and, as it's used in a similar manner, I'll only give a short summary of its main features. Chart 2 does, however, require one extra step in its use, and this will be covered shortly. As with the maximum load graph, Chart 2 has two sets of lines - a series of red SWG wire lines, and a set of dark coil ratio (D/d) lines, but the layout of the lines is different because the background mathematics is different. This chart, like the load chart, has been drawn for carbon steel springs, but can be used just as well for other materials and the method will be explained further on. Also, alternative non-SWG wire sizes can be used with the aid of fig. 2 (this figure and the method of using it were shown last month).

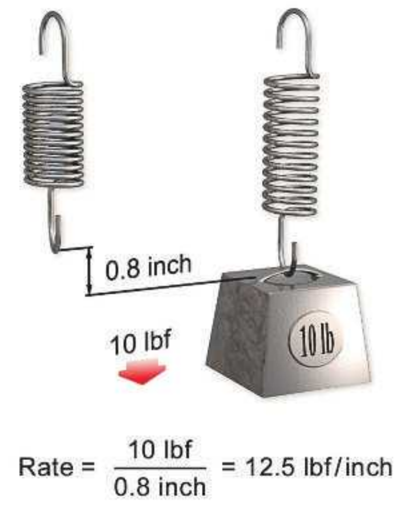
Chart 2 shows the rate value for a spring with just one coil, so the extra step needed with this graph is to convert this value to the rate for the whole spring. This is done simply by dividing the rate for one coil, read from the chart, by the number of active coils in the spring. Alternatively, for a spring with known rate and number of active coils, these two values can be multiplied together to get the single coil rate value before the chart is used.

An example

If you are familiar with last month's load chart, the rate chart will present no new problems, so I'll just give a single example of its use. No great precision is given for the values shown in this example, and this will be true generally, because the graph, like Chart 1, will be used mostly in the initial trial-and-error design stages of finding a suitable spring (although it will give quite accurate results if used with care).

Supposing a spring has to be made from 16 SWG carbon steel wire, and with an inside diameter of 0.65 inches. What will the spring's rate be if it has 35 active coils, and will these parameters make a practical spring? From fig. 2 (last month), 16 SWG is roughly 0.06 inches. Added to the inside diameter of 0.65 inches, this gives a mean coil diameter of 0.71 inches. This value is just slightly larger than the 0.7 inch vertical grid line on Chart 2, so follow this line upwards until the 16 SWG line is reached. Near the intersection of the two lines is a horizontal grid line which gives the rate for one coil as 70 lbf/inch. Dividing this value by 35, the number of active coils, gives a spring rate of 2 lbf/inch.

Fig. 5



It can be seen that, at the crossing point of the 0.7 inch grid line and the 16 SWG line, there is a D/d line with a value of 11. This is within the preferred coil ratio range of 5 to 14, so the design parameters in this example will make a usable spring.

Designing a spring can sometimes involve juggling the rate/number of coils combination, and a piece of Blu-tack or tape may be handy to keep Scale 2 temporarily in position on Chart 2.

Alternative spring wire

The rate also depends on a further parameter not yet mentioned - the shear modulus (also called the torsional modulus of elasticity). This is a constant value which is specific to the particular metal that the spring is made from. Chart 2 has been drawn using the shear modulus of carbon steel. It can, however, be used for springs made from other metals if the rate for one coil values are multiplied by a number (which is the ratio between the shear moduli of carbon steel and the metal of interest - see ref 1, given in part 1, for the method). You probably won't be surprised to learn, though, that there is an alternative visual way of doing this.

The rate values of Chart 2 can be adjusted for other metals by using the same method that was used with the load

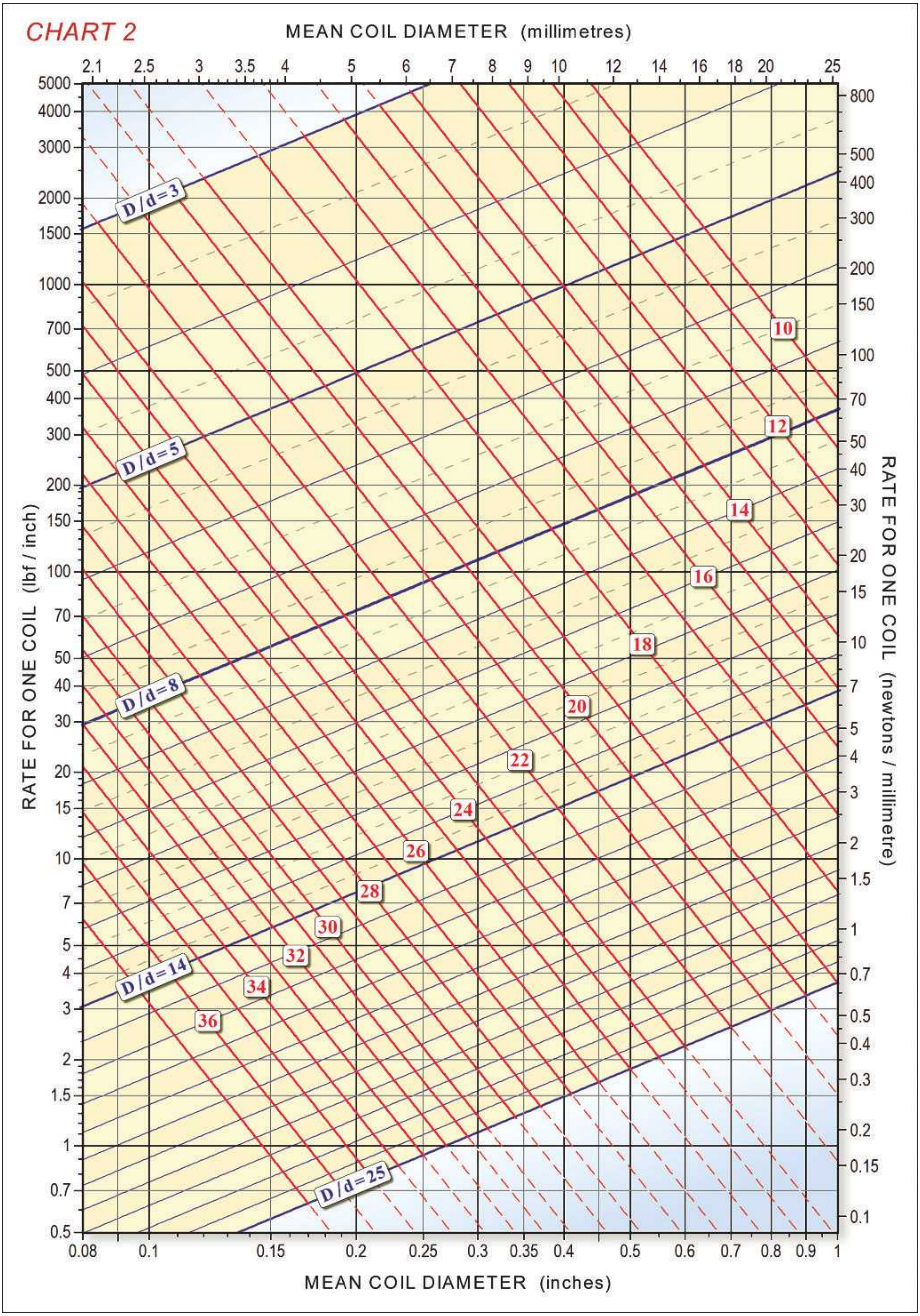


CHART 2
MEAN COIL DIAMETER (millimetres)
2.1
2.5
3
3.5
4
5
6
7
8
9
10
12
14
16
18
20
25
RATE FOR ONE COIL (lbf / inch)
5000
4000
3000
2000
1500
1000
700
500
400
300
200
150
100
70
50
40
30
20
15
10
7
5
4
3
2
1.5
1
0.7
0.5
RATE FOR ONE COIL (newtons / millimetre)
800
500
400
300
200
150
100
70
50
40
30
20
15
10
7
5
4
3
2
1.5
1
0.7
0.5
0.4
0.3
0.2
0.15
0.1
D/d=3
D/d=5
D/d=8
D/d=14
D/d=25
10
12
14
16
18
20
22
24
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32
34
36
0.08
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0.15
0.2
0.25
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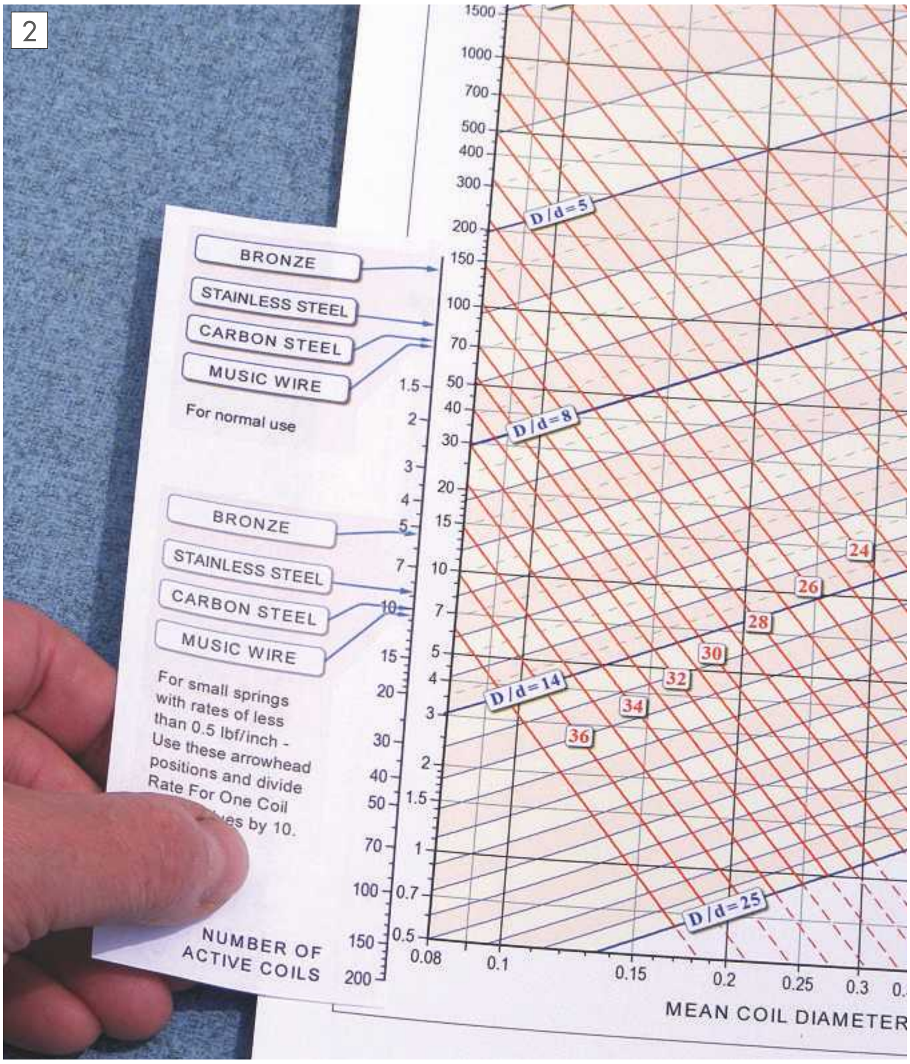
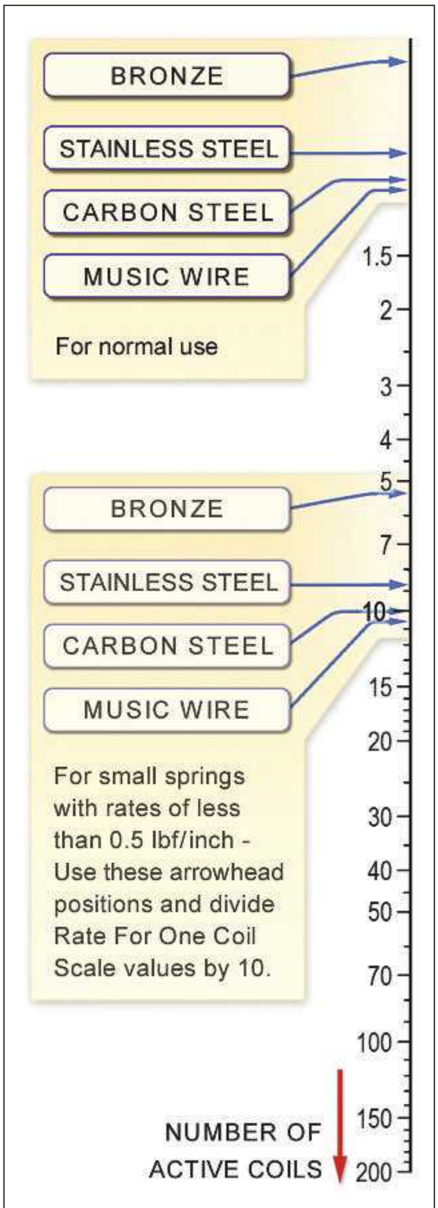
1
MEAN COIL DIAMETER (inches)





Scale 2

chart in part one: that is applying physical offset distances to the rate scale, instead of multiplying the values by an adjustment ratio. But - as described previously - this scale's values already have to be divided by the number of active coils to get the final spring rate. Is it possible to combine this division, and also the multiplication of the shear moduli ratio in one visual operation? The answer is yes, and a scale for doing this is shown in **Scale 2**.

In use, this scale is moved up and down the rate for one coil scale on Chart 2 (**photo 2**). A (careful) copy of the scale can be made on paper, or, if it is drawn out on a sheet of thin clear plastic with permanent marker (e.g. CD) pens, the underlying scale can be seen. What this scale does is to add a direct visual conversion chart between the active-coils numbers and the rate values of a spring. At the same time, it includes the adjustment for the metal that a spring is made from.

To use Scale 2, place it on Chart 2 so that one of the ARROWS in the 'For normal use' shaded region points to the vertical POSITION on the rate for one coil scale. The values shown by this latter scale are now read as rate values for the whole spring, and not as the rate for a single coil. With Scale 2 in position, it is now possible to see instantly how changing the number of coils will affect the rate, or vice-versa, simply by reading the values on the two scales which are next to each other.

Springs which have rates less than 0.5 lbf/inch are below the range covered by Chart 2, but in this case, Scale 2 is positioned using the 'For small springs . . .' arrows. If this is done, the values read on Chart 2's single coil scale should be divided by ten to get the actual rates.

Two visual examples

It's easy to use Scale 2 in practice, but not so easy to describe the method in words, so here are a couple of examples which should make the procedure clear:

In the example described before, The rate for one coil value found on Chart 2 was 70 lbf/inch, and the spring had 35 active coils. Dividing 70 by 35 gave a spring rate of 2 lbf/inch. The same operation could have been done visually by placing the 'carbon steel' (normal use) arrow of Scale 2 at the 70 lbf/inch position on Chart 2 (as shown in photo 2). Looking at the 35 active coils position on Scale 2, shows that the adjacent rate value for the whole spring is 2 lbf/inch. This is the same result as that obtained by calculation, but the visual method shows all possible combinations of the spring rate and number of coils. So, say a physical constraint in an application means that the spring length has to be reduced, which in turn means reducing the number of active coils from 35 to 25, the altered rate can be instantly read off as 2.8 lbf/inch. (Designing a spring can sometimes involve juggling the rate/number of coils combination, and a piece of Blu-tack or tape may be handy to keep Scale 2 temporarily in position on Chart 2).

If, in this same example, the spring parameters were unaltered (still 25 active coils) except that bronze wire was used instead of carbon steel wire, what would be the new spring rate? This time, the 'bronze' arrow on Scale 2 would be placed at the 70 lbf/inch position on Chart 2, and at 25 active coils, the new spring rate is found to be 1.48 lbf/inch.

The next example will demonstrate working the other way around; that is, starting with a required rate value for a spring, then finding the rate for one coil position to be used on Chart 2. These are the required parameters: 28 SWG stainless steel wire, with a rate of 1.7 lbf/inch, and with 10 active coils. What mean coil diameter is needed to make this spring? Place Scale 2 so that the 10 active coils number is at the 1.7 lbf/inch position on Chart 2 (= the rate for the whole spring). The 'stainless steel' (normal use) arrow on Scale 2 should now be pointing to the 20 lbf/inch position (= the rate for a single coil). Follow the horizontal grid line at this point rightwards until it intersect the 28 SWG wire line. At this point, the value indicated by the D/d lines is about 10.3. This is within the preferred coil ratio range of 5 to 14, so will produce a practical spring. Following the vertical grid line downwards from this same intersection shows that the required mean coil diameter is 0.15 inches.

Theory and practice

Theoretical prediction methods are of no use if they don't help with practical problems, so I made some rough tests to see how dependable the results obtained from the charts were. Finding a real spring's maximum load, though, is not easy, and I didn't want to try this, because any tested springs would have to be overstressed, at least a by a small amount. Measuring the rate, on the other hand, is a relatively simple matter of sticking some weights on the end of a spring and seeing how much the coils are deflected. So, if the rate chart was tested and proved reliable, it was likely that the maximum load chart was good also.

Some rate values for the 15 springs shown in **photo 3** were found, and then compared with the predicted values for these size springs. This selection covers a reasonably wide area on Chart 2, with 31 to 12 SWG spring wire, coil diameters of about 3 to 19 mm (roughly ⅛ to ¾ inches), and coil ratio values of 4.6 to 23. The measured rates and coil diameters for the springs were used to plot some points on Chart 2, and these were compared with their predicted positions on the graph. The maximum positional difference was about 6 mm (¼ inch), with the average difference being about 3 mm (⅛ inch). Calculations (described in the next sections) show that these differences correspond to a maximum predicted/ measured rate disparity of about 28 percent, with an average of 14 percent. This is a reasonably good result considering the test measurements were rough-and-ready, and the exact composition of the steel springs wasn't known. It was therefore very worthwhile doing this test because it showed that Chart 2 could be relied on to give useful and practical rate predictions. (In the test, the biggest differences occurred with springs which had rates which were difficult to measure. In these cases, I suspect that the theoretical predictions are more accurate than the actual measured rates).

Checking the results

Before making or buying any springs it may be a good idea to verify the results obtained from the charts with an independent spring design method. To some extent, the four charts in this series do this automatically, because the second pair of charts are used to find the same parameter values as Charts 1 and 2 (but Charts 3 and 4 are more precise). The two pairs of charts work in dissimilar ways, however, and therefore provide some independent confirmation of each others results.

An alternative way of checking the charts' results is by calculation, and this is the subject covered in the rest of this article. This section does involve using mathematical equations, which may appear rather off-putting at first, but they use nothing more complicated than multiplication and division. Even if you don't want to try the calculations for yourself, you may like to skim through these mathematical sections just to see why using graphical methods are so much easier! If you would prefer to skip this section, though, there is one further possible way of checking the results: there are dozens of websites which provide free spring design calculators. These do all the mathematics for you, and only require some spring parameter values to be typed in to get some instant results. (Note: there are alternative mathematical ways of predicting spring behaviour, so small variations in the results should be expected).

As in the other information shown in these articles, the explanations in the following sections are aimed more towards beginners; readers with a mathematical background would probably ignore most of the text and use the equations straight away.

3

Calculating the safe load

The equations for finding the safe maximum load of a spring are shown in **fig. 6**. Equation (1) is the main one. Put in words, this says that the maximum load (W) is equal to the maximum shear stress (fs) multiplied by pi (= 3.14) multiplied by the wire diameter cubed (= d x d x d). This value is then divided by eight times the mean coil diameter (D) multiplied by a correction factor (K1). Figure 6 also shows the units that are used for each variable in the equations; both imperial and metric are shown, but the following calculations will be done in imperial measurements only. (Note: metric diameters are in metres, not millimetres).

Finding the maximum load with equation (1) would be straightforward except that two of its parameters depend on other factors. Firstly, the maximum shear stress depends on the metal the spring is made from, the spring's wire diameter, and an allowance for safety. This allowance, in turn, depends on the type of application that the spring is to be used in. In practice, the maximum shear stress can be found from graphs which show how all these variables are related. Reference 1 has four such graphs for carbon steel, music (piano) wire, 18-8 hard-drawn stainless steel, and bronze (figs 5, 6, 7 and 8 in the book). To use the most accurate stress values, these graphs can be consulted, but **table 1** is a summary of the information they show (the table is created with some simplification and approximation, but still gives good results). The table shows ten metal/application categories (ICE - internal combustion engine). Each category shows a range of maximum stresses; the lower value is for 0.08 inch diameter wire (14 SWG), the higher value for 0.01 inch diameter wire (33 SWG). For other wire sizes, the stress can be estimated from the table ranges. The values shown must be multiplied by 1000 when they used in the equations, so, for instance, if a spring is to be designed for an 'average duty' application with 0.08 inch diameter carbon steel wire, the stress value used in equation (1) is 75,000 (lbf/sq. inch). (If you prefer to work in metric, the stresses in table 1 can be multiplied by 6900 to get the values in pascals. I have a question in connection with this: the graphs in figs 5-8 in ref. 1 can be redrawn for metric units, but does anyone know of a source for metric equivalents of these graphs, including those for other metals?).

The second difficulty in using equation (1) is that the correction factor, K1, depends on the coil ratio, C. (Equation (3) is a reminder that C is equal to the mean coil diameter divided by the wire diameter). K1 is just a number which varies between 2.06 (for C = 2) and 1.03 (C = 50). It's value can be found from equation (2), but it is perhaps easier to find it from a graph, and this is shown in **fig. 7** (example from the graph: for a coil ratio of 5, K1 is about 1.31). A second correction factor curve, K2, is also shown in fig. 7, but ignore this for now; it's used for finding the spring rate.

Here is an example of using equation (1) to find the maximum load: a spring is needed in an undemanding application. It will be made from 18 SWG carbon steel wire, and have a mean coil diameter of 0.6

$$W = \frac{fs \times \pi \times d^3}{8 \times D \times K_1} \quad (1)$$

$$K_1 = \frac{4 \times C - 1}{4 \times C - 4} + \frac{0.615}{C} \quad (2)$$

$$C = \frac{D}{d} \quad (3)$$

$$W = \frac{fs \times \pi \times d^2}{8 \times C \times K_1} \quad (4)$$

$$fs = \frac{8 \times W \times D \times K_1}{\pi \times d^3} \quad (5)$$

where:

W - Load (lbf or newtons)

f_s - Shear Stress (lbf/sq. inch or pascals)

d - Wire Diameter (inches or metres)

D - Mean Coil Diam. (inches or metres)

C - Coil Ratio

π - Pi (= 3.14)

K_1 - (Wahl) Correction Factor

Fig. 6

MAXIMUM WORKING STRESS
(lbf x 1000 / Sq. inch)
First value: 0.08 inch diam.
Second value: 0.01 inch diam.

Carbon Steel	
Average Duty:	75 - 95
ICE Valve Springs:	65 - 80
Music Wire	
Average Duty:	105 - 145
ICE Valve Springs:	80 - 110
18-8 HD Stainless	
Average Duty:	85 - 110
ICE Valve Springs:	65 - 85
Steam Safety Valve:	55 - 65
Bronze	
Average Duty:	45 - 50
Severe Duty:	40 - 45
Steam Safety Valve:	30 - 35

Table 1

inches. What maximum load can it support? From fig. 2 (in part one), 18 SWG wire has a diameter of 0.048 inches. The coil ratio is therefore 0.6 inches divided by 0.048 inches, or 12.5. Using this value and fig. 7 (or equation (2)) gives a value for K1 of about 1.11. From the 'carbon steel - average duty' range in Table 1, the maximum stress, fs, can be roughly estimated to be 85,000 (lbf/sq. inch). (The same value found from fig. 5 in ref. 1 is 82,000 - the two values are close enough for this type of work).

The value of all the variables in equation (1) are now known, so the calculation for the maximum load is 85,000 (fs) x 3.14 (pi) x 0.048 x 0.048 x 0.048 (d cubed), all divided by 8 x 0.6 (D) x 1.11 (K1), which gives the answer of 5.5 lbf.

As with graphical methods, some values used in this example calculation are only rough as there is no need to work with great precision in spring design work. The example shows that none of the individual steps in the calculation are difficult, but the whole process is laborious. You may like to try this example with the graphical method described in part one, and compare results.

Before finishing this section, I'll just mention equations (4) and (5) in fig. 6. These are just rearrangements of equation (1), and are sometimes more convenient to work with in some situations. Equation (4) is for finding the load from the wire diameter and the coil ratio (instead of the mean coil diameter), and equation (5) is for determining the wire shear stress when a known load is applied to the spring.

Calculating the spring rate

Figure 8 shows the two equations required for calculating the spring rate. Equation (6) says that the rate is equal to the shear modulus (G) multiplied by the fourth power of the wire diameter (= d x d x d x d) multiplied by a correction factor (K2). This result is then divided by 8 multiplied by the mean coil diameter cubed (= D x D x D) multiplied by the

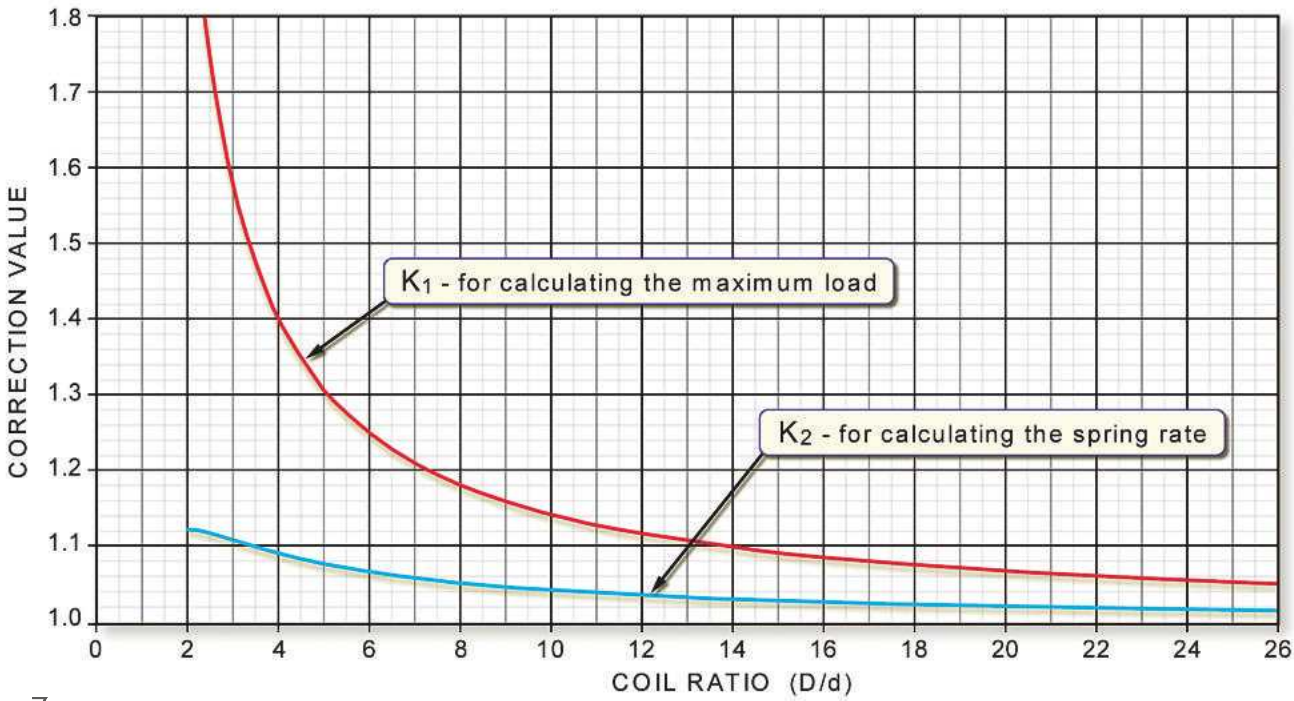


Fig. 7

$$R = \frac{G \times d^4 \times K_2}{8 \times D^3 \times n} \quad (6)$$

$$K_2 = \frac{2 \times C^2 + C - 1}{2 \times C^2} \quad (7)$$

where:

R - Rate (lbf/inch or newtons/metre)

d - Wire Diameter (inches or metres)

D - Mean Coil Diameter (inches or metres)

C - Coil Ratio

n - Number of Active Coils

K_2 - Rate Correction Factor

G - Shear Modulus (lbf/sq. inch or pascals)

Fig. 8

SHEAR MODULUS (lbf / Square inch)	
Carbon Steel:	11,400,000
Music (Piano) Wire:	12,000,000
18/8 Stainless Steel:	10,000,000
Bronze:	6,000,000

Table 2

number of active coils (n). The rate is a little easier to calculate than the maximum load is, because its parameters do not depend on so many other factors. The correction factor, K2, depends on the coil ratio value. This relationship is shown by equation (7), but it is perhaps easier to find this value from the graph in fig. 7. (The K2 correction factor is relatively small, however, and could probably be ignored in undemanding applications). The shear modulus has a fixed value for the metal that the spring is made from, and four such values are given in **table 2** (for metric calculations, multiply these numbers by 6900 to get the values in pascals).

To end this article, here is an example calculation for finding the rate of a spring: Say a spring made from 26 SWG bronze wire has a mean coil diameter of 0.2 inches, and has 15 active coils. What is its rate? Figure 2 (part one) shows that 26 SWG has a diameter of 0.018 inches. The coil ratio is therefore 0.2 inches divided by 0.018 inches, or 11.1. Figure 7 (or equation (7)) shows that for this coil ratio, K2 is about 1.04. From table 2, the shear modulus for bronze is 6,000,000 lbf/sq. inch. Putting all these values in equation (6) gives: R = 6000000 (G) x 0.018 x 0.018 x 0.018 x 0.018 (d x d x d x d) x 1.04 (K2), all divided by 8 x 0.2 x 0.2 x 0.2 (D x D x D) x 15 (n). This gives the calculated rate value of 0.68 lbf/inch, and you may like to see if the graphical method of using Chart 2 gives a similar result.

(**Note:** in the calculation examples, the powers of variables have been shown as multiplications, so that they can be done on any calculator - the fourth power of d is d x d x d x d, for example. Some calculators have an included power function, however - its usually shown as the letter 'y' with a small 'x' to the top-right. In this current example, with such a calculator, the fourth power of the wire diameter could have been entered as 0.018 [power function button] 4.).

To be continued...

NEXT MONTH

Part three will introduce nomograms, which are a simple visual method of solving complex equations. The first nomogram will show how the wire stress in a spring can be found with almost no effort.

In our Next Issue

Coming up in issue 236

On Sale 4th December 2015

Mike Checkley describes a micrometer end stop for his CNC vice.

Andy Clark won a trip to a Maker Faire in New York, he shares the experience!

Keith Wraight constructs a power cross feed for Myford lathes.

The Interesting Dynamic Properties of Blu Tack

'Experimental engineers' amongst the readership will be intrigued by this exercise suggested by Michael Gilligan.

On a recent forum thread at www.model-engineer.co.uk ('Dampened boring bars for long overhangs'), I mentioned that 'Blu Tack' is useful for damping mechanical vibrations. I also commented that 'It may be the most thixotropic material known', and I think that remark merits some further exploration.

Here is a demonstration, which is easily reproduced and very convincing:

Note: The quantities, shapes and moulding technique are not critical, but they have proved to be convenient for the demonstration.

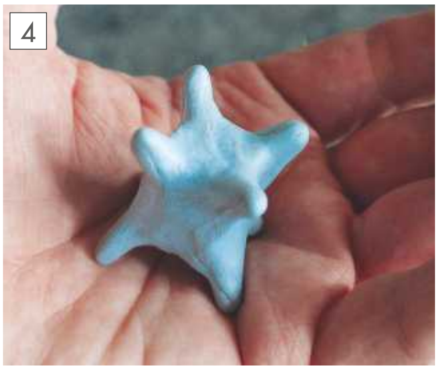
1. Using a suitable quantity (approx. 22grams – older readers may prefer to use three quarters of an ounce, Ed.) of Blu Tack, make a ball about 25mm diameter, **photo 1**: If the material is old, or reclaimed, it is best to knead it first, to ensure that the ball is reasonably homogeneous.
2. Mould the ball between the thumb and forefinger of each hand, to produce a cube, of side approximately 20mm (**photo 2**).
3. Pinch each of the eight corners and draw these out into stubby points (**photos 3** and **4**).
4. Make a mental note of the softness and malleability of this material.
5. In a suitably 'safe' location (away from people, animals, precious objects, etc.) Throw the shapely lump of Blu Tack, as hard as you can, against a smooth hard surface, such as a wall or floor.
6. Retrieve the material and inspect it.
7. Think about what you have observed!

I will not ruin this amusing experiment by describing the result; but I do encourage all readers to try it for themselves. Please note that I have only done this demonstration with the original Bostick Blu Tack ... There are 'similar' alternative materials available, but the results may vary, and it would be helpful if experimenters could report any similar or differing behaviour.

Make a Ball.

Pinch to form a Cube.

Extend the Corners.



A suitable projectile.

Etymology: The term *thixotropy* is derived from the Greek, and means 'changeable touch'. Many readers will be aware of thixotropic paints, which are gel-like when in the can, but become fluid under the pressure of brushing: These exhibit 'positive thixotropy'.

Blu Tack, however, exhibits 'negative thixotropy', which means that it is malleable under slowly applied pressure, but becomes stiffer with increasing speed. It is probably best described as a 'negatively thixotropic non-Newtonian fluid'.

In the late 1970s through late 1980s, I was working in a Vibration Test-House, and we sometimes used Blu Tack as a convenient adhesive for 'tacking-down' accelerometer cables. Further investigation revealed that it has useful damping properties when used in this way [i.e. applied externally] on small components.

We then tried it as a 'constrained layer' and found its characteristics to be especially useful; not so much for simple damping, but because it becomes increasingly stiff as the frequency rises. We used Blu Tack very successfully as a thin gasket layer under an accelerometer: By this means, a screw-fitted accelerometer can be rigidly coupled to a less-than-perfectly-flat surface without using excessive force to tighten it. Although we were doing this in a Lab environment, it is worth noting that 'Audiophiles' were already using the same technique, to improve the coupling of a pick-up cartridge to the tone-arm on a record player deck: What we demonstrated using instrumentation, they had already found by listening.

A little thought will suggest numerous possibilities in the workshop: Aside from its intended purpose, Blu Tack is a useful damping material when applied externally, and makes an excellent gasket when constrained ... surely an uncommon mix of properties. ■

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The Miller's Tale - Part 2

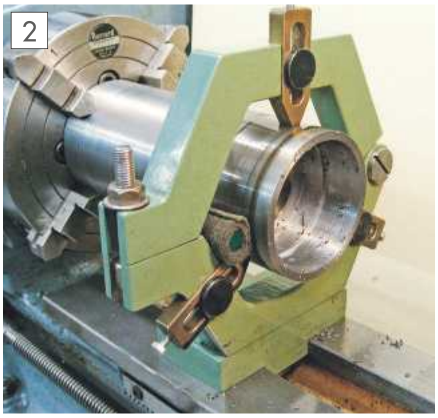
By Ian Strickland.

The Story so Far
In my previous article, I mentioned my plan to make a vertical head for the Trident C horizontal mill based on the article by J.M. Wilson published in *Model Engineer* in 1984 (**ref 1**). His design has no vertical feed, but on reflection I can live without it by using the vertical movement of the knee, and so save myself a lot of extra work both in design and construction.

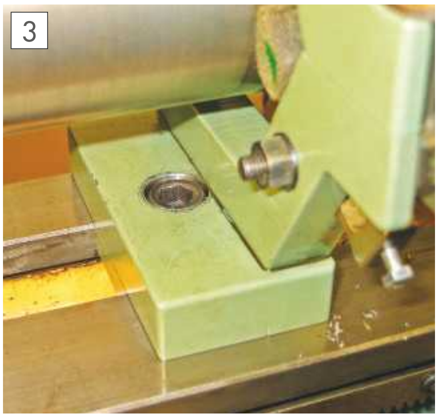
In Part 1, *'The Miller's Tale'*, I mentioned that the bores for the horizontal spindle and the overarm needed to be rebored as they were somewhat out of line. The plan was to use the vertical head mounted on its backside, i.e., horizontally, on the milling machine table, and use it to bore out the offending holes. Drive for the head was taken from the lathe by moving the mill in front of the lathe and using a belt drive from a pulley mounted between centres. The advantage is that all the lathe spindle speeds are available to drive the boring head at the correct speed.

The spindle for the vertical head was made about 8 inches longer than the finished length, and the extension used as the boring bar to bore out the holes mentioned above. This was later cut off and the spindle finished to length and bored out to take R8 collets and a draw bar, as per the original design by Mr Wilson.

Spindle top cover being separated from spindle body.



Screw adjusters added to fixed steady.



Allen screw countersunk into foot of fixed steady.

Construction

Construction followed fairly closely the design by Mr. Wilson. Work started by roughing out a 3 inch diameter billet of mild steel for the spindle body, initially supported by the tailstock. Once it was turned down to diameter (2.9 inches), it was time to use the new fixed steady, which had to be made especially for this job. The billet was made somewhat longer so that the top cover for the spindle could be machined and then parted off; actually hacksawn off! (**photo 1**).

Two mods were needed to the new fixed steady. The first was to add screw adjusters to the fingers to facilitate adjustment (**photos** 1 & **2**). (Note the small roll of felt acting as an oil pad for the fingers of the fixed steady.) The second was to counter sink the Allen screw (**photo 3**), so that a cut down Allen key could be inserted below the workpiece to lock the steady in place. Although the steady was designed to accommodate a diameter of 4 inches, 3 inches is the practical limit on a 3½ inch lathe.

Opposed Timken taper roller bearings (**ref 2**) were used to mount the spindle. Very careful machining of the spindle and the body was needed for the bearings to seat snugly. Even so, I had problems with the top end of the spindle being a whisker undersize. To stop the bearing rotating on the spindle, the centre punch was used to raise the surface with a pattern of dots. To enable the outer races to be easily removed from the spindle body, extractor rings were inserted first into recesses behind the outer races. The extractor rings have three M6 tapped holes so the outer races can be jacked out without damage.

As mentioned above, the spindle was made about 8 inches longer than needed, the extra length to be the integral boring bar for boring out the spindle and overarm holes. The maximum length of 20 inches can just be accommodated between centres on a Myford ML7 or Super 7. The ends of the bar were marked using V blocks on a flat surface. It was then transferred to the lathe for centre drilling (**photo 4**). The positioning being achieved by initially using centres to line up with the marked ends and then carefully packing it up off the cross slide. It was then securely clamped to an angle plate on the cross slide, and centre drilled both ends. The bar was turned between centres. **Photograph 5** shows the spindle end to the right, and the integral boring bar to the left. The bar was supported mid span with the Myford fixed steady. Two diagonal holes were drilled for the TCT tipped boring cutters, one for boring the nearer holes; the other for the far holes at the back of the milling machine column. They were drilled by mounting the spindle on the vertical slide set round at an angle of about 45 degrees.

The bracket plate was the next lump to be tackled. It is the large block of BMS attached to the end of the overarm to support the vertical milling head (**photo 6**). This was fly cut initially on the lathe (**photo 7**), then cut to size (5 x 3.5 x 1.48 inch) on the mill (**photo 8**) and finally fly cut on the mill to clean up the sides. After drilling the mounting holes on the lathe (**photo 9**), it was transferred to the mill for boring out the hole for the overarm (**photo 10**). The bracket plate was Loctited to the new overarm, and not press fitted and pinned as in the original design. The brackets to secure the spindle body were made out of ½ inch steel plate (4 x 3.5 inch). They were bored (2.9 inch) as a pair on the faceplate to ensure concentricity (**photo 11**) and M8 Allen screws were used to secure them to the bracket plate. Clamping action was achieved by a sawcut at right angles to the mounting surface close to one of the fixing holes. About 0.020 inch was then filed off the shorter face to give the clearance needed for the clamping action. This is clearly explained in the original article.

With the vertical spindle head assembled, it was mounted on its back on

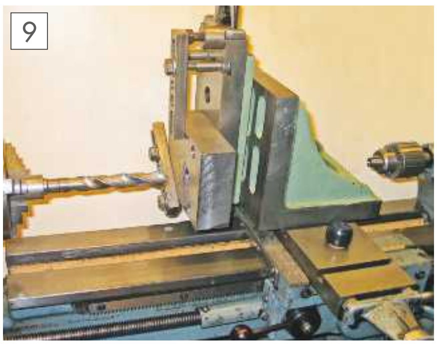
Spindle being centred.

Spindle, with integral boring bar to LHS.

Bracket plate Loctited to new overarm, and trial fit of spindle.

Fly cutting bracket plate mounted on the lathe.

Bracket plate being milled to size on the mill.



Drilling mounting holes in bracket plate.

Bracket plate being bored out for the overarm on the mill.

Brackets being bored to size as a pair.

Using the lathe to drive the boring bar on the mill.

Reboring the overarm bore to 1.850' diameter.

Drilling hole for collet guide pin in the spindle.

the milling machine table to bore out the milling machine headstock. The mill was mounted on a trolley and placed in front of the lathe from which the drive was obtained (**photos 12** & **13**). Alignment of the milling head on the milling machine table was critical and despite my best efforts the holes did not come out quite as square as I had hoped, but much better than before. (You may have noticed that the grey ML7 has been superceded with a green Super 7.)

With this job complete, the surplus boring bar was cut off and the spindle bored out to accommodate R8 collets. **Photograph 14** shows the setup for drilling the hole for the collet guide pin. Note the QC tool holder providing support against the thrust of drilling.

The drive to the spindle is from a 0.55kW, capacitor run 1,370 RPM single phase 4 pole motor mounted on a hinged plate on the rear of the overarm (**photo 15** & **ref 3**). The motor feet can be bolted to any of three sides of the motor, thus the connections and capacitor box could be placed to the side (**photo 26**), rather than to the rear of the motor, thus allowing the mill to be placed that much nearer the wall. Using three pulleys, (like many pillar drills), would give 17 useable spindle speeds. I played around a lot with spreadsheets to obtain a good spread of spindle speeds from about 2,800 down to about 100 RPM. The gaps between the speeds to be about plus or minus 40%. Belts were to be Poly V, and the pulleys cast in zinc. **Photograph 15** shows the general arrangement. The motor pulley has five steps and the spindle pulley four steps. The middle pulley is mounted on a swinging arm (**photo 16**). You may notice that there are two steps the same diameter in the middle of each of the three pulleys. This is to avoid losing the middle speed of about 800 RPM. Patterns were turned up from birch ply before the fun of casting the pulleys in zinc, which was obtained from wheel weights from the local tyre depot. **Photograph 17** shows all the patterns and all the castings. Most had to be cast two or three times due to flaws found in the castings. (I discovered later that adding about 10% aluminium to the melt produces much better castings. How can aluminium be added to the zinc which melts at a much lower temperature? Quite simply the aluminium dissolves in the molten zinc.) There are six castings for three pulleys. This was to simplify pattern making and the amount of metal to be melted for each pattern. The two halves of the pulleys were made to be a snug fit to each other to ensure concentricity. Four M6 Allen screws were used to bolt the halves together. **Photograph 18** shows the bottom half of the spindle pulley in the process of turning the belt grooves. Note the spigot for locating the top half of the pulley. **Photograph 19** depicts the spindle pulley assembled and setup for static balancing. The lathe bed has to be dead level for this job. You can just see one balancing drill holes at the start of the balancing process. It was all a bit cut and try, but in the end the balancing worked well for all the pulleys.

The original intention was always to retain the horizontal milling facility. As the overarm had been increased in diameter

Three pulley Poly V belt drive.

Middle pulley mounted on a swinging arm.

Pulley patterns and castings – one part machined.

Bottom half of the spindle pulley with part turned belt grooves.

Static balance setup for static balancing of spindle pulley.

Reboring the overarm bracket for fit new overarm.

Milling trolley with castoring wheels and corner screw jacks.

Close up of a corner jack – note greasing nipple.

Jacking up the mill to enable trolley to slid underneath.

Trolley in place and mill bolted down.

from 1.75 to 1.825 inches, the overarm bracket to support the milling arbor had to bored out (**photo 20**). The red plastic bottle top is there to keep swarf out of the cross slide feedscrew.

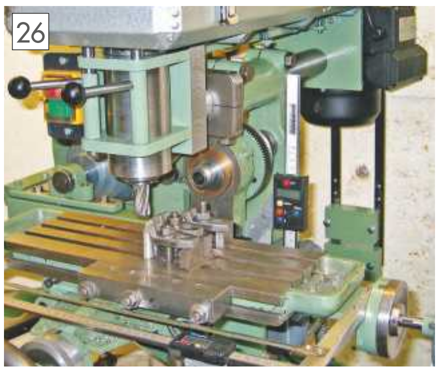
Due to limited space in my workshop, the milling machine must be able to be moved away from the wall when used in the vertical mode, as the whole vertical assembly has to be slid backwards so the vertical spindle is in a useable position over the milling table. A substantial trolley with four corner jacks was fabricated out of 2 x ¼ inch angle welded together, and four 125 mm diameter castors bolted on. **Photographs 21** & **22** show the finished trolley. The jack tubes are 1 x ⅛ inch thick square tube to keep swarf and dirt away from most of the jackscrews. (Note the greaser nipples to lubricate the jackscrews.) The screws are made from M12 threaded rod. Getting the trolley under the milling machine was a bit of a challenge as it weighs about ¼ ton. Judicious use of angle iron bolted to the front and rear of the base of the pedestal, enabled the whole lot to be carefully jacked up with 5 jacks (**photo 23**). Once enough height had been achieved the new trolley could be rolled into place, the mill lowered, and bolted to the pedestal. **Photograph 24** shows the final result. The pedestal is offset to the right, on the trolley to counteract the weight of the motor etc., on the left hand side. I guesstimated that the centre of gravity coincided with the left hand side of the pedestal. It's a bit heavy and awkward to wheel about, but very stable on its wheels. It is rock solid when the jacks are screwed down. Placing the mill on the trolley has raised it about 6 inches to a more convenient working height. The inspiration for the trolley was from Mick Knights' article about making a mobile stand for his hacksaw (**ref 4**).

A no volt release switch was mounted on the LHS of the vertical spindle head, and a belt guard was bent up from 0.040 inch (1 mm) thick steel sheet culled from an old plan file cabinet. The belt guard is slightly tapered from front to rear, and is made in two halves, the total length being about 3 feet. It also has 45 degree bevels on all edges to soften the outline (photo 26). This proved to be quite difficult to set out, especially at the front corners. So the whole thing was marked out full size on card. The front panels were cut out in card, bent up and stuck together to understand how the steel would have to be cut and bent. In fact the front panels overlap the bevels of the top and base panels. The whole thing was then pop riveted together. A piano type hinge was also obtained from the plan file cabinet, and is riveted on the left hand side. Strips of car inner tube were cut and stuck on the meeting edges with double-sided adhesive tape to stop any rattles. For fixing, the belt guard has three lengths of galvanised 15mm square steel tube riveted on the under surface (**photo 29**). Fixing to the 1.5 x 0.750 inch rectangular tube, which supports the swinging arm pulley, is by M5 screws through the 15mm tubes into ⅛ x ½ inch flat strips below the rectangular tube. It has to be demountable to use the horizontal mode for turning large diameters.

Bending up the belt cover guard.

The sheet folder was a double sized version of the one featured in the article by Jayne Reeve in *MEW* in 2009 (**ref 5**), but lengthened to take 20 inches (500 mm.) I wouldn't want to use it on steel more than 0.040 inch (1 mm thick.) Even so, the folder had to be beefed up to prevent undue bending around the hinges, by welding end plates onto the angle iron. **Photograph 25** depicts one of the completed 45 degree bends. **Photographs** 26 & **27** show the finished belt guard pop riveted together. In the background are lead counter balance weights attached to two straps bolted to feet fixing points on the back of the motor. These are needed, as the whole vertical assembly is somewhat top heavy. **Photograph 28** shows a laminated chart of the spindle speeds fixed inside the beltguard cover. The spindle pulley is on the left, and the motor pulley to the right.

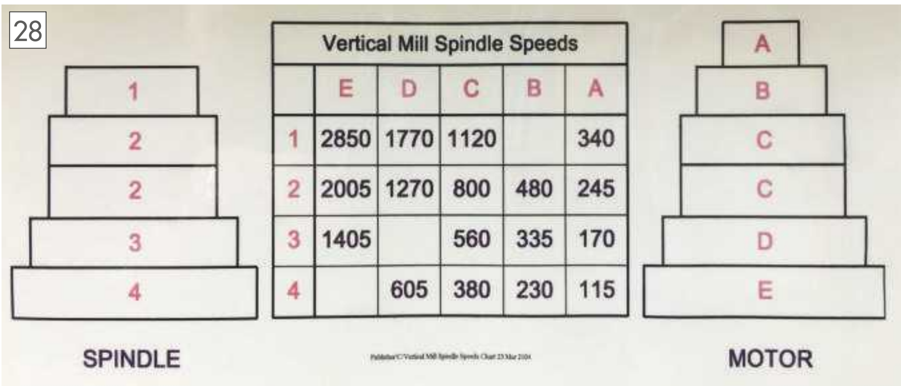
The two levers with black plastic knobs on the front of the vertical head (photo 26) are, on the left hand side, for a spindle lock which operates by being lifted about ¼ inch and the top registers in one of eight



Finished belt guard.

27

Belt guard with spindle speed chart.



28

	E	D	C	B	A
1	2850	1770	1120		340
2	2005	1270	800	480	245
3	1405		560	335	170
4		605	380	230	115

Vertical spindle speeds chart. Motor on RHS, spindle on LHS.

slots in a steel ring in the underside of the spindle pulley (**photo 30**). The other lever is a hand brake with a beech brake block bearing on the inside of the pulley. The pivot point is offset so there is a sort of cam action when the brake is applied. Both features are part of the original design by Mr Wilson and work well in practice.

Initial setting of the head vertically is done by setting an engineer's square against the flat side of the bracket plate, (**photo 31**). This is quite accurate, but final setting is achieved with a DTI or Protram mounted below the vertical spindle. There is some slight play around the M8 Allen screws which hold the vertical assembly clamps to the bracket plate. So some careful repositioning before retightening the Allen screws will hopefully eliminate any slight misalignment in the vertical sense. If the head vertical axis is not parallel to the front face of the milling machine upon which the knee slides, (the z-axis), then one or other of the clamps holding the vertical spindle assembly can be adjusted with shimstock.

The whole vertical milling head assembly is removable in order that large diameters can be turned in the horizontal mode (photo 10). This necessitated having I.E.C., plugs and sockets in the electrics close to the motor, as the motor together with its hinged mounting plates have to be first detached from the rear of the overarm, before the rest of the vertical assembly can be removed, (**photo 32**).

Other improvements to the mill included adding DROs to the table (x axis) (**photo 33)**, and to the vertical axis, (z axis) (photo 6). You should be able to make out a strip of Perspex to keep swarf off the horizontal DRO in photo 33. Also visible in this photo is a front extension to the milling table to enable clamping of wide items, such as the machine vice. It is 6 x 1½ x 1 inch. The table is only 14 x 5 inches. I have yet to devise a DRO arrangement for the fore and aft movement of the table, the y-axis.

Conclusion

It has taken two years with interruptions to complete this modification, at modest cost. I now have a combined horizontal and vertical milling machine, which only takes up floor space for one machine. There is no way I would be without the horizontal facility. The motor was the most expensive item, followed by the taper roller bearings, the Poly-v belts, and the no-volt release switch. Much of the rest was 'ex stock'. In use, the vertical mill has come up to my expectations. End milling is much stiffer than end milling in the Myford lathe, even with a substantial vertical slide (photo 9). The Myford vertical slides are only suitable for very light milling as the mounts are insubstantial, particularly that of the swivelling vertical slide. ■

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1. 'A vertical milling head.' by J.M.Wilson, U.S.A. *M.E.* 3731, p.708, and 3733, p.93.
2. Imperial Timken taper roller bearings LM29749/LM29710, 1.500' x 2.5625' x 0.710' from Simply Bearings Ltd, web: www.simplybearings.co.uk
3. Electric Motor Man, web:www.electric-motor-man.co.uk.
4. 'Making a bespoke power hacksaw stand.' by Mick Knights, *MEW* 167, p.26.
5. 'A sheet metal folder', by Jayne Reeve, *MEW* 153, p.14, & 154, p.13.

29

Method of fixing belt guard to a rectangular tube.

30

Steel locking ring on underside of spindle pulley.

31

Initial setting spindle vertical with a square against the bracket plate.

32

I.E.C plugs and sockets to enable vertical head to be easily removed.

33

X axis DRO with Perspex swarf guard.

An Arduino-Based Screwcutting and Leadscrew Drive

Arduino microprocessor boards have become popular building blocks for many workshop projects. Bob McMenemie describes the screwcutting system he has made using one.

This control unit can be used for automatic screwcutting of practically any thread with reasonable accuracy or positioning of the lathe saddle with a range of speeds for positioning or finish cutting.

1

The Atlas Lathe.

Some history

The unit was built a number of years ago with the intention of saving an old Atlas lathe destined for the scrapheap, it had a worn out leadscrew and no backgearing, without which finish turning or screwcutting is not possible (**photo 1**).

Since it was quite old I didn't really want to spend too much on the project and I obtained quite cheaply a 20mm diameter stainless steel threaded rod of 2.5mm pitch and fitted it to the lathe. I was surprised ! It worked quite well with the clasp nut I made for it fitted with a spring Bulldog clip which stopped it popping open (**photo 2**).

Ball screws?! ... who needs Ball screws?

Leadscrew drive

The lathe worked quite well and so I made a stepper motor drive controller using an Arduino to provide drive pulses for a CW8050 microstep driver.

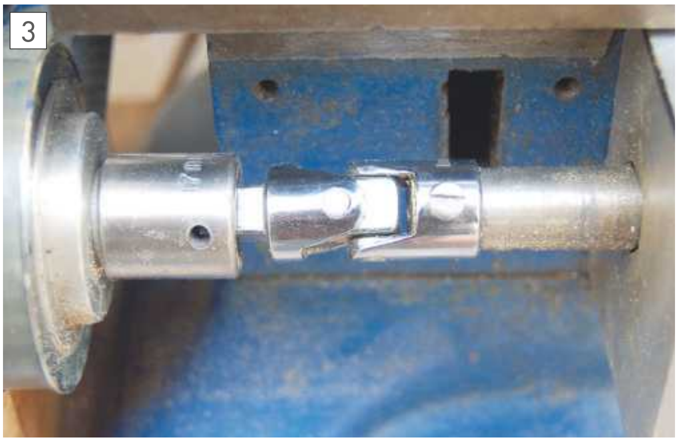
The Arduino is used for manual control only and uses the Arduino 'Tone' program to produce pulses of up to 20kHz with a switched potentiometer to control leadscrew speed.

The leadscrew drive from the motor is belt driven with a 10 tooth gear to a 40 tooth gear which can be connected to the leadscrew with a simple clutch and universal joint made from a spanner socket set universal joint (**photo 3**). The 3.1Nm stepper motor I used objected to driver pulse rates above 14kHz, which with the driver microstep set at 16 represents 875 steps per second which equates to about 262rpm as the motor rotates once for every 200 steps.

To be precise as to what 'pulse rate' or 'pulse frequency' means, this is the number of complete ON, OFF cycles per second and this maximum of around 14kHz needs to be considered when working out the pulse rates for the spindle.

2

The bulldog-clip leadscrew nuts.



3

The leadscrew drive arrangement.

The spindle belt drive.

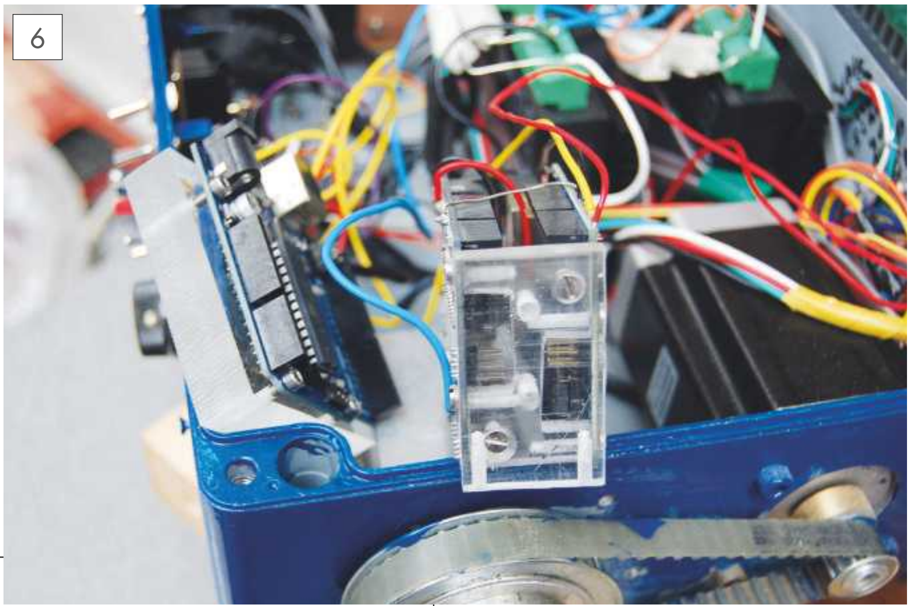
The control box.

Screwcutting drive

The Spindle motor is connected by belt drive through an 18 tooth gear to a 72 tooth gear (**photo 4**). The Arduino drive is built into a box at the left hand end of the lathe (**photo 5**).

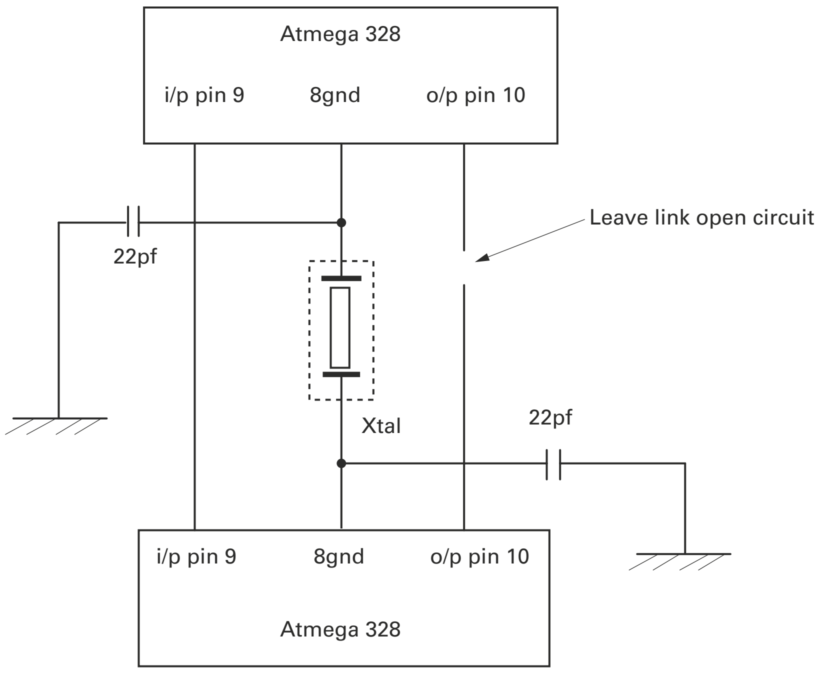
The basic idea of threading is to have the leadscrew in some relative motion synchronised to the Spindle, the problem is solved in a normal lathe with gearing; Using this method with two separate motors, the problem of how to keep them in step is solved by using two Arduino boards synchronised with a common 16 Mhz crystal circuit.

This means that one board has to be modified and its 'xtal' output connected to the other, there are perhaps other methods of synchronising Arduino's I am sure, after much deliberation I thought I would give it a go and see what happens.



The Arduino units.

Fig. 1



Connecting A Common Xtal To Two Arduino Boards

This an unorthodox method and although it is a simple procedure it needs someone with good soldering skills as the crystal or resonator on one board has to be removed and wires soldered to the common grounds and crystal inputs of the Atmega 328 IC's on the boards (**fig. 1**).

I decided to use the cheapest boards I could get in case I made a mess of it! In the end I used three boards, to give me manual feed control as well, fig.2.

The Arduino's I used were fitted with a resonator, it is good practice to make the leads required to connect the inputs together as short as possible. I kept them to about 1inch and the boards are mounted with the components side facing each other.

Well it did work, and I had an oscilloscope to show it, I could also see that the simple 'Blink' program from the two boards was producing synchronised flashes from the LED's which did not vary in synchronism over time (**photo 6**).

The screwcutting program

Another 'unorthodox' method is used for setting the spindle/leadscrew speeds; using the 'Blink' program a range of suitable pulse frequencies for the motor drivers can be obtained.

Those familiar with the Arduino will recognise the very simple Blink program, it can switch a pin on the board ON & OFF with a set time period in milliseconds or microseconds.

The method uses one fixed delay period for the Spindle driver, but the board controlling the Leadscrew driver can have different ON & OFF times, and the average value of these periods combined with the set Spindle time period are selected to give as near as possible the Spindle/ Leadscrew ratio for the thread required.

A problem arises when wanting to cut imperial threads with a metric thread leadscrew, the spindle/leadscrew pulse ratio will most likely be a number with producing a pulse time with numerous decimal places, and some metric threads will also produce difficult ratios to emulate.

Don't forget that once the Pulse time/s have been found and shown to work, it is stored in the Arduino file ready to be used again, one more thing; do not use any other instruction in the 'loop' such as 'println' this will upset the timing periods and cause errors.

Selecting thread ratios and pulse times

With the synchronisation problem out of the way the data needed to produce the right relative speeds using spindle and leadscrew driver pulses are:

1) Leadscrew pitch.
2) Required pitch.
3) A suitable spindle speed for screwcutting.
4) Driver microstep settings.

1 and 2 are known, 3; the spindle speed I use is about ½ spindle rotation per second, and item 4; a Driver microstep setting of 16.

With 200 motor steps per rev and a spindle gear of 4:1 calculation shows a pulse cycle time of 156 microseconds as below:

One Spindle rotation per second requires 16 x 200 x 4 = 12800 pulses.
This is ½ x 12800 = 6400 pulse cycles for ½ a rotation per second.
And equates to a cycle period of 1/6400 sec = 156 µsec
So that each Pulse Time ½ x 156 = 78 µsec

That is, each ON pulse and each OFF pulse is 78 microseconds.

I have rounded this to 80microsecs which seems to provide many whole numbers for various types of threads, but this can be altered to produce ratios with suitable decimals.

In order to find the leadscrew pulse delay times for the Blink program with a spindle pulse time of 80microsecs the calculation is as below:

(Leadscrew pulse time) µsec = (Leadscrew pitch x 80 µsec)/Required pitch
For example if your leadscrew pitch is 2.5mm
and required pitch is 8tpi = (3.175mm pitch)
(Leadscrew pulse time) µsec = (2.5 x 80) /3.175 µsec
= 62.992 µsec

This is rounded to 63 µsec and so the ON and OFF delay times in the program are set to this value, I have tried it, and it works with no measurable errors in the thread over a 2 inch length (**photo 7**).

Ah! I know what you are thinking, that period 62.99 µsec was a lucky outcome!, true it was; so let's try a not so lucky period. For example, if the required thread is 12 tpi, it turns out that the LS pulse is 94.3396 µseconds.

I can round this to 94.3 µsec without worrying too much about errors.

I could set the ON period to 94 µsec and the OFF period to 95 µsec as there is no setting for periods less than 1 µsec, the average value would then be 94.5, which is near to 94.3 ...but not quite.

An even better way is to use TEN periods, nine of which are 94 µsec and one of 97 µsec, and although this will work it can be even more refined by having Seven periods of 94 µsec and Three periods of 95 µsec, this idea helps in creating a smoother pulse drive, and actually gives the 94.3 µsec on average.

To check this... get your calculator out, blow the dust off it, and try:

(9 x 94) + (1 x 97) = 943 and if you average out by dividing by 10, = 94.3.
Or using the more refined method:
(7 x 94) + (3 x 95) = 943 ... and again the average over 10 pulse times = 94.3.

Please note that in the above for example these are the actual ON & OFF pulse times.

Using this idea any time period within 0.1 µsec can be produced, the idea can be extended even further to get within 0.01 µsec but in practice I don't think it is necessary.

The unit was built a number of years ago with the intention of saving an old Atlas lathe destined for the scrapheap, it had a worn out leadscrew and no backgearing, without which finish turning or screwcutting is not possible.

7

Arrangement for testing the pitch.

Operating the drives

There is some skill attached to the operation of screwcutting using this system.

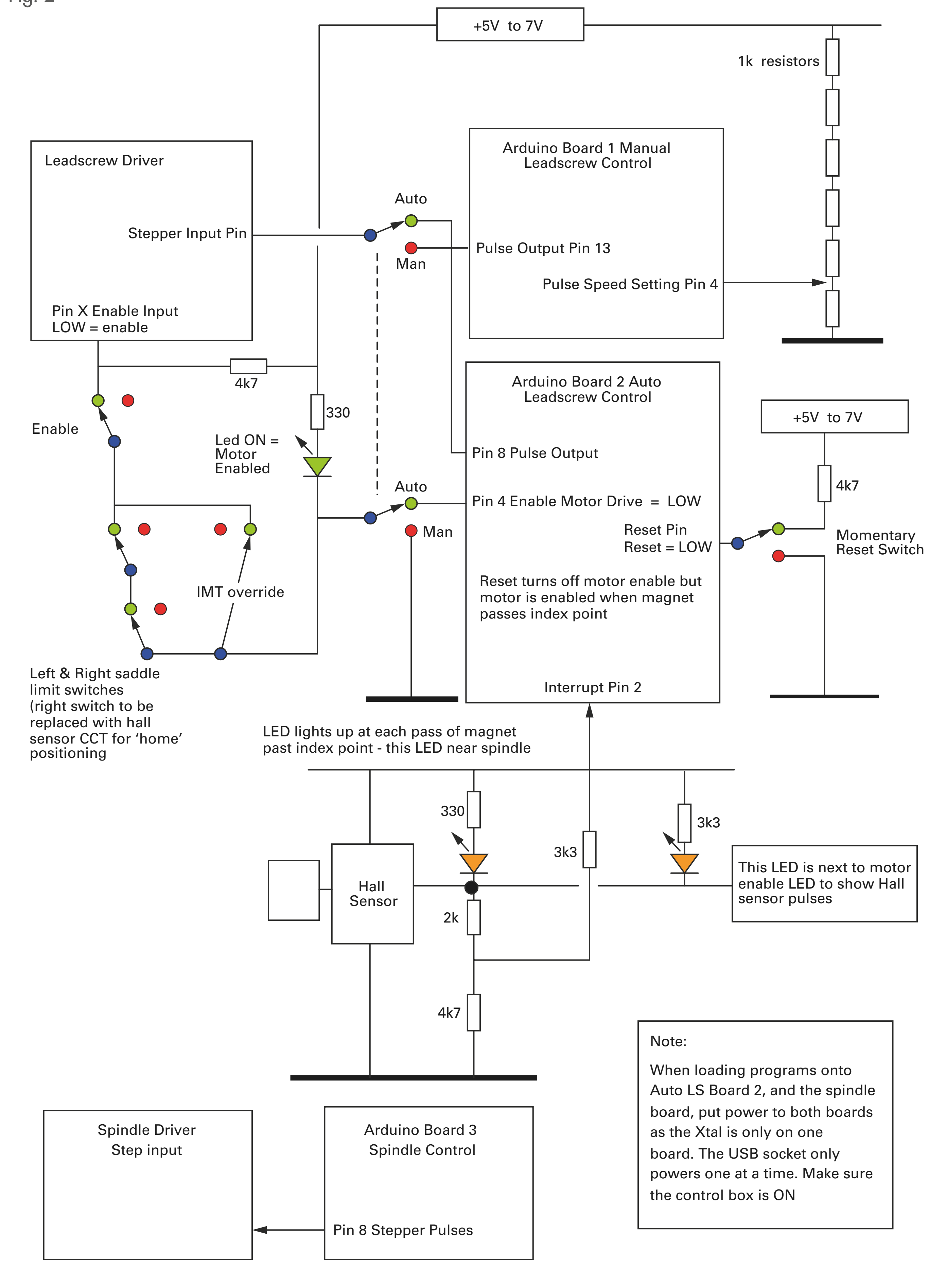
One of the main concerns is slack in the leadscrew mechanics which has to be taken up before cutting commences. The cutting tool is put past the thread start position using the Manual speed control; with slack taken up by reversing the leadscrew motion. The tool is taken to the start position on the work and a pointer on the leadscrew handle shows its angular position which is noted and used when the tool is re-set for following cuts, this puts the tool at exactly the right start position.

The skill is in stopping the leadscrew rotation at the right point and a very slow Manual Leadscrew speed helps in this.

The screwcutting starts when the spindle reaches a certain point as determined by a Hall effect sensor at the index point; just after passing this point, the leadscrew enable reset switch is thrown and just afterwards the leadscrew motor switch enabled; when the spindle moves to the index position an interrupt signal actuates leadscrew control pulses and the leadscrew starts up immediately.

There is more to be said about the setup and the programs but I think the main points have been covered which will provide enough material for an understanding of how the unit works, I have provided circuits and some Photographs which may be of interest. ■

Fig. 2



+5V to 7V
1k resistors
Leadscrew Driver
Stepper Input Pin
Pin X Enable Input
LOW = enable
Arduino Board 1 Manual
Leadscrew Control
Auto
Man
Pulse Output Pin 13
Pulse Speed Setting Pin 4
4k7
330
Enable
Led ON =
Motor
Enabled
Arduino Board 2 Auto
Leadscrew Control
+5V to 7V
Pin 8 Pulse Output
4k7
Auto
Pin 4 Enable Motor Drive = LOW
Man
Reset Pin
Reset = LOW
Momentary
Reset Switch
IMT override
Reset turns off motor enable but
motor is enabled when magnet
passes index point
Interrupt Pin 2
Left & Right saddle
limit switches
(right switch to be
replaced with hall
sensor CCT for 'home'
positioning
LED lights up at each pass of magnet
past index point - this LED near spindle
330
3k3
3k3
Hall
Sensor
2k
This LED is next to motor
enable LED to show Hall
sensor pulses
4k7
Note:
When loading programs onto
Auto LS Board 2, and the spindle
board, put power to both boards
as the Xtal is only on one
board. The USB socket only
powers one at a time. Make sure
the control box is ON
Spindle Driver
Step input
Arduino Board 3
Spindle Control
Pin 8 Stepper Pulses

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90mm 90° Capacity
0.54HP Motor
£195 inc vat
Model B Lathe/Mill/Drill
520mm Between centres
420mm Swing over bed
£989 inc vat
Century Mill
400mm Vertical travel
600x180mm Table size
£1086 inc vat
DB7VS Lathe
300mm Between centres
180mm Swing over bed
£699 inc vat
626 Turret Mill
320mm Spindle to table
660x152mm Table size
£2364 inc vat
Conquest Super Mill
270mm Spindle to table
460x120mm Table size
£547 inc vat
Conquest Lathe Imperial
300mm Between centres
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