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DECEMBER 2015

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A Vice End-Stop

COVER FEATURE

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Andy Clarke reports from the World Maker Faire

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On the Editor's Bench

I'm sure that all readers of *MEW* will join me in offering sincere sympathies to our readers in France and anyone else affected by the terrible events in Paris.

This month highlights of my workshop activity have both been in the workshops of other people! I was fortunate enough to visit David Piddington, I plan to return to further pick his brains and share some of his wonderful experiences with readers.

My other visit was to the fabled 'Bodger's Lodge', where I received an introductory course in MIG welding from John Stevenson. We both agreed that I am not quite ready for Rolls Royce, but progress was made! It turned out that the main problem I had been having was because I hadn't pushed the gas pipe all the way into the fitting and most of my shielding gas was just contributing to the greenhouse effect and not my welding!

As my article explains I was able to figure out how the machine should work on my own, but was not getting the sort of welds I had hoped for. But once I handed the machine to John, he had me up and running in minutes and left me to practice.

There's a serious point here – an awful lot of readers are 'lone hands' and many of them are largely self-taught. But every so often we all come across problems or barriers that need no more than a bit of advice or a gentle tweak on the controls. We all need a bit of help at times, and sometimes there's no better solution than hands on guidance.

So whether you're a horny handed veteran engineer or a total newbie, if you are struggling, don't be afraid to ask for help, whether that's through a forum like www.model-engineer.co.uk, calling on a fellow hobbyist or going along to your local club.

SNEAKING ONE IN

Having spotted a couple of workshop tool builds in *Model Engineer* recently, I'll get my own back with a gratuitous picture of one of the favourite locos for visitors to the Bluebell Railway in Sussex. This is *Captain Baxter*, an 0-4-0 tank locomotive of diminutive size. The locomotive was originally used by Dorking Greystone Lime Works. Numbered 3 the little tank loco was built in 1877 by Fletcher Jennings & Co. at their Lowca Works in Whitehaven.

The loco was joined the Bluebell Railway in 1960, was restored for 1982, and was fully overhauled in 2005, and it is now capable of hauling small passenger trains. A wonderful little chunk of the past.

I find it hard to believe, but I took this photo back in the spring of 1989 when I had two weeks off between jobs! The film used was Fujichrome Velvia, a wonderful transparency film, which shows incredible detail. This was taken with my lovely old Pentax SP1000 using an unbeatable Helios 58mm lens from a Zenit TTL.

F MODELLING…NOT TO BE MISSED!

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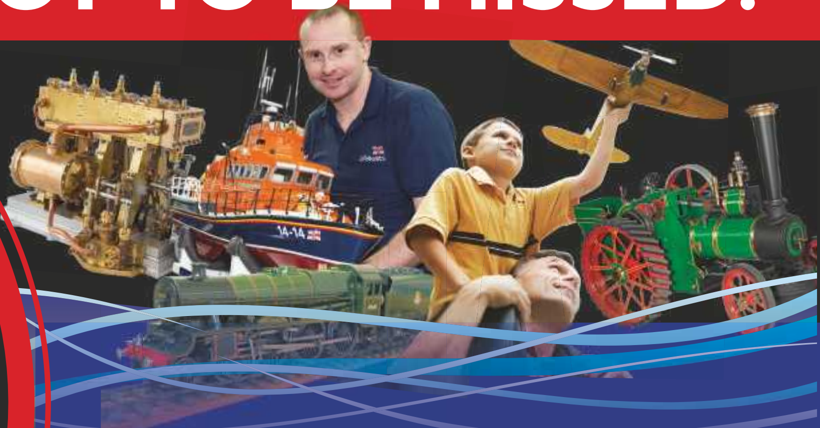

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Contents

Coming up...
in the January issue

GOING ROUND THE BEND
Stuart Walker revisits and updates a pipe bender first described in *Model Engineer* in 1947.

PLUS Richard Gordon shows how to make a handy set of precision parallels, Geoff Walker shares the story of his Drummond Lathe and some Gold-star work with Marcus Bowman.

Regulars

ON THE COVER

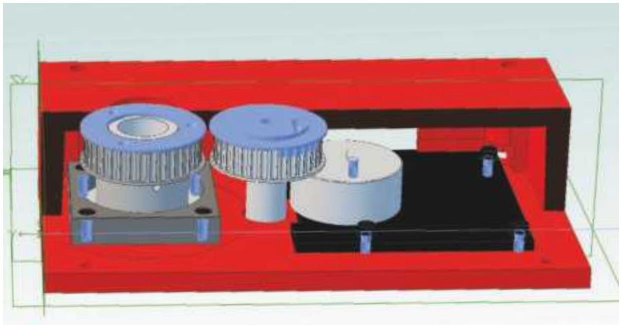
Held in New York each year, the World Maker Faire is an explosion of practical ingenuity and creativity, Andy Clark snapped this huge robot at the event.

HOME FEATURES WORKSHOP EVENTS FORUMS ALBUMS

Visit our Website
for extra content and our online forum

www.model-engineer.co.uk

The X3 Mill Gearbox
Download pdf files with fully rotatable 3D diagrams that accompany this month's article by David Thomas on a belt drive conversion for his X3 mill. You only need Adobe Acrobat to view the files, no fancy software required!



Other hot topics on the forum include:

- **What is the most useful workshop tool you have made?**
  Share yours and pick up some inspiration form other people's tools.

- **6 inch Ruston Proctor Traction Engine**
  It's a live steam model build not a workshop tool, but *MEW* contributor Paul Lousick demonstrates some very interesting big machining operations in this thread.

- **Acute (a cute?) Tool Sharpening System**
  Following our recent review, follow John Haine's detailed build from the Eccentric Engineering kit.

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CVR125B	125mm	Swivel	£29.98	£35.98
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CBB210B	10 Dr Chest	710x315x475	£139.98	£167.98
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A Vice End-Stop

Mike Checkley describes a neat accessory to aid repeatability and precision with milling vices.

Have you ever removed a part from the vice only to realise that you had not yet finished or it needed to go back in the vice in the same position for a second machining operation?

Adding an endstop to any vice is a simple addition that can save time and frustration during the fixturing of a component that requires multiple operations.

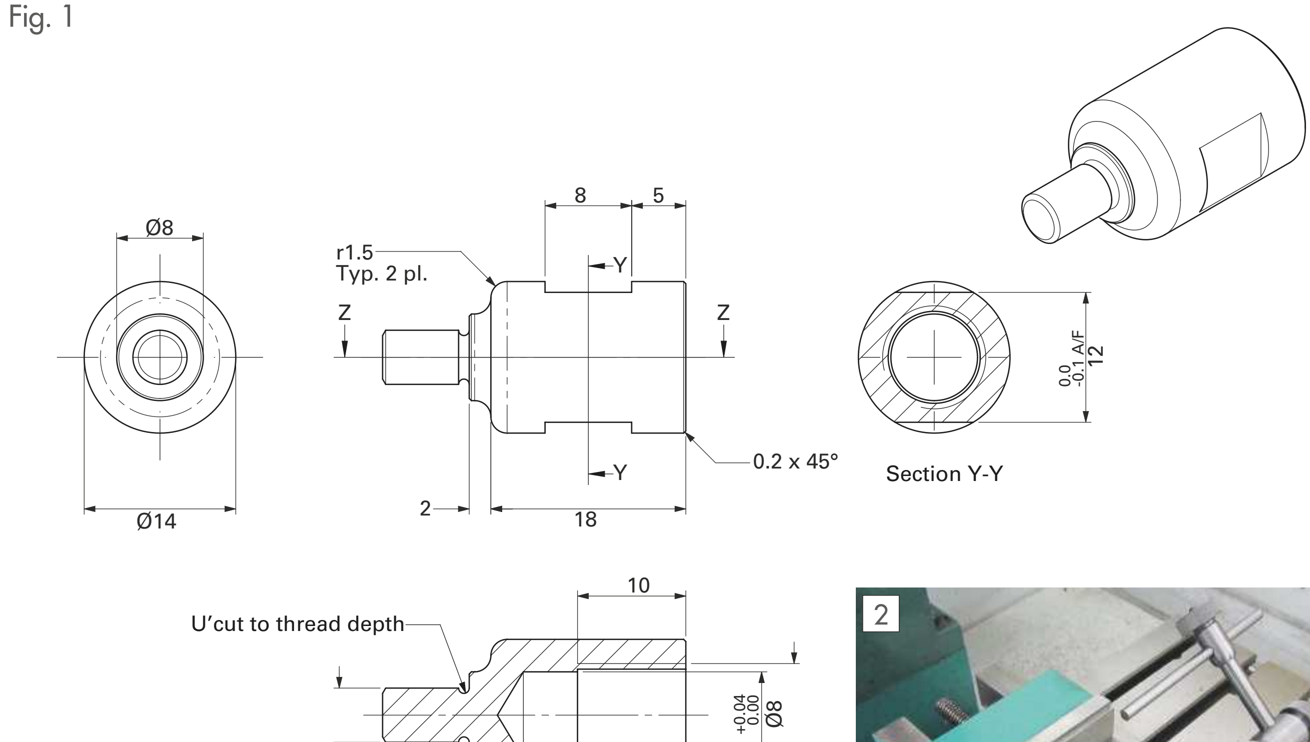
This endstop consists of 9 parts (**photo 1**) all made from silver steel. Silver steel was chosen because stock bar has an accurate outer diameter meaning that little finishing is required and I currently I have a good selection of sizes in stock. All parts can, of course, be made from any stock material/size that suites your application, stock or scrap bin!

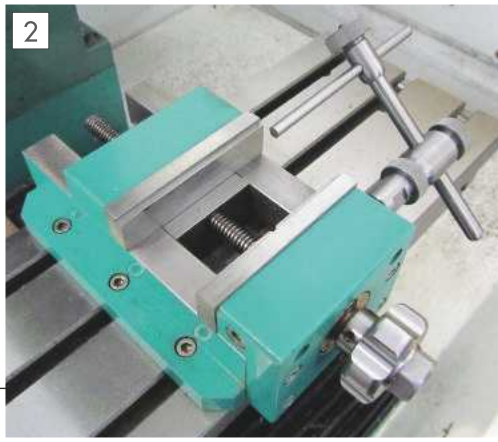
Working from the mounting end the first part, the pillar (**fig. 1**), provides a means of attaching the endstop to the vice at one end and allows angular adjustment of the endstop relative to the vice (**photo 2**) at the other. This part is quite small once cut to length and does not provide much land to hold for machining the spanner flats so I decided to machine these flats first. Chuck a piece of 14mm silver steel bar in a dividing head on the milling machine and mill the flats to suite a 12mm spanner. The flats do not require great accuracy so the bar could be clamped on a V block and rotated 180 degrees by eye but I had the dividing head on the mill already so it made sense to use it.

In the lathe, chuck the bar and turn one end to 5mm diameter 8mm long ready for cutting an M5 thread. Turn an 8mm diameter shoulder 2mm deep on to this

Collection of parts.

Fig. 1





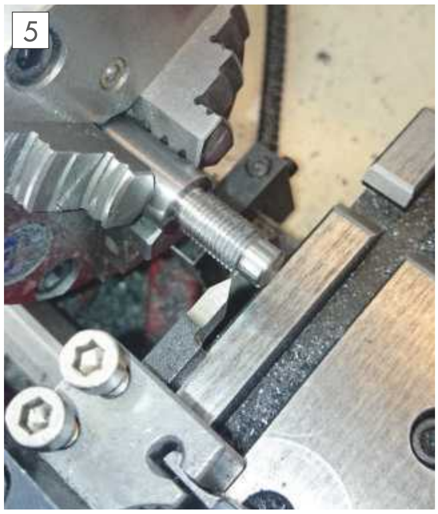
Endstop fitted to vice.

newly machined face, a nice radius here will improve the usability of the endstop as with most things that require adjustment there are fingers and thumbs everywhere and the last thing we want is sharp edges (**photo 3**). Cut the M5 thread and undercut the root to thread depth to ensure the part can thread all the way in to the vice body. Reverse the part in the lathe chuck and drill and tap for ⅜-24UNF 10mm deep, this thread provides one-half of the mating parts that allow the endstop to rotate. A finer thread is best and I chose this thread simply because the tap was close to hand. Still in the lathe drill and bore to a diameter of 8mm and 5mm deep, beyond the depth of the thread. This bore provides a locating feature for the mating part and its purpose is better explained during the description of the machining of the swivel post. Add a chamfer to the outer diameter and clean up any burrs.

The swivel post (**photo 4** and **fig. 2**) is the most complicated of the set and provides the other half of the rotation feature and the ability to clamp the Y-axis rod. Using the same 14mm stock bar start by drilling the 8mm hole through the bar, remove any burrs and chuck the bar in the lathe. Turn to 5mm diameter 16mm long ready for cutting the M5 thread, this thread is for the clamp and therefore an undercut is not required. Cut the M5 thread and round the end to remove the sharp edge. Add a small chamfer to the newly machined face, remove from the lathe and cut to length. Chuck the bar back in the lathe but flipped around and turn to ⅜ inch diameter 21mm long ready for cutting the ⅜-24UNF thread. This end of the part also features an 8mm diameter location spigot, which once machined fits smoothly within the bore of the mount. The purpose of this feature is to retain some support and location of the part when the locking nut is undone for angular adjustments. Just relying on the thread would mean the endstop assembly 'flops' about when the lock nut is loose making fine adjustments more difficult. Turn the thread undercut and cut the ⅜-24UNF thread. I decided to thread cut the ⅜-24UNF thread (**photo 5**) as it allowed me to make fine final cuts so I could get a well fitting thread in to the post, again to try to remove as much play as possible between the mating parts. Add a chamfer to the 14mm diameter and clean up any sharp edges.

Rounded off edges of the pillar.

Swivel post on its own.



⅜-24UNF thread cutting.

Fig. 2

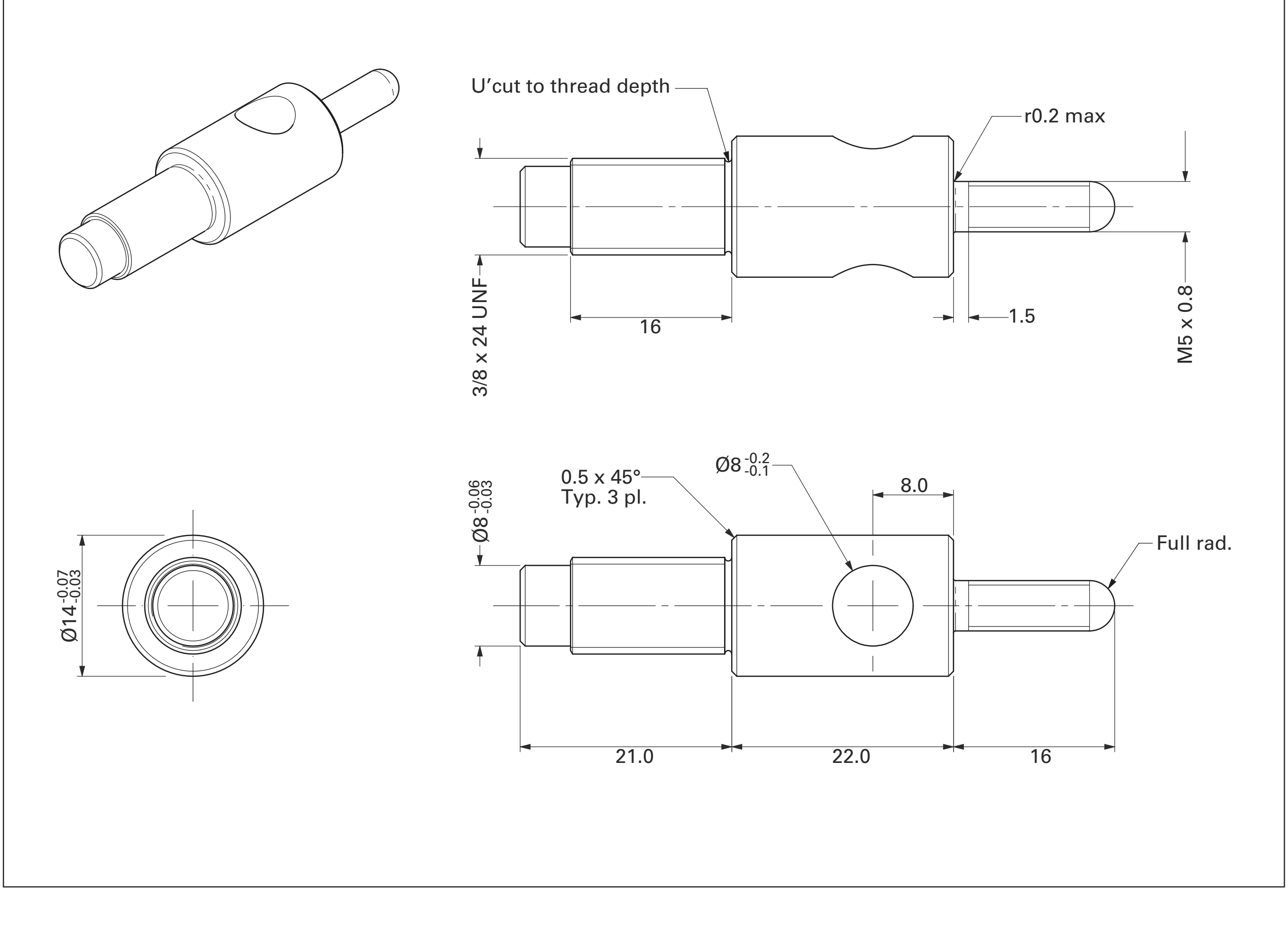


Fig. 3

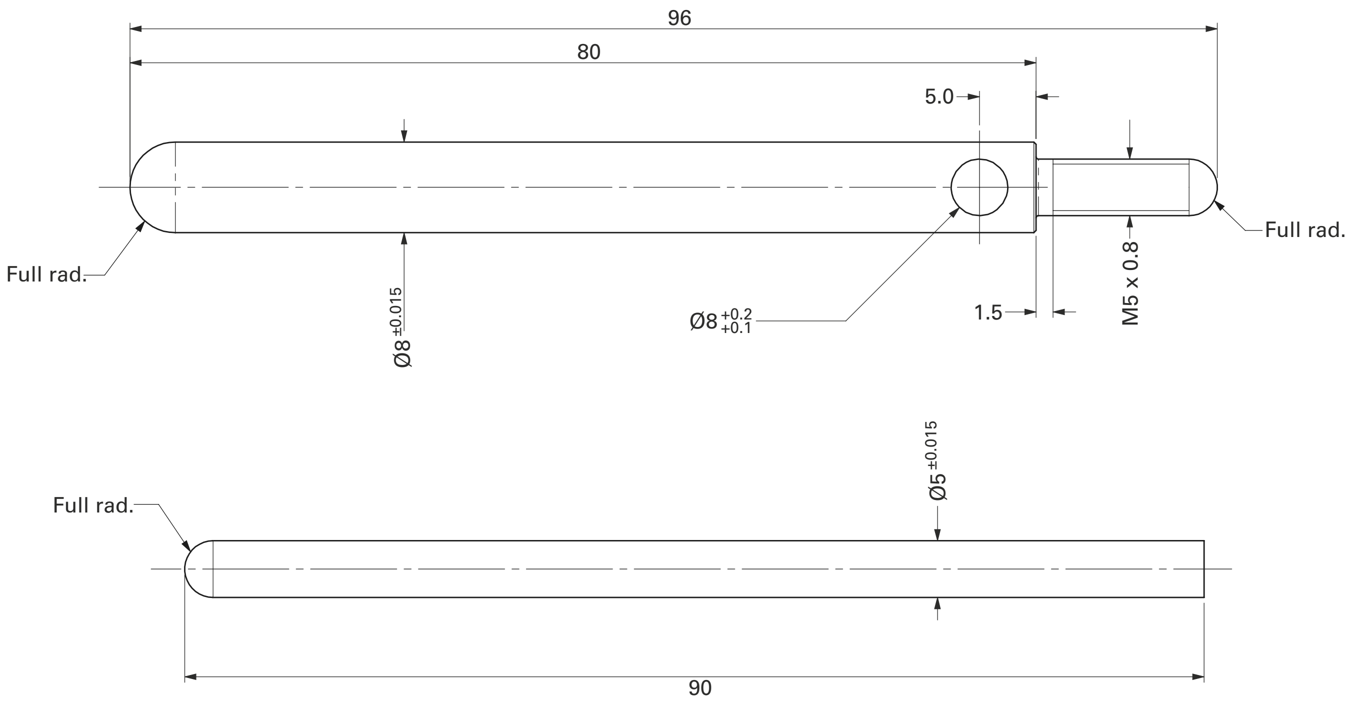
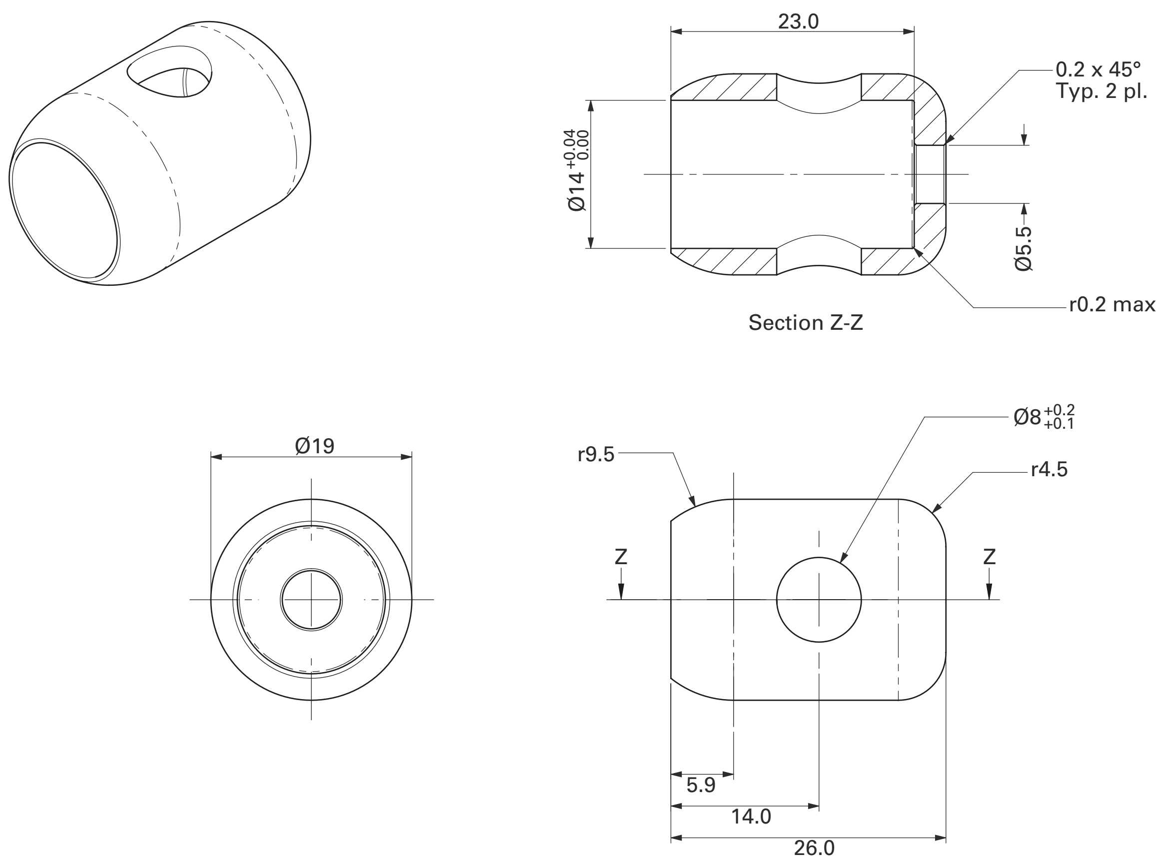

96
80
5.0
Full rad.
Full rad.
Ø8 ±0.015
Ø8 +0.2 +0.1
1.5
M5 x 0.8
Ø5 ±0.015
Full rad.
90

Fig. 4


23.0
0.2 x 45°
Typ. 2 pl.
Ø14 +0.04 0.00
Ø5.5
r0.2 max
Section Z-Z
Ø19
Ø8 +0.2 +0.1
r9.5
r4.5
Z
Z
5.9
14.0
26.0

The Y-axis rod (**fig. 3**) requires the most machining of the two rods as it has the features necessary to provide a clamp for the X-axis rod. The rod is made from 8mm stock bar, chuck the bar in the lathe and turn down to 5mm diameter 16mm long. Cut the M5 thread and round off the end face with a full rad. No undercut is required on this thread as the position of the clamp steps the lock nut away from the finish of the thread. Remove the bar from the lathe and cut to length. The length of the rod can be whatever you like and the length shown in the drawing is as big as I could make it on my machine vice before it would exceed the maximum opening of the jaws. Chuck the rod in the lathe and turn a full radius on the freshly cut end. A 5mm hole is required 5mm from the clamping end face to allow the X-axis rod to pass through. Drill the hole, check the 5mm stock material passes through freely, and remove any sharp edges that might inhibit a smooth sliding on of the 5mm clamp.

Now would be a good time to make the X-axis rod, fig. 3, especially if you use any radius turning attachments to machine the full rad on the end of the rods. The X-axis rod is a plain rod with a flat face on one end for locating up against the part clamped in the vice and a radius on the other end to break the sharp edge. The length of the rod was chosen as this caters for the furthest away that a small part could be clamped in the vice away from the side of the vice on which the endstop is mounted.

The 8mm clamp (**fig. 4**) (named by the diameter of the rod diameter it clamps) is machined from 20mm stock material. Chuck the bar in the lathe and turn the outside diameter down to 19mm. Drill, and then bore to 14mm diameter 23mm long, this bore should be a sliding fit over the 14mm diameter outer diameter of the swivel post. To help with concentricity (although not essential for this feature as it is a clearance hole) drill the 5.5mm diameter hole about 5mm deep. This depth will be sufficient to leave a thru hole once the part is cut from the stock bar. Chamfer the bore and radius the outer diameter edge. The type of radius you add here is simply aesthetic and all that is required is that the sharp edge is removed. Either part-off in the lathe or, if your parting off skills are as limited as mine, remove the bar and free the clamp from the bar stock using a hacksaw. Chuck the clamp back in to the lathe and clean up the face and radius the outer corner.

The 5mm clamp (**fig. 5**) is identical in design to the 8mm clamp so there is no need to describe the machining of the 5mm clamp. To limit tooling swops and fixture setup I made the 8mm and 5mm clamps consecutively, both are compared with each other in **photo 6**.

All that remains to complete the set of parts are three knurled nuts (**fig. 6**) to allow for finger tightening of the clamps. The design of the nuts is very much up to the builder and knurling can be replaced with finger grips or spanner flats. I went

Two clamps together.

for a knurled finish as it allows for fast adjustment without additional tools.

The knurled nuts that secure the clamps are identical in design and made from 20mm stock material. Chuck the stock bar in the lathe and drill and tap M5 to about 10mm deep, this will be sufficient to provide a thru hole when the nut is cut from the bar. Turn a shoulder on the face of the bar, adding a nice big corner radius, and chamfer the outer edge, part-off or saw the nut from the bar. I made an arbor to allow me to mount the nut back in the lathe to machine a large radius across the face and a chamfer on the outer diameter.

Fig. 5

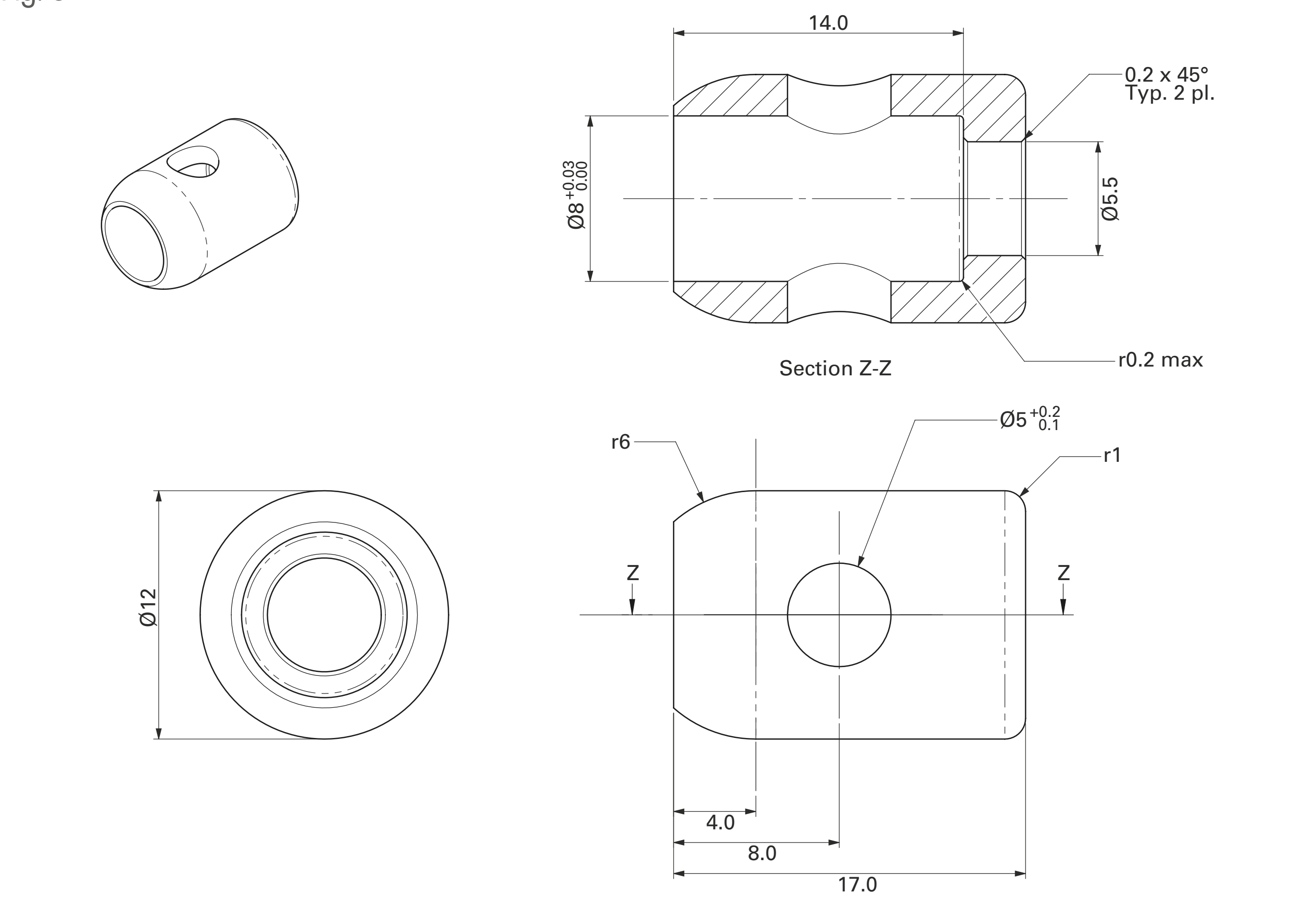
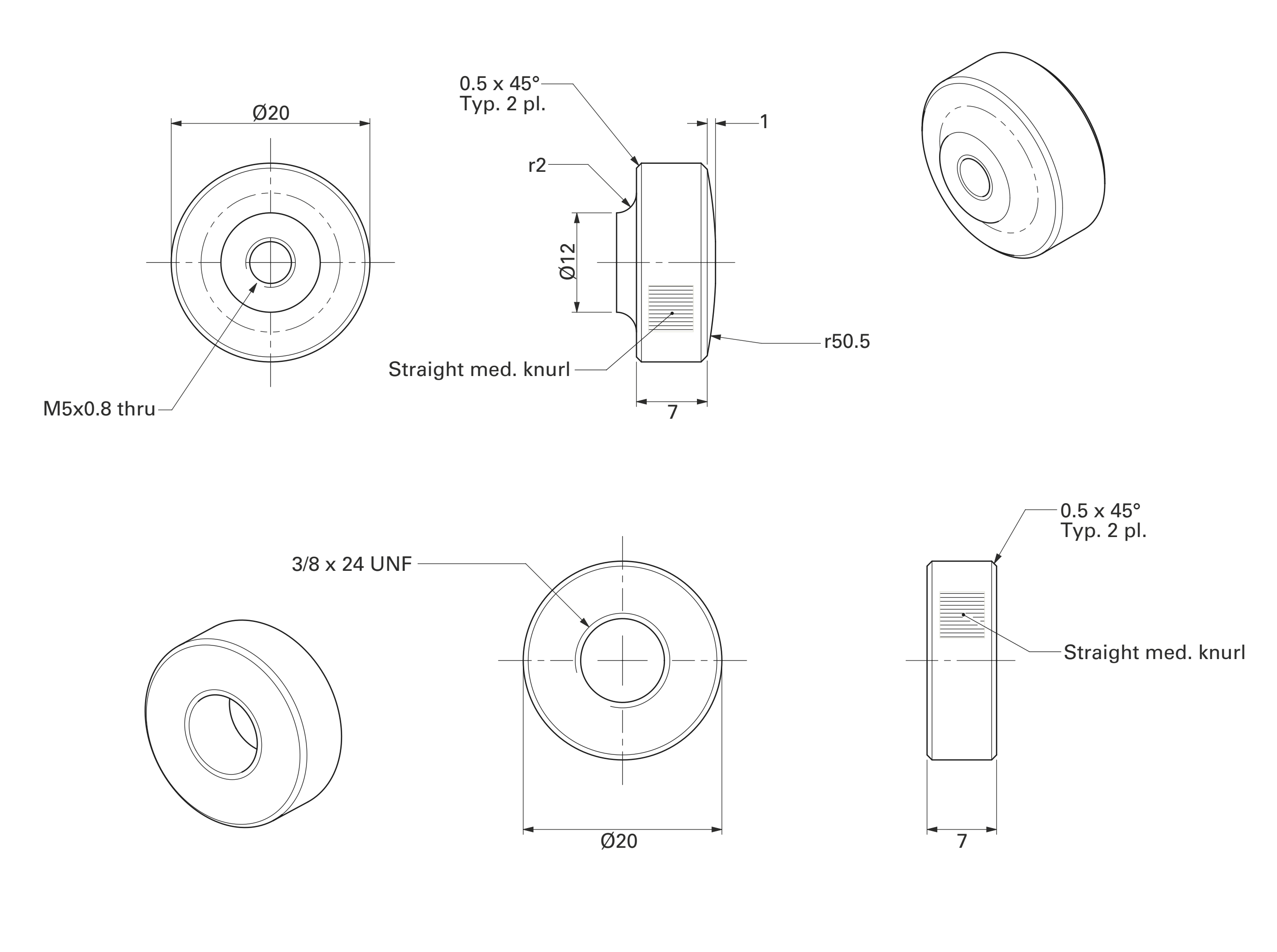


Fig. 6



These features are again just aesthetic but make the endstop nicer to use and adjust.

You may have noticed that I have not yet mentioned the knurl! Knurling is something that I have not quite mastered yet and does not appear to be coming easily to either myself or my lightweight equipment. After a couple of attempts and to keep the job progressing (I wanted to have the endstop fitting to the vice before the Midlands Model Engineering Exhibition which was a couple of days away!) I decided to cheat and machine the knurled finish using the mill using the 4th axis and a 45 degree cutter. This produced a nice clean finish and felt like a good grip for tightening and undoing.

The third knurled nut is the odd one out and has a ⅜-24UNF thread to thread on to the swivel post. Both sides are faced off square with no fancy radii and just a chamfer on either side of the outer diameter to break the sharp edge. Assemble the parts as shown in **photo 7** and mount to the vice. If you have drilled and tapped both sides of the vice then you can mount the endstop to either side depending on the part being machined and which side of the part upon which you can find a convenient reference face or edge. ■

7

Assembled endstop.

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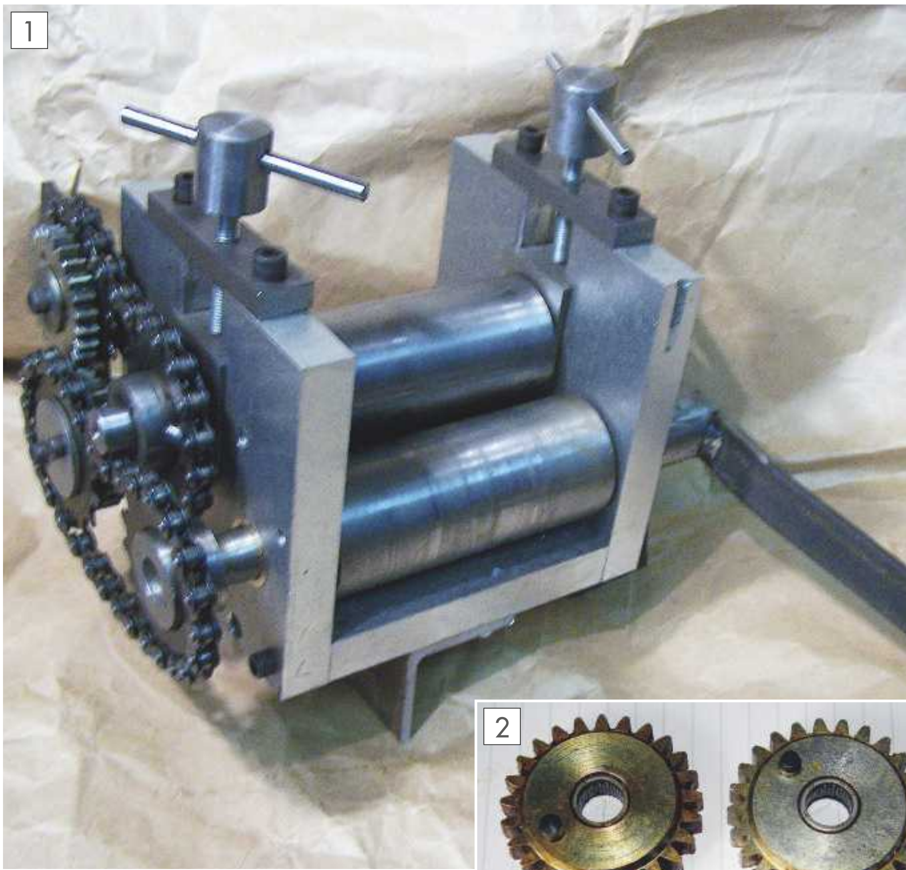
Heavy-duty Rollers

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

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



1

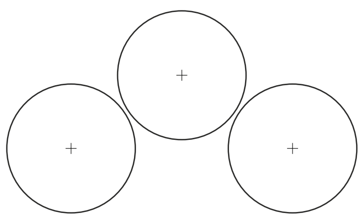
Finished heavy roller.

The concept

The idea was that the two bottom rollers would both work together. This would require some sort of drive system between them. I decided on three gears, the one in the middle of the train being an idler so that the two lower rollers rotate in the same direction.

The pressure roller would be pushed down in between the two bottom rollers so in use it would form the circle around the pressure roller, as opposed to the pressure roller coming up from the back in normal designs. The pressure roller would need to be removable. The front lower roller would be the driving roller, with the handle fitted to it with a clockwise direction for the handle and as I am right handed the handle would go on the right hand side of the roller. What follows is an account of the trials and tribulations of the manufacture and development i.e. making it up as I go along.

Sketch 1



Rough Sketch Of Rollers

Gears

Having got the idea sorted out the next thing was to select the gears to link the rollers, the ones I used I had in a drawer having found them some time ago and thought they would be useful at some point in time. The gears are 55mm in diameter and 12mm over all in width, the teeth are 8mm wide and are shown in **photo 2**. As can be seen two of the gears have bearings and pins. The pins were removed, as they were not required, also one of the bearings was removed. The other bearing was retained in the gear, as this would be used as the idler gear and the bearing saved having to make one in bronze. Note that my final design abandoned these gears for reasons that will become clear.

2

The gears.

To get the position of the holes for the rollers I sketched them out on a piece of paper this included the position for the pressure roller this is shown in **sketch 1**. This indicated that the two bottom rollers would be at 90mm centres at this position the rollers should give a tight circle if required.

The side plates

The sides for the rollers were machined to size as a pair. The sides are two pieces of second hand aluminium with holes in them, 20mm thick and finished 140mm

Machining the sides.

Reaming pressure roller.

The pressure roller.

wide and left at the original length of 270mm at this stage. The machining was done with a fly cutter to give a good finish off the machine (**photo 3**). I decided to make the pressure roller and support slide next as this would then give me an idea of the length the sides needed to be.

The pressure roller

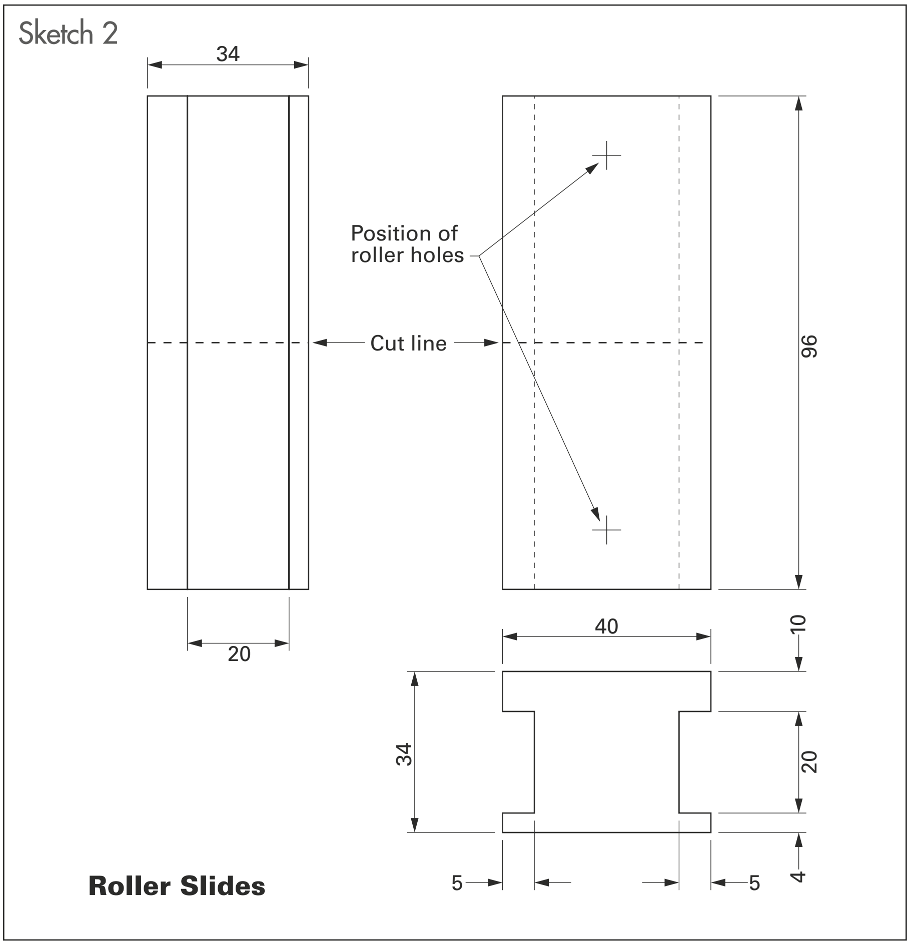
To make the pressure roller a piece of 50mm diameter steel, type unknown - but it machined okay, was used. It was 120mm long and the faces were finish machined so all that was required was an axle. So I then centred it in the lathe and drilled a 15 mm hole through, it this was supposed to be followed by a 16mm reamer but as I didn't have one I reamed it at ⅝ inch (**photo 4**). This meant that the shaft and bushes had to be made ⅝ inch as well, so the next job was to reduce the 16mm bar and shorten it to length of 170mm.

The 16mm steel was placed in the 4-jaw chuck and got to run centrally and then centre drilled both ends. Then using a revolving centre it was reduced to ⅝ inch dia. The ⅝ inch shaft was then put in the 2 inch roller using Loctite to secure it with 25mm over hang at both ends (**photos 5** and **6**).

The pressure roller support slide

For the pressure roller support slide I selected a piece of 35 x 96 x 200mm and cut a section off just over 40mm wide, **photo 7** shows the section being cut.

This was clamped in the milling machine vice by the 40mm sides, then a 20mm slot was machined in the 35mm face to a depth of 5mm on each side. **Photograph 8** shows the end of the first cut and **photo 9** shows the nearly finished first slot. After the slots were cut one face was reduced to 4mm, this is the face that will be on the inside off the walls and is intended to keep the roller as close to the side as possible (**photo 10**). When both slots and holes



One end of the pressure roller.

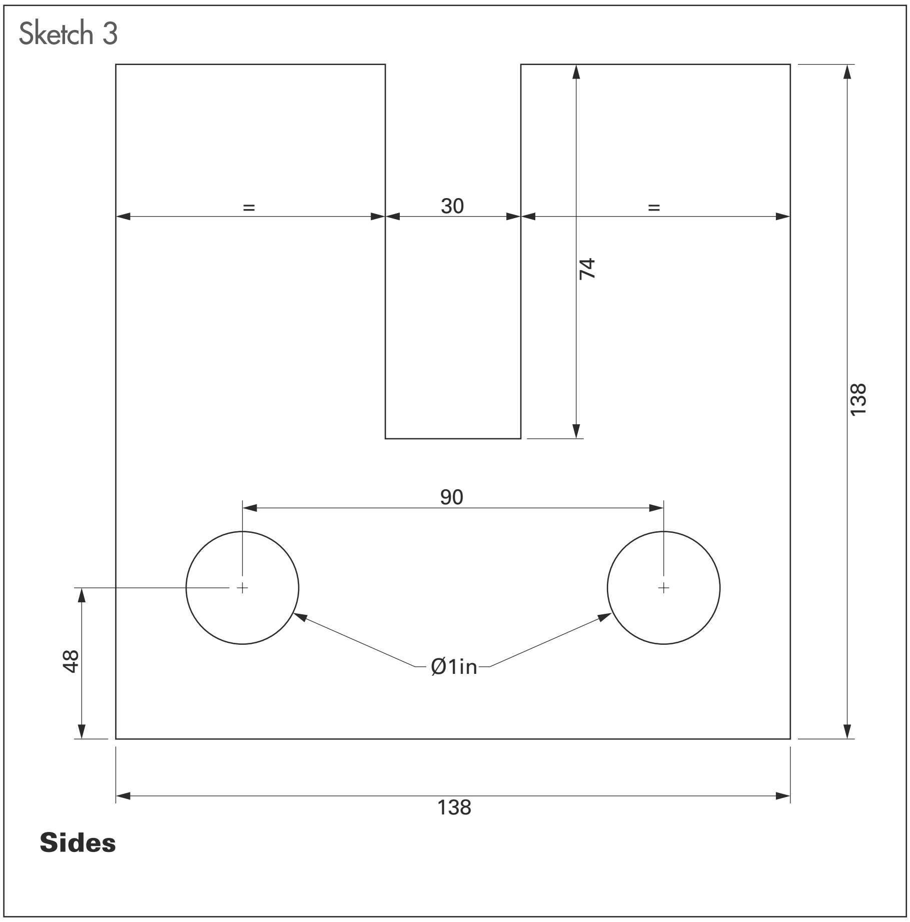
Cutting the pressure roller support.

Machining the roller support.

Cutting the slots in the support.

Reducing the size of the support.

The finished supports.



were finished it was cut in half to give a slide for both sides of the frame (**photo 11**). The general arrangement and dimensions for the roller support slide slots and holes are shown in **sketch 2**.

Now that the pressure roller support slides have been made the length of the sides was worked out as 138mm. The pieces were cut over length (**photo 12**) then clamped in the milling vice and finish machined to size (**photo 13**).

The next operation was to mark out the sides as shown in **sketch 3** for the slots for the pressure roller slides and the holes for the rollers (**photo 14**). I machined the slide slots with a long-series ½ inch end mill with the sides clamped to the bed of the mill with some packing under them. The slots are shown in **photo 15** after the machining was done but before cleaning up.

The bottom plate

I finished the bottom plate by milling both ends to the finished width of 128mm (**photo 16**). The bottom of the two sides were also machined. The bottom plate is one of the pieces that I cut from one of the sides when sawing them to size. I clamped the parts together as a trial and there was some fitting to be done as everything was a bit tight, but a few strokes of a file soon sorted it out. **Photograph 17** shows the pressure roller and the support slides clamped in position after the fitting.

Cutting the sides to length.

Sizing the side plates.

Marking out for slots and holes in the sides.

The slots finished machined.

Machining the bottom plate to size.

Testing for fit of the roller.

Drilling the bearing holes.

Both holes are drilled.

The phosphor bronze for the lower bushes.

Starting the bushes.

Drilling the bushes.

Parting off the first bush.

The four bushes.

Machining the first bottom roller.

Bearing pin nearly finished.

Testing for fit.

Testing the gear fit.

The side plate holes

To drill the side plate holes I clamped the two sides together again and marked out for three holes 10mm up from the bottom. The top ones were clearance size for ¼ UNF setscrews and the bottom ones were tapped ¼ UNF. These fixings were only temporary, the holes were be used to fix the sides to the bottom plate later by transferring the hole position to the bottom plate and then tapping it for holding bolts. The two sides were assembled using three socket head cap screws then put onto the mill/drill, setting the top of the side square to the table. Using three clamps with some timber-packing underneath they were clamped to the table to drill the holes for the bushing (**photo 18**).

The position of the first hole was located with a centre finder then a spot drill was used to drill a location hole. I then moved 90mm to the position for the next hole by indexing and this was also spot drilled. A 1 inch drill was fitted in the mill/drill, the bed way clamps were tightened and the first hole was drilled. The table was then indexed to the other spot drill hole, the clamps retightened and this hole was drilled. Photograph 18 shows starting the second hole and **photo 19** shows them finished.

Bushes

The bushes for the bottom rollers were made from some phosphor bronze 1 ¼ inch in diameter (**photo 20**). This was machined down to 1 inch diameter for 20mm (**photo 21**) and drilled just over 25mm deep (**photo 22**). They were then parted off (**photo 23**) to an overall length of 25mm. **Photograph 24** shows all four ready for deburring and fitting. After the bearings were fitted they were reamed to ¾ inch. After fitting the bushes, the side with the threads in it was drilled out so that the screw holes in the bottom plate could be marked out. To do this, the sides and the bottom were clamped together on a surface plate and the holes marked though with a ¼ inch transfer punch. The parts were then dismantled and the holes were drilled and tapped ¼ inch UNF.

Main rollers

The main rollers are of 2 inch diameter steel, also of unknown type. One finished at 9½ inches and the other at 8¼ inches. The longer one had the handle fitted to it; **photo 25** shows the start of turning and **photo 26** shows the first end nearing completion. The dimensions for the gear end on both rollers are 50mm overall, ¾ inch for 30mm and 16mm for 20mm, the shorter roller's other end is ¾ inch for 30mm only. The ¾ inch dimensions are to fit the bearings the 16mm is for the gears. The longer roller has a ¾ inch

The other end of roller.

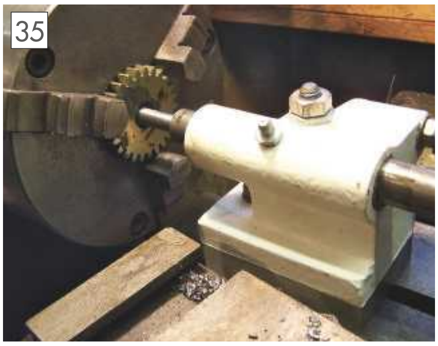
The main drive roller turning finished.

Cutting the keyway.

Also cutting keyways.

Cutting the clip groves.

Shaft in position.



Cutting a keyway.

Depth of keyway.

Handle drive shaft.

length of 60mm for both the bearing and the handle. The rear roller is shown in position in **photo 27** and **photo 28** shows the gear temporarily fitted. **Photograph 29** shows the other end of the rear roller. The front roller is shown in **photo 30** after the turning was done but before keyways were cut for the gears and the handle.

The next operation was to machine the keyways in the gear ends of each roller (**photo 31** and **32**). The slots are for ⅛ inch woodruff keys. After the keyways were cut a 1mm groove was machined for a circlip on the gear end (**photo 33**). **Photograph 34** shows the keyway and circlip groove.

Gear keyway

The gear keyway machining was done before the main rollers were made. I say machining, they were in fact only held stationery in the lathe so that I could use a slotting tool to cut the keyways (**photo 35**). The slotting tool was clamped to the lathe cross slide. **Photograph 36** shows the finished gear with keyway and **photo 37** shows the handle end of the shaft. The slotting tool used to cut the keyways was made some time ago from a casting that was supplied by College Engineering Supplies (**ref. 2**).

The connecting parts.

The transfer parts.

Connecting gear

The connecting gear parts are shown in **photo 38**. They consist of a flat plate 1½ x ¼ x 4 inch, with 8mm holes for fixing screws at 70mm centres, 8mm down from the top. The bearing bush is tapped M6 with a bolt to secure the bush to the plate at the back. Two 30mm spacers are made from 16mm diameter steel, drilled through for 8mm socket head screws used to fix the plate and gear in position over the other gears. These are screwed into tapped holes in the side at the geared end. The assembled parts can be seen in **photos 39** and **40**.

To be continued...

The transfer parts assembled.

REFERENCES

1. Workshop Bending Rolls, George H. Thomas. *Model Engineer,* October 1976

2. College Engineering http://www.collegeengineering.co.uk

Myford ML7R Power Cross Slide

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

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

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


1

The completed unit, removed from the lathe.

The first thing to do was to measure up the saddle, cross & top sides and get the details into cad, Turbocad 2015 in my case, and make a start on assessing the possibilities. A list of the requirements to be included in any design was made before going any further. The first requirement was that any modification to the machine could be reversed if required but any small changes, such as tapped holes in parts of the main body of the lathe, would not veto the project. Next, all safety requirements must be consideration at each stage of the development, these to include such things as limit switches, to prevent any dangerous situations arising from the modification. I also didn't want the modification to extend the cross slide more than two inches towards the operator, this because of the lack of space in my workshop, probably well understood by many model engineers. A third requirement was that the motorised unit could be overridden to allow manual control of the cross slide as normal.

With these requirements in mind it was back to the drawing board, cad in modern speak. The first requirement was could an electric motor of appropriate voltage, size and power be found and be available at a reasonable price? After much searching through catalogues and online I found what seemed to be the ideal motor, manufactured by 'MFA/combo drills', and available through a number of retailers; I used 'Rapid' (details at the end of the article).

Entering an outline of the chosen motor into my initial sketches, showed that whist it wold fit nicely and would couple to the extended lead screw via simple pair of bevel gears the problem of how to disconnect the motor was still there. After much doodling it was realised that with the motor mounted vertically below the lead screw it only required it to be mounted on a slide to enable it to be dropped down disengaging the bevel gear and allowing the lead screw control handle and dial to be used as normal. I decided to mount the motor on a small dovetail slide to enable it to move about a quarter of an inch to disengage the gears. At this point it was found that the modification extended the cross slide handle about one and a half inches towards the operator which was acceptable.

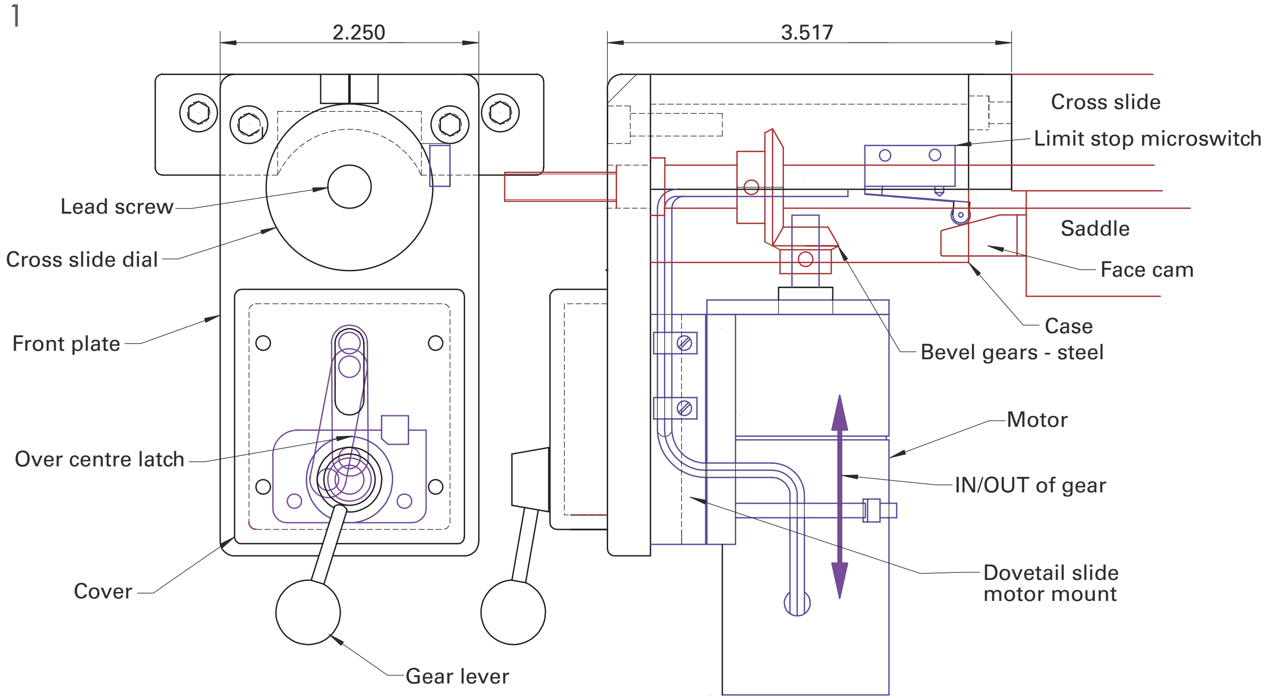
It was now time to start the detailed drawings. **Figure 1** (overleaf) shows a general arrangement of the unit with a few dimensions to give an idea of the overall size. I do not intend detailing the machine operations during manufacture of the prototype, we all have our own way of doing things and have different facilities in our workshops. Guidance will be offered when felt it could be helpful. You will see from my drawings that I still use imperial measurements although I sometimes now use metric fasteners.

Whilst this unit is designed for use on a Myford ML7R it would be likely to fit all other Myford models and also, with some small changes, could be made to fit other lathes of a similar size.

Main body

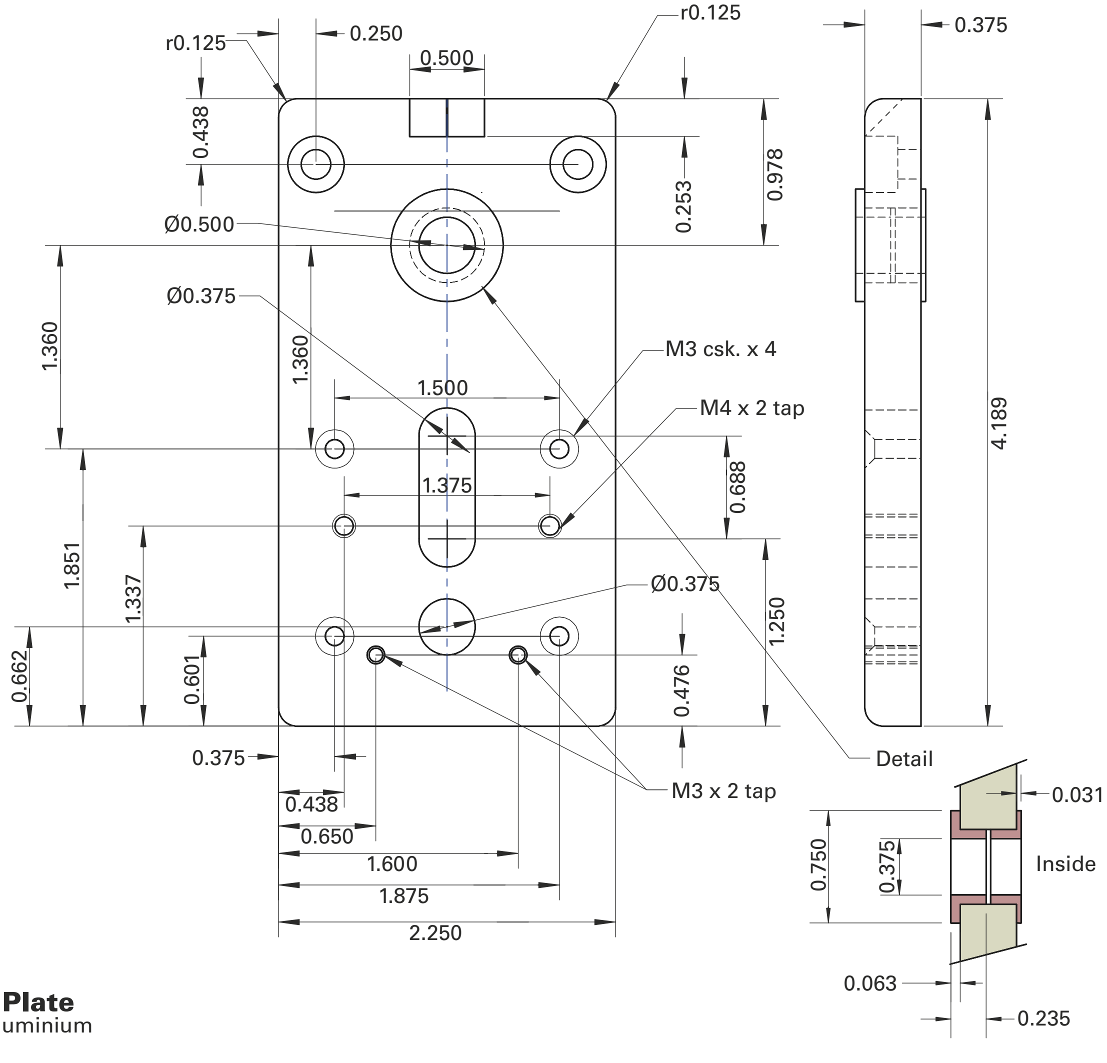
I had originally intended to make the main body from an aluminium casting but when I had drawn it out and calculated its volume it was found to be too large for my

Fig. 1



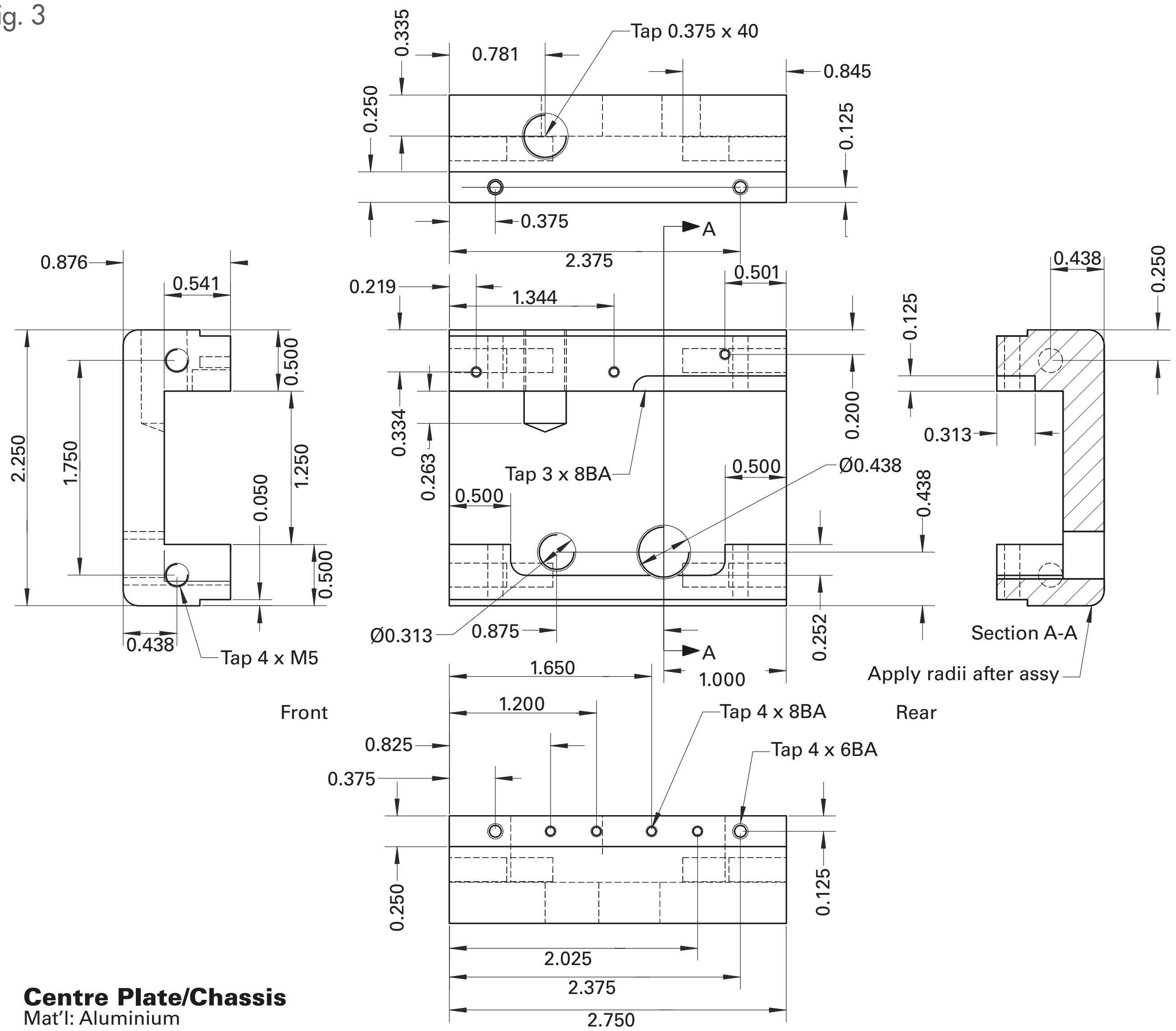
Power Cross Slide Assembly
General Arrangement

Fig. 2



Front Plate
Mat'l: Aluminium

Fig. 3

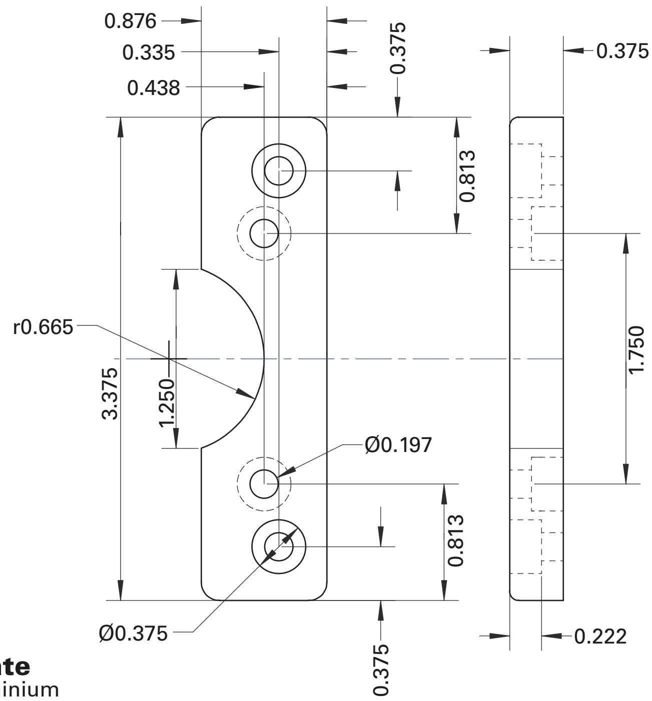


Centre Plate/Chassis
Mat'l: Aluminium

little crucible. I therefore decided to make it as an assembly of three sections, front plate rear plate and centre plate/chassis of aluminium extrusions and ordered the two sections of aluminium required. One length of 1 x 2.5 x 24 inch and a second at 0.5 x 2.5 x 24 inch, the lengths chosen to have a bit left for the odds and ends box. These sections were cut and milled to the dimensions shown in **figs 2**, **3** and **4**. It is best to carry out as much of the drilling, milling and tapping as possible before gluing and assembly. I didn't do this and finished up having to extend drills and cutters to work on the assembled item. The grade of aluminium used is HE30 and it machined very well to a good finish. The two bronze bushes, fig. 2, are inserted one from each side of the front plate in the upper 0.5 inch reamed hole, see detail on drawing, and retained by either Loctite or epoxy as preferred. The bush in the lower 0.375 inch reamed hole is retained in the latch plate so does not need to be inserted at this time. When all the machining is done, the three pieces of aluminium can be assembled.

Four 15mm long 5mm dia. Cap head bolts and J-B Weld are used after first roughing up the joint area. Do not tighten the bolts so tight that all the adhesive is

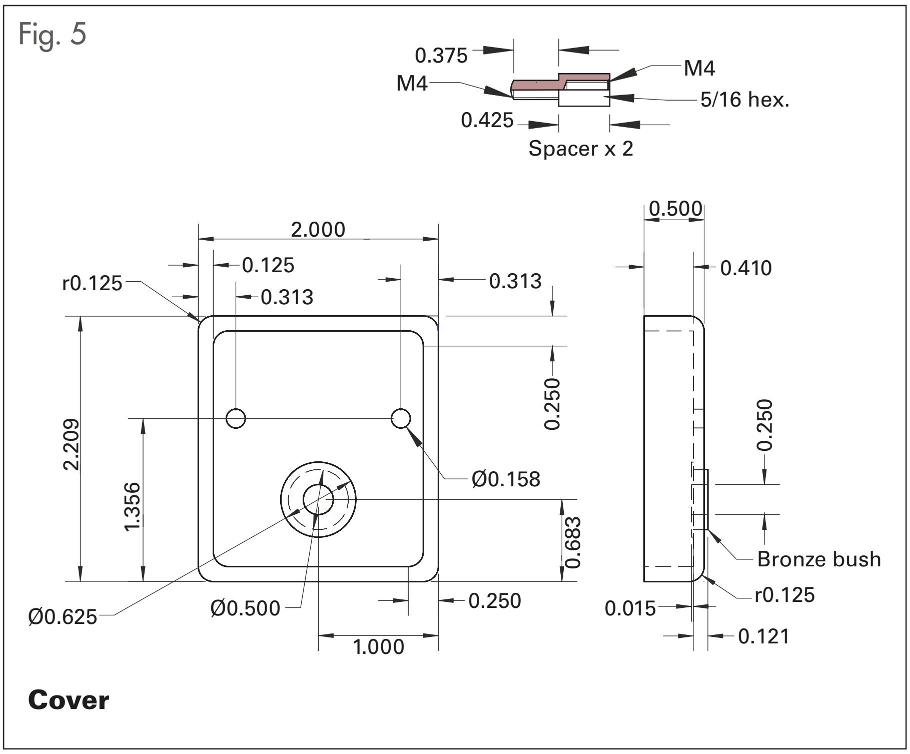
Fig. 4

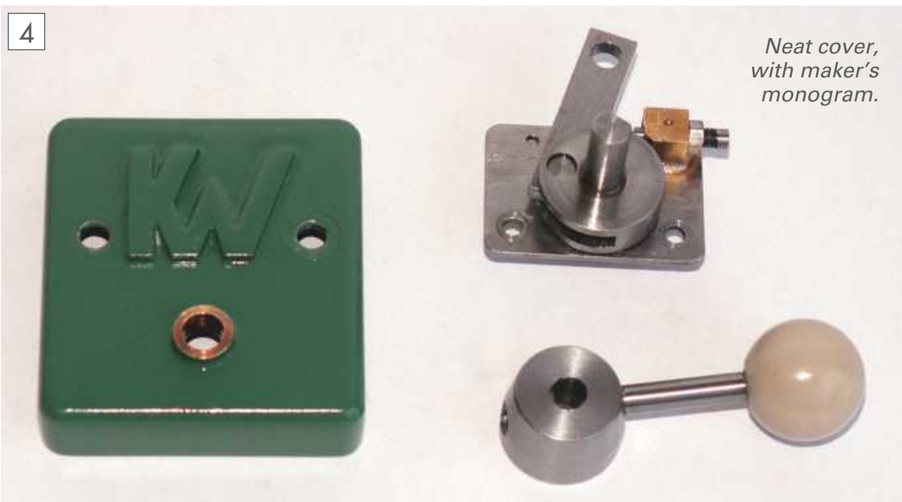


Rear Plate
Mat'l: Aluminium

The unit fitted to the machine.

Body of the unit.





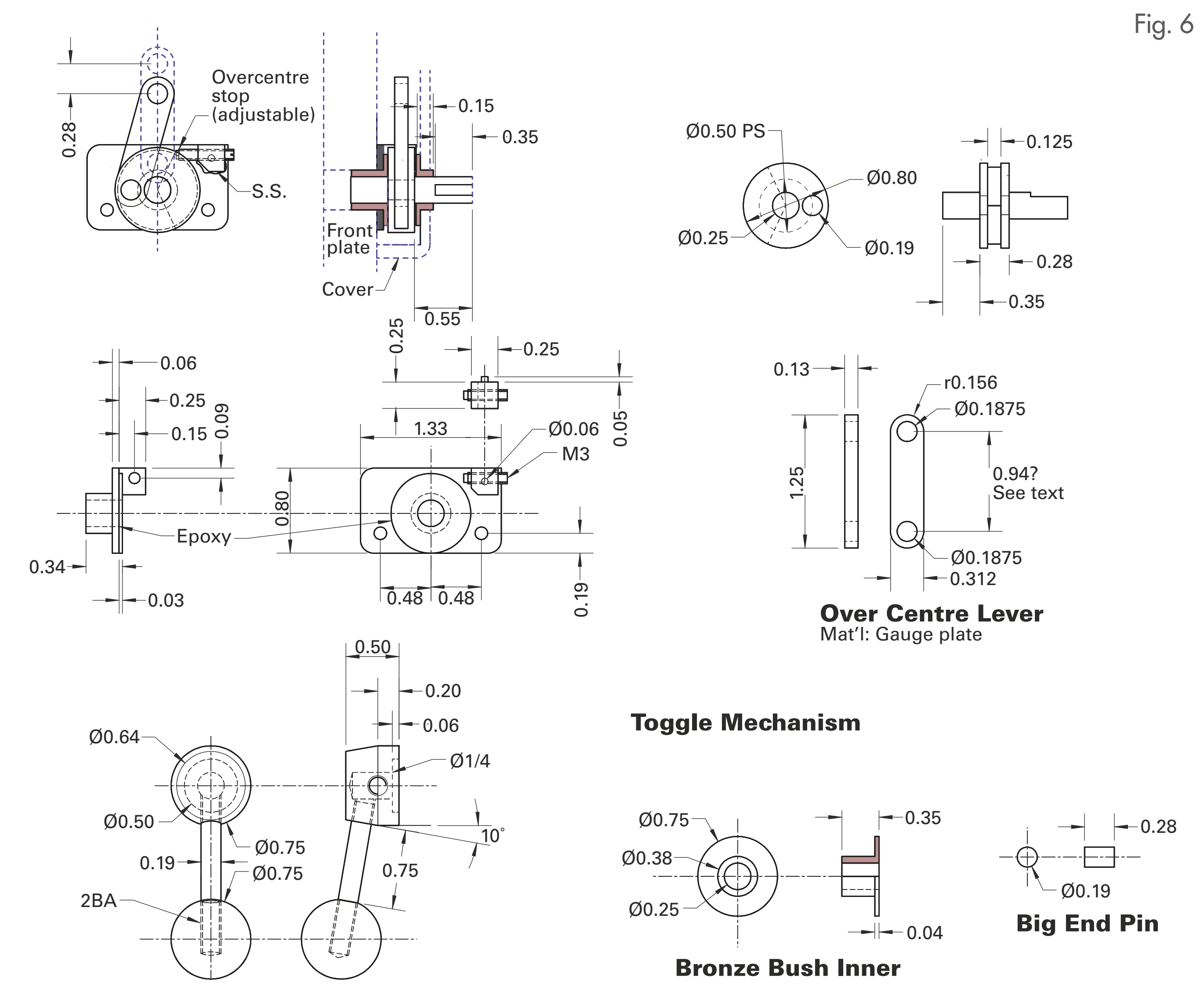
Neat cover, with maker's monogram.

squeezed out. Make sure the three pieces align properly by ref to a flat surface, straight edge or use dowels if you would rather. Once the adhesive has cured a bit of hand finishing is required to round of the external corners and clean up. The extent of this procedure is down to you. The cap heads, counter bored into the plates, needs to be filled level with the plates using Isopon P38 or similar before the hand finishing. **Photograph 2** shows the unit in a trial assembly before painting.

Once the Body is finished it can be painted a colour to match or contrasted with your machine. I always use car spray paints for this type of job and in this case chose a can of Ford Meadow Green as a good match for Myford green. First of all the parts to be painted need to be thoroughly degreased and then protected until about to be painted. For degreasing I use a liquid called Micro-90 which is added to warm water and makes an excellent degreaser. After a good scrubbing rinse in running water and dry. Next a coat of etch primer is applied. It is great that etch primer is now available in a spray can, the one I used is called U-POL ACID #8 and really seems to work well on aluminium, usual disclaimer. When dry follow up with a couple of coats of ordinary grey primer and finally as many coats of gloss finishing paint as you feel are needed (**photo 3**).

The cover

The item shown in **photo 4** is used to cover up the gear/latch assembly and also to support the outer bearing of the latch crank (**fig. 5**). The cover is manufactured from 0.5 inch HE30 aluminium and is a straight forward milling job. The X and Y stops on the mill were set to assist in hollowing out the back of the cover as shown. The bronze bush is turned and inserted through the 0.5 inch hole from the inside and again retained in place with epoxy adhesive. I have added a 'Y' stop to my Warco mill and it has come in useful so many times I wonder how I managed before I fitted it.



It can be seen from the photographs that the front of the cover is embellished with my logo. This was simply cut out with a piercing saw cleaned up and stuck on, again using epoxy. This is obviously a personal preference and you could do something similar or leave it plain as you will. A bit of hand finishing again improves the appearance of the cover and the outer edges are rounded to match the main body. When finished paint as for the body. Two spacers are used to mount the cover on the front plate of the unit. A simple turning job from 5⁄64 inch hexagonal mild steel.

Gear/latch assembly

Shown in photo 4 and **fig. 6**, the purpose of the latch assembly and gear lever is to raise and lower the dovetail slide, to which is attached the motor complete with the bevel gear. When in the fully raised position, the over centre device locks the slide in position, with the gears fully engaged therefore maintaining the drive. When in the lower position the motor/slide assembly is held in place by gravity and the drive is disconnected.

The mounting plate of the latch assembly is made from a piece of 16 swg mild steel sheet. A small brass block silver soldered to one corner, as shown in the drawing, has an M3 hole taped through it to take the over centre lock adjusting screw. I turned a small spigot on the back of the brass block to locate in a hole drilled in the plate to locate it whilst soldering. The bronze bush is turned from ¾ inch bar to the dimensions shown and fixed to the plate with epoxy adhesive. Make sure there is no adhesive left on the back of the plate as that would stop the bronze bearing fitting into the reamed hole in the front plate and sitting flat on assembly. The small crank is turned from EN1A free cutting mild steel, ensuring that all diameters are aligned, and a 0.125 inch slot is milled across the centre 0.8in Dia. disc to form the space for the loose crankpin/conrod. The 0.1875 inch diam. hole can now be drilled and reamed to take the loose crank pin which is a 0.28 inch long piece of silver steel. The pin is faced to length and can be left as it comes as it is only ever turned a quarter of a turn in use. The over centre con rod is made from a piece of 0.125 x 0.3125 inch gauge plate, again left soft. Both the holes are drilled and reamed at 0.187 inch and the ends rounded. The ends could be left square as it would not make any difference to the operation of the unit. The distance between the two hole centres sets the position of the dovetail slide when the over centre locks. This should be close to the dimension given but it should be checked on assembly of the unit. The 'gear lever' is made from two mild steel items and a 0.75 inch diameter plastic ball tapped 2BA or 5mm. photo 4. I made the ball from peek, which is a nice fawn colour plastic and it goes well with the green paint. The nose and arm are simple turning jobs, however the radial position of the 2BA hole should be left until assembly of the unit as it sets the position of the lever when in use. The arm is a short length of 3⁄16 inch mild steel screwed 2BA or 5mm both ends. I should mention that the big end pin does not require any form of retention as the large flanges of the two bronze bushes prevent movement in use. When complete the assembly can be attached to the front plate with two M3 cap screws in the holes provided.

To be continued...

SUPPLIERS

Radio Spares www.rsonline.com
Rapid Components www.rapidonline.com
MFA/COMO www.mfacomodrills.com
HP Gears www.hpcgears.com

Rebuilding a Warco Major Mill/Drill Part 3

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.

The restored machine.

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.

Assembly

Time to put it all together. One small problem, having increased the plate thickness to 15mm the pillars needed shortening to keep the top of the plate in the same place. I did the back two pillars that sit on the factory machine faces on the head first, and then one of the front ones. I put the clock gauge on top of the spindle and by rotating it by hand could check the runout (**photo 34**). A little fine tuning and its pretty good. The fourth pillar was then adjusted to fit its space.

Two problems when I tried to assemble it all. Firstly the back two mounting holes were a little tight so I marked them for easing. Bear in mind that the hole positions were originally for the guard and somewhat randomly drilled, and that I had measured them with some difficulty, then drilled them through the drawing printout, so I didn't feel too bad about a little adjustment. Secondly, it was obvious that the timing belt centres were a bit greater than had been indicated so the motor mounting slots would be better a bit longer. To make these alterations I had of course to refit the MDF plate. I must admit I began to wonder why I hadn't just stuck with it and saved myself a lot of bother. Finally the plate was mounted (**photo 35**). And then the drive (**photo 36**). I counterbored for the front two caphead screws to keep the plate clear in this area.

Testing runout.

Alloy plate finally fitted.

Motor in place.

Clamp plate with...

...extra tab for vice.

Lining up for a bend.

Guarding

To make the guard I bought two pieces of 1.5mm Aluminium 125mm wide. One piece was to go on the right hand side and one on the left, with both bent pieces to be fastened on their top edges to the motor plate with screws into tapped holes. The right hand piece needed a simple 90 degree bend but the left hand piece needed two low angle bends accurately spaced. I looked at various bending jigs on the internet but there were two problems, the cost just to make three bends and how to space the partial bends on the left hand piece. In the end I decided to make a jig specifically for the left hand piece and which could be used for the single bend right hand piece.

I had some 6mm diameter silver steel which I decided would be suitable for the inside radius of the bends and also some 10mm thick steel that I planned to use to locate and support the rods during bending. The rods would sit in steps 6mm deep accurately spaced apart so that the bent guard would fit the motor plate. To find the spacing of the steps I drew the part of the motor plate that the guard was to go around and then drew two 6mm diameter circles inside touching the edges (**fig. 3**). I then drew the stepped plate (**fig. 4**) and rounded off the spacing to 60mm. The steps were 6mm deep but reduced to 5mm wide to allow overbending for the 90 degree bend. I machined up this former, added a clamp plate held with two M6 bolts, and attached a piece of scrap 20 x 50 MS to the clamp plate so that it could be held in a vice (**photos 37** and **38**). The piece to be bent goes between the stepped former and the clamp and **photo 39** shows the right hand piece being clamped. When bending the 6mm rod goes under the aluminium and is located on one of the steps.

To make the bend a pressure plate presses the aluminium against the rod and rotates around the rod thus forming the bend. The rod forms the pivot. Again this is made up from scrap and is shown in **photos 40** and **41**. The pressure plate is attached with three countersunk screws to a back piece which has two holes for the two adjustable carriers for the 6mm rod. The rusty bit of steel forms a handle (jig is mostly scrap). In use the former is held in a vice with the aluminium sticking out, the pressure plate goes under the aluminium and the rod on top. Push the rod home into the step on the former and hand tighten the two nuts on the carriers. The pressure plate is now pressed against the underside of the aluminium. Press the rod firmly into the step and lift the handle and the aluminium is bent around the rod.

Fig. 3

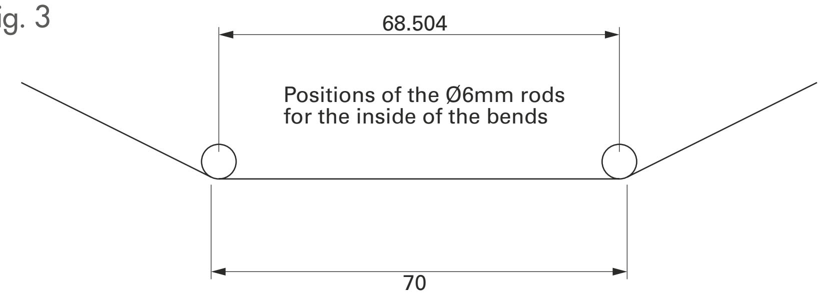
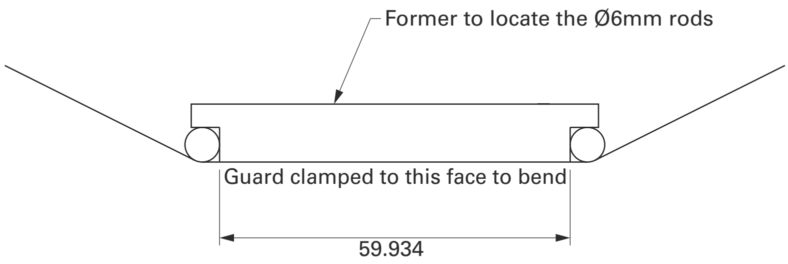


Fig. 4



Photograph 42 shows the completion of the 90 degree bend. I filed a radius on the corner of the motor plate and the bent piece fits nicely.

To bend the other side to the right angles I used my grandfathers pocket rule as a guide. The bent piece is shown in **photo 43** with the rule in place to check the

Pressure plate and handle.

Carriers for the 6mm rod.

Making a bend.

Preparing for second bend.

angle. The right hand guard was trimmed to size (using a small milling cutter) and the edges trimmed where necessary to give a good fit. I then drilled pilot holes in the guard, placed it in position and drilled through into the motor plate. Tapped the holes in the motor plate and opened up those in the guard to suit the M5 pan head screws used to fasten the guard in place (**photo 44**). A similar procedure to fit the left hand guard (**photo 45**). I machined a scrap of 15mm aluminium to fasten the bottom edges of the two sides together. This left a hole on the underside where you could put your hand up. I trimmed a piece of the MDF template used earlier on and fastened it into an existing hole in the head casting to block this off (**photo 46**). The completed guard is shown in **photo 47**. I may replace the MDF with aluminium some time (but perhaps not).

Controls on the head

This left me with just the irritation of operating with the inverter keypad. Everytime you put power on the frequency starts at zero and you have to wind it up with the touchpad. To make a remote control pad I bought a 1k potentiometer and an on/off switch together with a plastic box from Maplin. The box I mounted on the head using the two screws that had held the original control switch. The pot and switch were mounted in the box lid. You can see the control box mounted in photo 1.

I needed 5 cores for the signals and I was sure I had a part reel of multicore screened cable somewhere. My garage is rather full and it took rather a long time to find it. It turns out I have two boxes with cables in them – in totally different places in the garage. I also thought I had suitable cable glands – and I did eventually.

In case anyone has a BSL Electron Inverter FVR-G5S-7 these are the connections I made:

- Red to terminal 13 and to the left terminal on the potentiometer
- White to terminal 12 and to the middle terminal on the potentiometer
- Black to terminal 11 and the right terminal on the potentiometer
- Green to CM terminal and the common terminal on the switch
- Blue to FWD terminal and to the normally open terminal on the switch

You also need to link THR to CM in the inverter.

So everything was connected up and it didn't work. You have to program the

Right hand guard.

MDF filler piece.

inverter using the keypad by pressing PRG and then scrolling through the codes by pressing SHIFT. This changes the first two digits of the code. You use the up/down keys to change the second two digits and press SET to set the code. Pressing PRG takes you out of program mode. The codes to set are 1900,2501, and 2700. Do not make my mistake and set 2701 which is listed as 'Remote control panel' because it doesn't work!

Left hand guard

All finished.

The completed work is shown in **photo 48**. This also shows how the base of the mill now sits against the wall – one of the main original objectives. I shall probably fit digital readouts on the Y and Z axis next, and then I am thinking of fitting stepper motors to the table to provide power feeds. ■

Ready for action.

The World Maker Faire 2015

Andy Clark won a trip to New York to visit the World Maker Faire.

Earlier this year I entered a design challenge to 'add enchantment to an everyday object'. My idea was to internet enable a traditional weather house (**photo 1**). I took apart the simple catgut based mechanism and replaced it with 3D printed parts, a micro-servo and electronics modules to control the movement and connect to the internet. After 16 weeks of building and writing about progress, my project came out top and I won a trip to the World Maker Faire in New York.

Andy with his project.

The Maker Faire is based in the New York Hall of Science and surrounding park land. It's on the site of the old World's Faire and hence there are some great things to see such as the *Unisphere* (**photo 2**) and the now decaying observatory buildings. I visited those before the show opened on Saturday morning.

Whilst we were waiting for the gates to open, we were serenaded by a stilt walking jazz band accompanied by a giant dancing cardboard dinosaur (**photo 3**). Throughout the day we had a variety of bands performing around the site and people wearing unusual costumes. There is a lot of silliness and craft at a Maker Faire but there is also a lot of engineering and mechanical skill.

One such example is the jet powered go-kart made by Christopher Tomko of *Amateur Turbine Propulsion* (**photo 4**). The engine uses parts from a turbocharger along with welded stainless steel ducts. Chris says that he likes the simplicity of a turbine in comparison to an internal combustion engine. It's his second engine build and it took 10 months to construct. He also showed examples of machined turbine blades he was working on.

Other vehicles on show included a pair of multi-user multi pedal cycles (**photo 5**) and a range of electric cars (**photo 6**) that were competing in the Power Racing Series. These wacky racers had to navigate a narrow course with tight twisting bends as fast as possible and then stop within an eighteen feet box. The other criteria was that the car must fit in a size limit and not cost more than $500 to make. On Sunday, Charles Guan from MIT gave us advice on how to make your own, including a top tip that it's easier to repair things if you did not make them with 10 different sizes of screw.

No faire would be complete without some Stirling engines, and this one is no

Winning the Maker Faire ticket and trip was a fantastic prize and I thoroughly enjoyed the weekend. There was loads to see for all curious minds and it was amazing how much people had achieved with sometimes little knowledge or skill.

Unisphere.


Jazz band and Dino.


Jet powered Go-kart.


Multiuser bike.

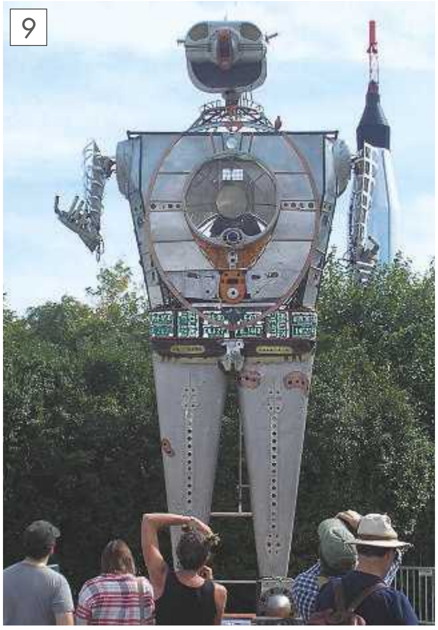

Power racers.

Stirling engines.

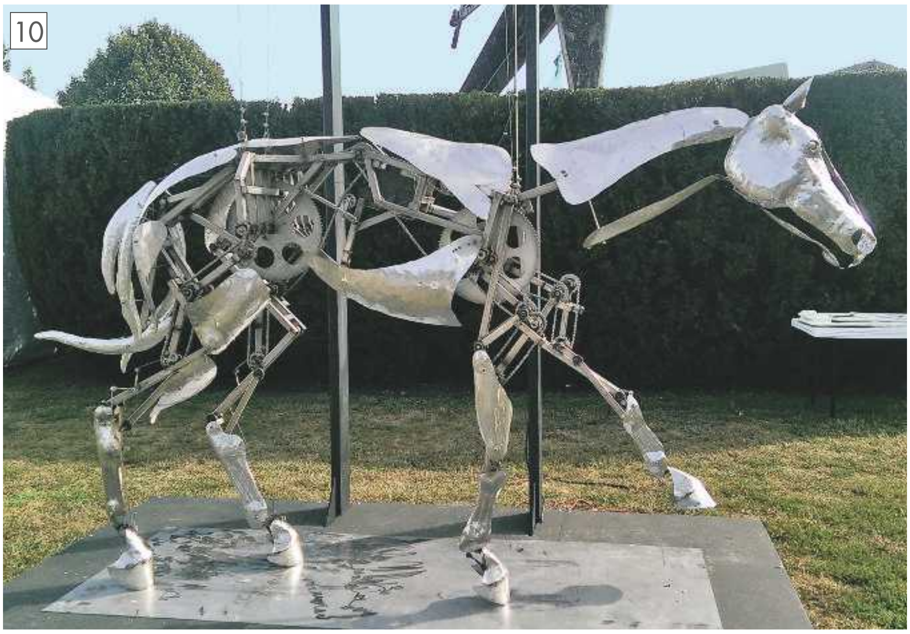
Robots with balls.

exception with some fine examples from John Schneider (**photo 7**). John has been scratch building hot air engines for the last 20 years. His low temperature models are so sensitive that they can run from the heat in his hand. The smallest model is the size of a US dollar, about 25mm in diameter. It took him a year to design and build that, and it's won awards around the country.

Equally well engineered were some of the robots on display such as the big wheeled rover built by Greg Brill from *Infusion Drive Systems*, robot arms from *Hadlington Dynamics* and Jeffrey Boerner's 12 foot long *Tobor the Great* which incorporated 'haptic feedback' so you could feel what the robot was manipulating. The schools had also built some top robots for the *FIRST* robotics competition. Teams of children had designed and built the remote controlled robots over a period of six weeks. Each year is a different challenge and this year was throwing and catching balls. The examples on show at the Maker Faire were the best of those that had been entered in the competition and were impressive to watch in action and could throw a large ball several meters (**photo 8**).

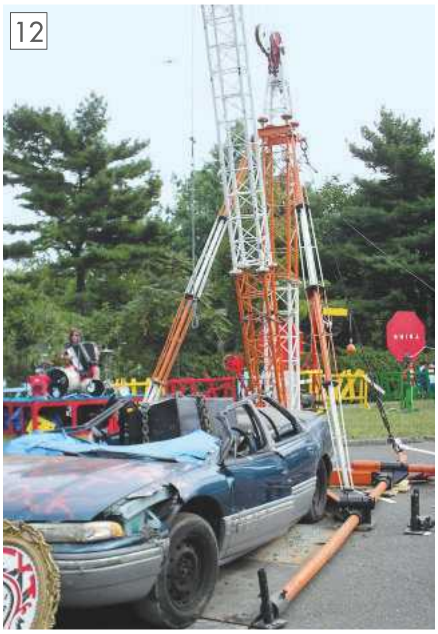


Robot resurrection.



Mechanical horse.

Mousetrap.



Mousetrap with safe and crane.

One of the biggest creations at the faire was *Robot Resurrection*, a 30ft tall sculpture made by Shane Evans (**photo 9**). It was assembled from old aeroplane parts. Robot Resurrection seems cheery but you wouldn't want to get in the way of his dual flamethrowers. Another kinetic sculpture was Adrian Landon's mechanical horse, a welded fabrication of steel tubes, panel beaten sheet metal and chain geared mechanics (**photo 10**). As the gears were turned the horse galloped in mid air.

My favourite fabrication had to be the Life Sized *Mousetrap* (**photo 11**) this was made from scrap metal and old lift parts. It took Mark Perez 14 years to build and he built it in his backyard. It all packs up into a lorry and is shown around the country. It takes four days to assemble and two more to pack it away again. In a similar manner to the original board game it's based on modules connected together with triggers. Mark and team demonstrate the operation of the machine in the form of a show with audience participation and music. The machine does not always work perfectly but the clown engineers are on hand to give it a shove. The final piece rather than being a mouse cage is a 2 ton safe that's winched up with a stiff legged derrick crane that Mark built himself (**photo 12**). You can feel ground shake when that comes down!

The weekend was packed with talks and presentations spread over six different venues. I attended a few of these including the splendid *Les Machines de L'île de Nantes* who explained their giant ride-on mechanical elephant project as well as their upcoming stork tree which is inspired by the works of Jules Verne. I also listened to Mike Daly and Peter Heinz from PS 143 who have introduced boat building to their school. They have their youngest children assembling simple plywood model boats and their older kids have built a real boat that can be used on the nearby lakes. It was fascinating to hear how the simple act of a team of two young kids using screws and a screwdriver could help cognitive and communication skills as well as the more obviously physical ability.

Education played a big part of the show with many local schools attending and showcasing their projects. However, there were also several providers of adult education in the form of short courses in woodwork, metalwork and sewing. There were also many Makerspaces represented offering use of tools and space for a regular fee. For those who were more interested in the results than the process a large number of 'Fab Labs' could build you parts using 3D printers or laser cutters.

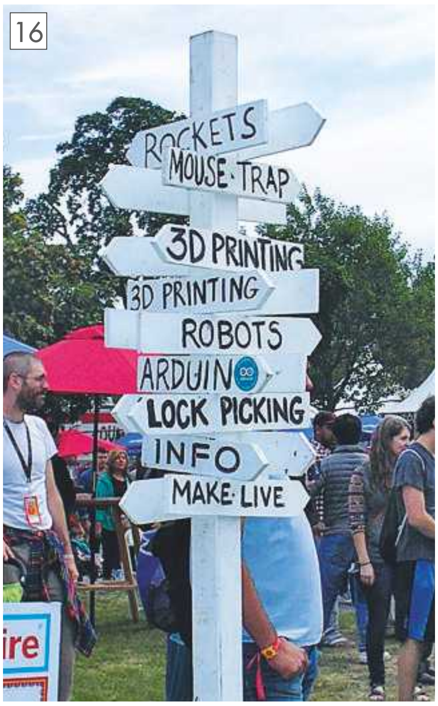
Not unexpectedly 3D printing featured heavily. There was a whole section dedicated to 3D printing but also printers were visible or had been used in many of the projects such as jewellery at the craft stalls to 3D printed mechanisms for Mario the Magician. There were numerous examples of models created with 3D printing. Fred Kahl's giant diorama of a castle and crowds was outstanding and I visited that several times (**photo 13**).

There also seemed to be a competition for the bigger printer with the Italian Trade Association stand having a large number of jumbo sized printers, *Gigabot* had a machine which they claim to be the

3D printed castle.

Toilet sized printer.

Filament recycling.

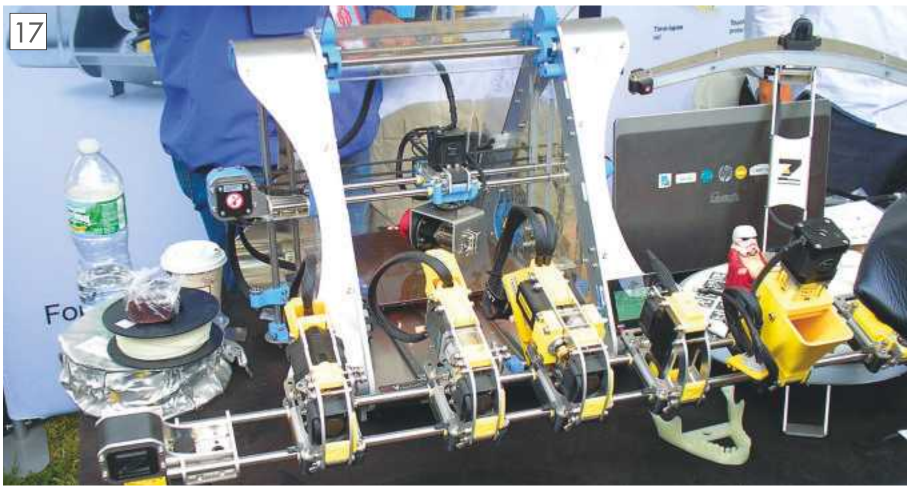


Where next?

world's first affordable toilet-sized 3D printer (**photo 14**) and I also saw an even larger 3D printer that was taller than me.

Filament recycling and re-extruding was also popular with several devices on show to help keep down the costs of printing failures (**photo 15**). I also caught the end of a talk on how to design parts to reduce failures in the first place. It was such a big site with so many distractions that sometimes it was difficult to be in the right place at the right time (**photo 16**).

There were several examples of multi headed devices on show. A 3D printing extruder could be swapped out with a small milling head or drag knife (**photo 17**). I've yet to be convinced by these machines, as the mechanisms don't look robust enough for any serious milling and wonder if there would be calibration issues as the heads are swapped.



Z-morph.

Dremel.

When you talk to makers they think of CNC as being a flatbed router rather than a mill or lathe. They are also biased towards rapid prototyping techniques rather than heavy engineering. I suspect that this is the reason that there were no suppliers of conventional lathes and mills. However, there was a new CNC mill, the PCNC 440 from Tormach at the Faire that actually had the ability to cut metal. Dremel were present, showcasing their handheld devices (**photo 18**) and new 3D printer.

Electronics and computing featured heavily at the show with big stands from *Atmel*, *Microsoft* and *Google* (**photo 19**). Atmel are the chip makers who make the microcontrollers in many boards such as the *Arduino* series. That part of the fair felt a bit like a trade show where as the rest was more like a village fete.

The weekend finished with splashy grand finale. After the show was finished, we headed over to the *Unisphere* to see Fritz Grobe and Stephen Voltz creating

Electronics zone.

Coke and Mentos.

By the Big Robot.

fountains to music with the help of a few hundred bottles of coke zero and mentos sweets (**photo 20**). They explained how the reaction worked due to lots of CO_2 bubbles forming on the tiny pits on the sweets and how shaped nozzles controlled the height and direction of the fountain. We were also advised on the challenges of gluing PVC pipe to PET bottle tops and they recommended 3M DP-8005 Structural Plastic Adhesive for that job.

Winning the Maker Faire ticket and trip was a fantastic prize and I thoroughly enjoyed the weekend (**photo 21**). There was loads to see for all curious minds and it was amazing how much people had achieved with sometimes little knowledge or skill. It's a long way to go for a weekend so I'd recommend combining it with a longer trip. I've been told that the Detroit Faire has a lot more vehicles and the Bay Area Maker Faire at San Francisco is even bigger than the New York show. ■

10% OFF

Designing Springs ~ Visually

Part 3

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

The first two charts in this series - showing the load and rate characteristics of springs in graphical form - may be all that is needed to design a satisfactory spring for an undemanding application. However, if some further refinement in the design is required, this can be done with alternative graphical charts called nomograms, and one of these is shown in this article for finding the wire stress in a spring.

The first thing to say about nomograms is that they are easy to use, even though the term itself may give the opposite impression. They are graphical representations of mathematical relationships, and although the mathematics behind them may be highly complex, using a nomogram is not. It's almost certain that you have used this type of chart before, as any two scales plotted side-by-side as measurement converters are a simple form of nomogram; examples are: mile/kilometre and centigrade/Fahrenheit conversion scales.

Two nomograms are described in the last articles of this series - one to find the wire stress in a spring, and one to determine the spring rate. Mostly, they would be used to get some accurate spring parameter values after the initial design stages have been done with charts 1 and 2, but they can also provide an independent check of the results obtained from the first two charts. The nomograms are a visual method of doing the calculations that were described in part two. The mathematics involved with this was a relatively lengthy process, but the same task can be done with a nomogram in only a few seconds.

The wire stress chart in this article is an alternative nomogram to that shown in fig 16 in ref 1. This diagram in the book should be treated with caution because it gives stress values that are on average 10 percent too low, but in some cases the values can be underestimated by more than 30 percent. In contrast, the large size of chart 3 provides results which are quite accurate; if used with care, it should give stresses which differ by no more than two percent from their true values, and this is more than adequate for spring design work. Readers with ref 1 to hand will notice that chart 3 has a different layout compared to fig 16, and this provides some advantages (a nomogram can be drawn in an almost unlimited number of ways, providing the underlying mathematics is followed).

The construction of nomograms was a completely new subject for me, so at this point I would like to acknowledge the help provided by *The Art of Nomography* by Ron Doerfler. This is given as **ref 2** because it contains some interesting comments on the many different types of nomogram (although it is very mathematical in places).

Using the wire stress nomogram

Chart 3 (see page 64) combines equations (1), (2), (4) and (5) (shown in part two) graphically in one nomogram. It has four separate scales, one for each parameter that influences the stress in a spring's coils. The four scales are used in two pairs, and the grey and green shaded areas indicate which scales go with each other; in the two-step procedure for using the chart, do not mix a green and grey scale together (this would only produce meaningless results). One thing to note is that the values on two of the scales increase in an upward direction, and with the other two scales, the values increase downwardly. When I first started using spring nomograms, I found that it was sometimes easy to forget this, and the descending scales could be misread occasionally. These two scales therefore

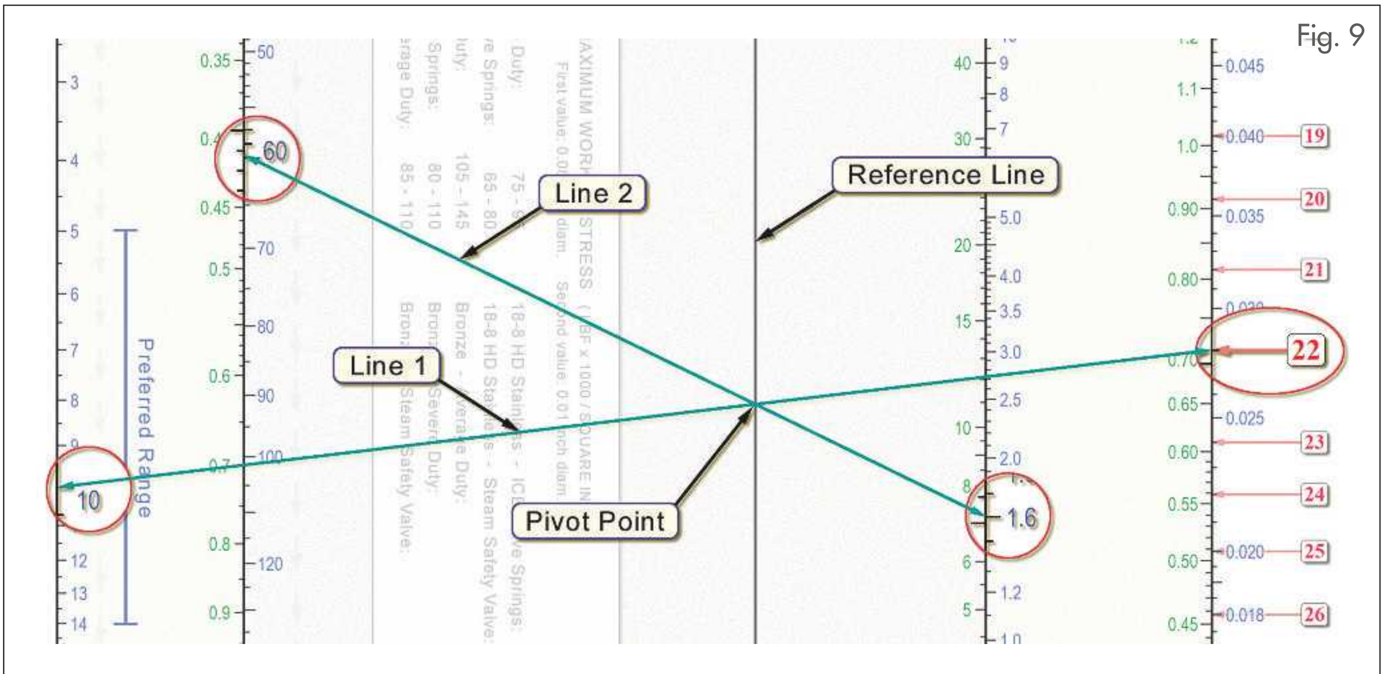


Fig. 9

have a series of down-arrows as a reminder. The chart has both imperial and metric scales, and it's possible to use both systems at once, for finding a metric load of a SWG wire size, for instance. Don't, however, use an imperial value on a metric scale, or vice-versa. It's an easy mistake to make - I write from experience!

The nomogram is used with a rule or other straightedge, and it's helpful if this is made from clear plastic so that the underlying scales can be seen; the technical name for this tool is an **isopleth**, or index line. Perhaps the best way of explaining how nomograms are used is with an example: Suppose a spring made from 22 SWG wire has a mean coil diameter of 0.28 inches. If the spring is for an undemanding application ('average duty') with a maximum load of 1.6 lbf, will the stress in the coils be at a safe limit if the spring is made from carbon steel wire, or alternatively with bronze wire?

From the wire diameter scale in Chart 3, 22 SWG wire has a diameter of 0.028 inches. Dividing the mean coil diameter (0.28 inches) by this value gives a coil ratio, C, of 10. Place a rule accurately on Chart 3, so that it touches the 22 SWG arrowhead on the wire diameter scale, and also the value 10 on the C scale (Line 1, **fig. 9**). Draw a short, light line with a sharp pencil at the place where the rule crosses the reference line. This point is called a pivot point. If the rule is now rotated around the **pivot point**, it will show all possible load and stress value pairs for the spring, where the rule crosses these two scales. For this example, put the rule so that it touches both the previously marked pivot point and the 1.6 lbf value on the load scale (Line 2, fig 9). You should find that the rule crosses the shear stress scale at a point just short of (above) the 60 value mark. The wire stress in this example is therefore about 60,000 lbf/sq. inch (the stress values on the chart should be multiplied by 1000 to get the true stress, but this can usually be ignored unless the values are used in calculations, for example).

For convenience, the maximum working stress table shown in part two is reprinted on chart 3. From the table, it can be seen that the stress value of 60 (x 1000 lbf/sq. inch) is less than the range of 75-95 given for 'carbon steel, average duty', so a spring made from this metal is certainly within its stress limits. On the other hand, the table shows that the range for 'bronze, average duty' is only 45-50, and less than the value 60 found from the chart, A bronze spring with the same coil diameter and wire size would therefore not withstand a load of 1.6 lbf.

A second example

Spring design work is not always a simple procedure of looking up some parameters on a chart, and I hope that the next example of using the nomogram will begin to give a flavour of what can be involved.

If a IC engine valve spring made from piano (music) wire has to withstand a load of 20 lbf, what would be a suitable combination of the mean coil diameter and wire size? This example is not so straightforward. Here, the maximum working stress depends on the wire diameter, but this diameter can't be found unless the stress is known! Problems like this, though, can be solved with a little initial guesswork, followed by some refining of the design. This is where nomograms win-out over calculations, because the fine-tuning can be done simply and quickly by moving the isopleth over the chart.

The value range in the stress table for 'music wire, ICE valve springs' is 80-110 (x 1000 lbf/sq. inch). The first value in the range, 80, is for 0.08 inch diameter wire. I'll start with an assumption that the spring can be made with wire that is no thicker than this, so the spring can therefore withstand any stress up to 80,000 lbf/sq. inch. Put a rule on chart 3 so that it touches the stress scale at 80, and also the required value of 20 (lbf) on the load scale. Then mark the pivot point where the rule crosses the reference line. Rotating the rule around the pivot point will now show any combination pair of the coil ratio and the wire diameter on the relevant scales. The only limits are that the wire should not be larger that 0.08 inches (14 SWG) - the assumption made above, and the coil ratio should (preferably) be between 5 and 14 (a constrained coil diameter in the required design could further limit the choice). You should find that rotating the rule around the pivot point will give the following wire size and (approximate) coil ratio pairs: 14 SWG/8.5, 15 SWG/6.6 and 16 SWG/4.9. Multiplying the wire size and the coil ratio together for each pair gives mean coil diameters of 14 SWG: 0.68 inch, 15 SWG: 0.48 inch and 16 SWG: 0.31 inch, and any of these combinations would be suitable for the spring in this example (space permitting).

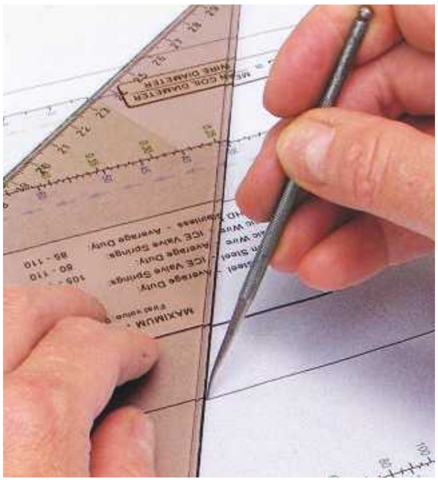
Note, however, that the 15 and 16 SWG wires can withstand slightly higher stresses than the value for 14 SWG used in this example, and this may be helpful in a design. Taking 16 SWG for example: from the wire diameter scale on chart 3, this has a size of 0.064 inches. The maximum stress for this wire size can be estimated from the same 80-110 range (for 0.08-0.01 inch wire) that was used before; I'll use 88,000 lbf/sq. inch (I've actually taken this value from ref 1, fig 6 which is a bit easier to use). Putting a rule between 88 on the stress scale and 20 lbf (the same as before) on the load scale, results in a new pivot point on the reference line which is about ⅛ inch (3 mm) lower than the previous one. If you now put the rule between this point and the 16 SWG value on the wire diameter scale, it will cross the coil ratio scale at (about) 5.6. 16 SWG is 0.064 inches, and multiplying this by the new coil ratio gives a mean coil diameter of 0.35 inches. This is not greatly different from the previous value of 0.32 inches (an internal diameter increase of about 1/32 inches), but this refinement, using the revised stress value, may be just enough to allow the spring to be made from 16 SWG wire when it has to fit around a rod of a specific size.

Further comments

Chart 3 is easy to use, but it would be worth trying many examples on it before attempting some serious spring design work (I found that the results obtained with the chart became more accurate with practice). It's easy to make up exercises, and you could also try the examples in ref 1 (bearing in mind that the results found from the nomogram in the book will differ by as much as 30 percent from those found from chart 3).

There isn't really much more to be said about using the stress nomogram, but I'll just finish the article with a few notes about the chart:

1. Fig 2 (in part one) can be used as a visual guide so that non-SWG wire sizes can be located on Chart 3's wire diameter scale.
2. Readers familiar with logarithmic scales may notice some apparent distortion in the upper part of the coil ratio (C) scale. This isn't a mistake; it occurs because the scale includes an adjustment for the K1 correction factor, and this tends to shift the coil ratio values, particularly the lower ones, upwards.
3. Compared to the nomogram in ref 1, chart 3 uses a different metric scale for the shear stress; that is gigapascals (GPa) instead of newtons/sq. millimetre. Most metric charts now use this preferred unit. One pascal equals one newton per square metre, and a gigapascal is a billion (1,000,000,000) newtons/sq. metre. Newtons/sq. millimetre can be converted to gigapascals by dividing the value by 1000.
4. If you use the chart a lot, the reference line may soon get cluttered with marked pivot points. An alternative method I use is to press a narrow, pointed tool - a scriber for example - lightly against the chart at the pivot point (**photo 4**). As the straightedge is rotated around the pivot point, it can be kept physically in contact with the tool, and this is a very quick and accurate way of using the nomogram.

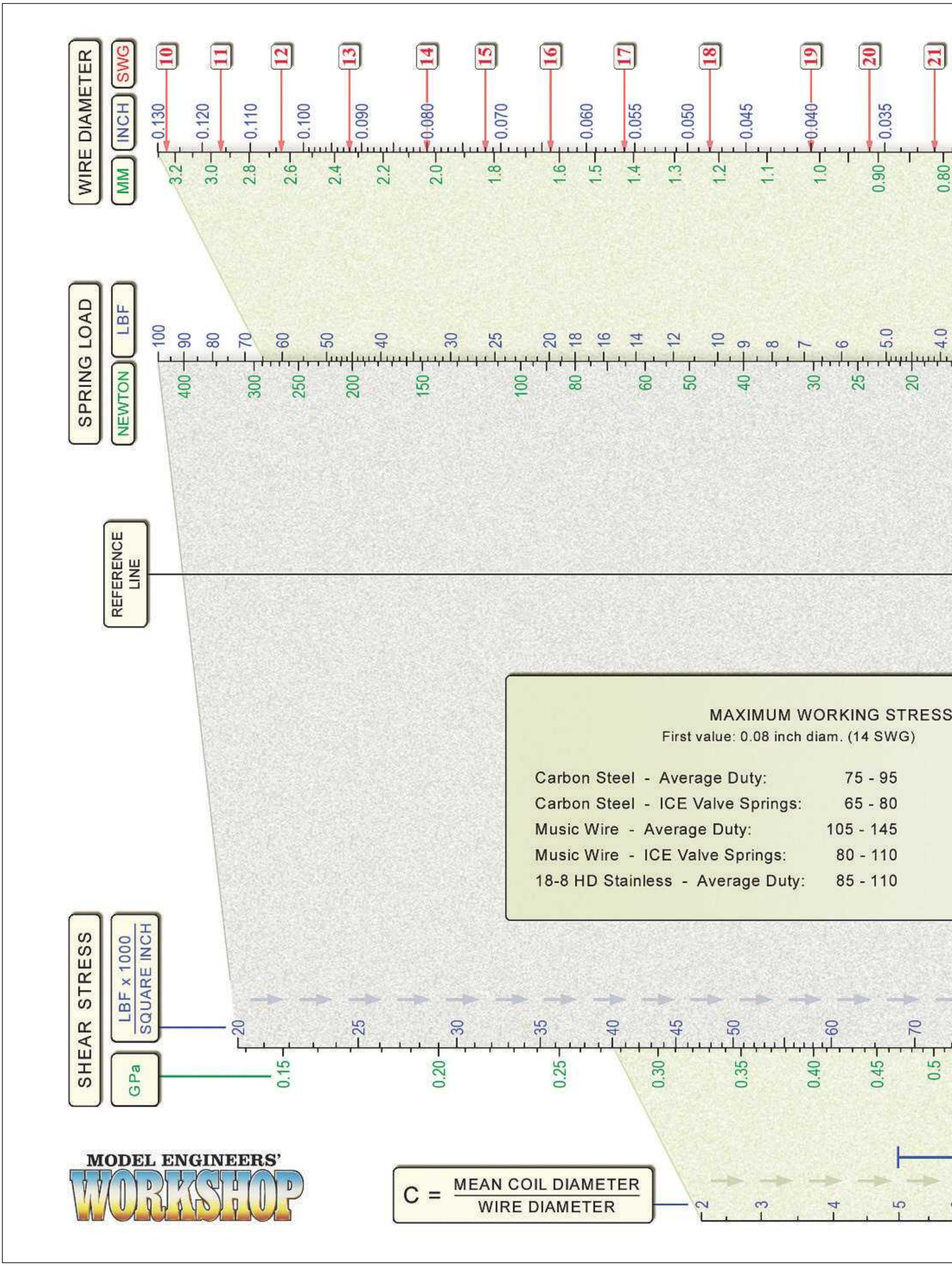


This series will conclude next month with a nomogram to find the spring rate and a spring design example.

To be continued...

REFERENCE

2. Ron Doerfler, *The Art of Nomography*, can be found at this website: www.myreckonings.com/wordpress as both web pages and in PDF format.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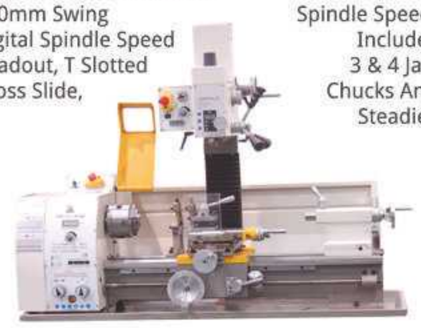

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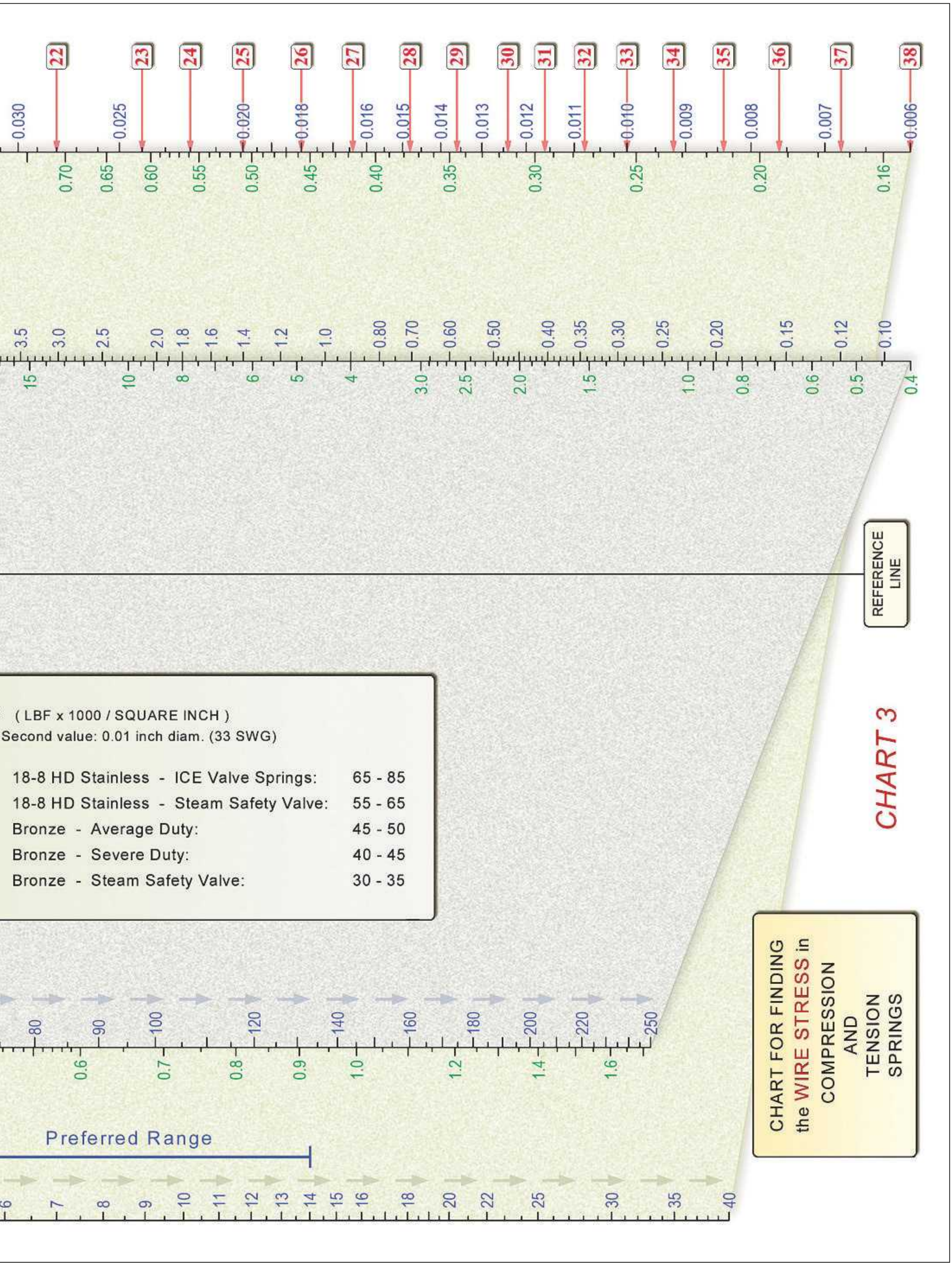
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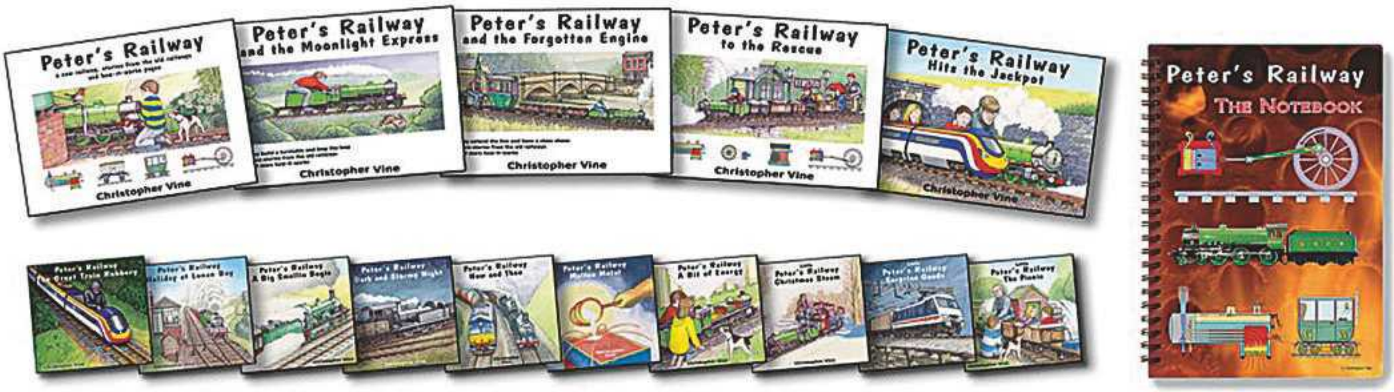
On the Wire NEWS from the World of Hobby Engineering

Books for Christmas and Vogon Poetry?



Chris Vine has been in touch with a reminder that the 'Peter's Railway' series of books make an ideal present for youngsters with an interest in model engineering. He's even written another of his 'wonderful poems', but he says that if enough people buy the books, he won't have to send us a poem next year – so please, get ordering those books!

In response to many requests, Chris has created a new page on the website: **Sets of books and Special Offers**. There are various combinations of paperbacks, hardbacks and gifts which should make ordering easier (and cheaper too!). Please take a look at www.petersrailway.com

"It's Christmas time, but never fear,
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London Model Engineering Exhibition 2015

LONDON MODEL ENGINEERING EXHIBITION

The London Model Engineering Exhibition will return to the iconic venue of Alexandra Palace for the 2016 event, its 20th Anniversary.

The exhibition covers the full spectrum of modelling from traditional model engineering, steam locomotives and traction engines through to the more modern gadget and boys toys including trucks, boats, aeroplanes, helicopters and robots as featured on 'The One Show' last January.

Visitors can travel between the show's different zones, trying the activities and watching fascinating and technical demonstrations.

Over 50 clubs and societies will be present displaying their members work and competing to win the prestigious Society Shield. In total nearly 2,000 models will be on display.

All of the leading suppliers will also be present giving hobbyists an excellent opportunity to see and compare products under one roof. You will be able to purchase virtually anything you need for your next model or project or to get you started in a hobby.

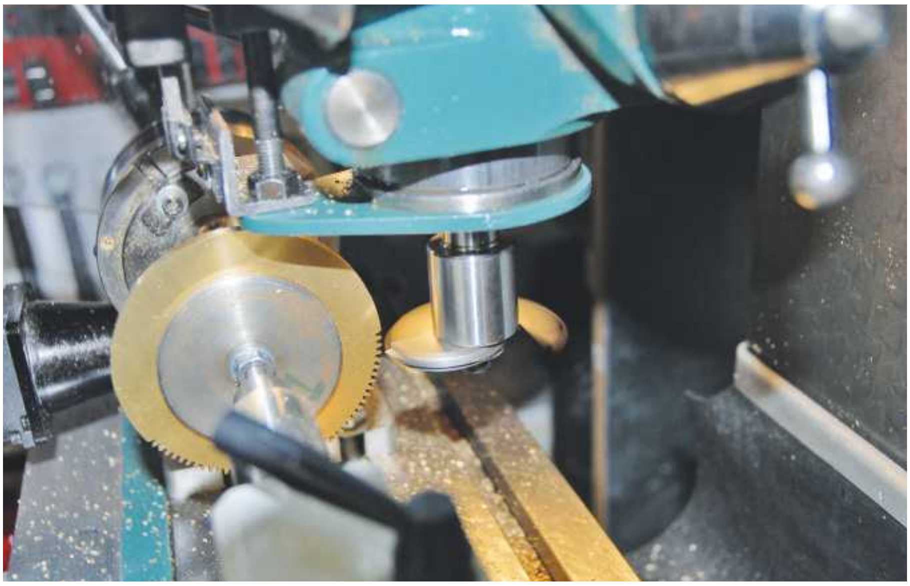
The show runs from Friday 15 – Sunday 17 January 2016. It is open 10 - 5 Friday and Saturday and 10 - 4.30 Sunday.

Adult tickets are £9.50 online in advance and £11.00 on the door, with concessions for senior citizens and children. The website is www.londonmodelengineering.co.uk

Adventures in Clock Wheel Cutting Part 2

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.

Setting up for cutting

Photograph 10 shows the set up for cutting pinions on my Tom Senior Light Vertical machine. It's worth ensuring that everything is set up as accurately as possible when cutting clock gears and pinions. With cutting gears there is a small leeway for error without impacting results but with pinions consider that there isn`t any and you wont be disappointed, a small error off centreline (we are talking .001 or .002 inch) will be quite visible in the results. With your pinion exhibiting leaning teeth.

10

The cutting set up for pinions.

Checking alignments

A rotary table is mounted horizontally along the length of the milling machine bed. A three jaw chuck or (better) a collet system is used to clamp a bar of EN8M or Silver Steel between the rotary table and a tailstock. A tailstock is used to maximise the rigidity of the set up, this will ensure the correct form is generated and achieve the best finish.

Getting the best results at this stage will reduce hours of polishing with abrasive compounds later. For best results check and minimise the radial run-out of the bar stock in the collect or chuck (to within .005 inches or better), ensure that the centreline of both the clamping system and tailstock are the same height and parallel, make sure every thing is clamped down.

The pinion bar stock

The pinion material bar stock should be prepared on the lathe prior to cutting. A smaller diameter is turned on one end where the pinion cutter tool path will start. This will reduce the forces as the cutter feeds in, reducing chatter and minimising poor pinion flank finish by gradually increasing the load on the pinion material. A slight reduction in the diameter of the material at the opposite end also benefits the process for the same reason. Make the bar length enough for several pinion blanks and allow extra material at the start and end of the bar for cutter clearance. Anticipate having to discard the some

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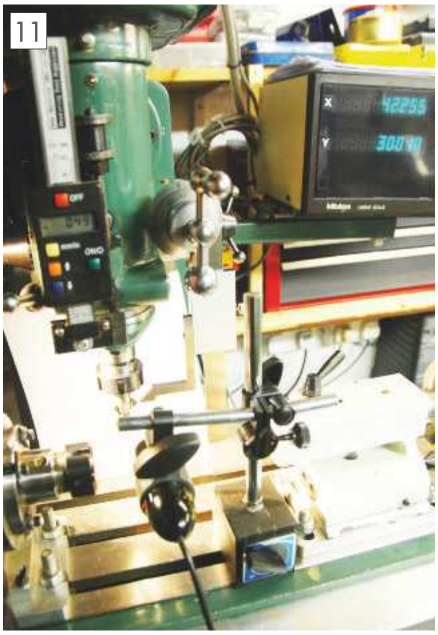


The USB microscope camera used to check centreline height of cutter.

12

Another view of the USB microscope.

pinion material at the front and back of the bar stock as this always has inferior form and finish imparted into it.

The end of the bar stock is centre drilled to enable location of the tailstock dead centre. Incidentally, my tailstock came from a mini lathe but I have adapted it to suit my needs on the milling machine.

Finding the work piece and cutter centreline

Once I was happy with all the jigging alignments, I then used my height gauge to establish the centreline height of the work piece (I.E. overall height - half the diameter of the pinion bar stock). With the height gauge set at the work piece centre line, I set about putting together an impromptu shadow graph, a more modern version that's within the pocket of most model engineers.

As you can see from **photos 11** and **12**, I used a 25x to 200x USB microscope camera. I ditched the stand that came with it and adapted a vacuum hose fitting to clamp the body of the microscope camera onto a standard magnetic based stand. This was used to hold the camera in front of the height gauge and cutter. A piece of white paper is placed behind the objects to help with clarity and definition of the components, using a PC that normally acts as the CNC controller for my milling machine, I focus on both items. (it helps to have them on the same plane).

Photograph 13 shows a screenshot of the USB microscope software. I believe that most microscope camera`s come with software than enable the user to turn on a grid view filter. This is very handy as one can move the position of the pinion cutter up or down in comparison to the grid and milling machine measuring system (in my case a DRO).

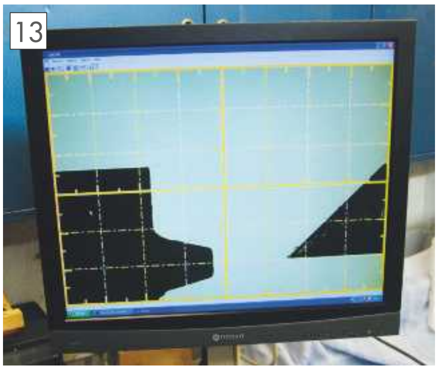
Measure overall thickness of the top land on the cutter and then align the mid point with the height gauge which has been set to centre line height of the work piece and aligned with the grid.

Using this method very accurate set ups can be achieved and this minimises any mistakes or errors.

The cutting process

Photographs 14 and **15** show the pinion cutting process. Initially I manually traversed along the bar of EN8M taking 0.010 inch cuts at a time. After a short while and whilst suffering from arm ache, I resolved to engage the CNC functionality

13



Screen shot of the USB Microscope software.

on my machine and write a short CNC program. I generated a toolpath that had a slow infeed, traversed along the work piece at a feed rate of 50 mm/min and then rapid out to a clearance position.

After cutting two tooth slots I stopped the process, reviewed the top land material that was left on the formed tooth and made my adjustments to depth. The blank was covered in blue marker prior to any cutting in order to help identify any remaining material. I repeated the exercise until all the blue maker was

14

Starting to cut a pinion.

15

Slowly forming the pinion blank teeth.

Softwood polishing wheel and profile cutting blank.

Single blade cutter cutting a escapement wheel.

removed on the pinion tooth top land and then let the process run for the complete blank.

A note of caution, at this stage be careful about any backlash in the rotary table, ensure you always travel to the start position from the same direction. I removed as much backlash a possible from my rotary table but I was still caught out initially discovering that a number of teeth were slightly thinner than the others.

Problems with spindle motor

I used a spindle speed of 150 -200 rpm and a cutting feed of 50mm/min. The spindle motor on my Tom Senior machine is non standard and has a slightly higher spindle speed range than normal. This meant that although the pulley configuration was on its slowest setting the spindle speed was still too fast. The machine is equipped with an inverter for the spindle motor so I was able to adjust it and turn the speed down. Unfortunately, because the motor was not running very fast this had an effect on the built in fan which was not cooling efficiently and I found that I had to allow the motor assembly to cool down before considering cutting the next pinion blank. I partially resolved the situation by placing a copper sheet around the motor to help channel the air and fitted an electric fan on the top of the motor to assist in driving air past the cooling vanes in the motor. Before I next make a clock I have resolved to make some modifications to my spindle assembly adding an additional pulley in line to increase the ratios.

Pinion polishing

Now, like me, before you remove the now freshly cut pinion from the grasps of the collet/ tailstock muttering mild congratulations to yourself on a job well done; think! Pick up Malcolm Wild`s book Wheel and pinion Cutting in Horology and refer to the section on pinion polishing because it is far easier using Malcom`s technique of polishing the pinion with a softwood profiled wheel than by your own hands.

The polishing wheel I refer to is shown in **photo 16**. This shows a newly profiled softwood wheel which charged with a lapping compound is used to remove cut marks and improve the flank finish of the newly cut pinion blank, but this can only be achieved if the blank is not disturbed or removed from the cutting set up.

It is virtually impossible to line everything up again once the pinion blank has been moved. The softwood wheel would of course be set up in the same manner as the pinion cutter.

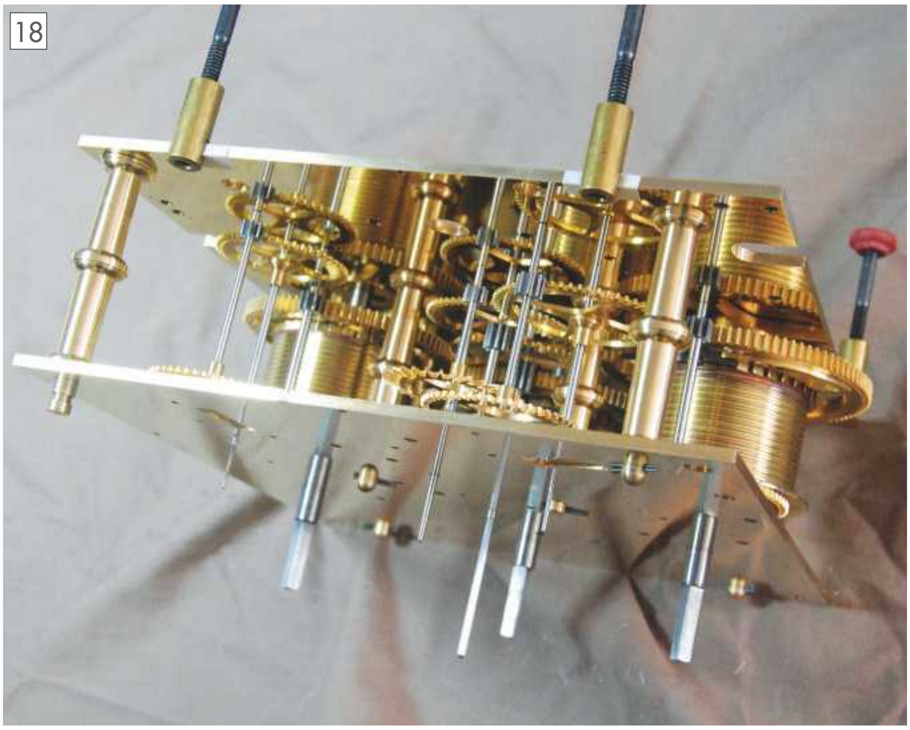
Instead I resolved to polish the unhardened pinion flanks using softwood wedges and valve grinding paste. Indeed in Alan Timmins Making an Eight Day Longcase Clock he goes as far as to saying that lapping by hand is therapeutic - believe me after four of five hours constantly rubbing pinion flanks with ever finer abrasive paste, sore fingers and aching arms its anything but therapeutic!

Clock gear wheel cutting

Setting up for clock wheel cutting with the single blade cutter is relatively easy compared to pinion cutting. I used the set up as described for pinion cutting. The differences are spindle speed and feed rate. Spindle speed should be as fast as possible or in the region of 3-4,000 rpm. I manually fed the single blade cutter into the brass wheel blank taking a full depth cut traversing from one side of the wheel to the other in a nice regular but slow move. This achieved the best finish. **Photograph 17** shows a single blade cutter cutting a escapement wheel.

Summary

As you can see from **photo 18**, my home made cutters worked well and using the techniques mentioned above I was able to make my own clock gears, pinions and escapement wheel. I focussed in this article on the making of the cutters and the set up for cutting, the theory i.e. tooth dimensions and geometry and heat treatment, final finishing and polishing I've left for the reader to delve into the books referred to earlier in my narrative. Both are excellent and describe the topic in a far more detailed but interesting way than I ever could in a short article. ■



Some of the many Clock wheels and pinions cut with my home made cutters.

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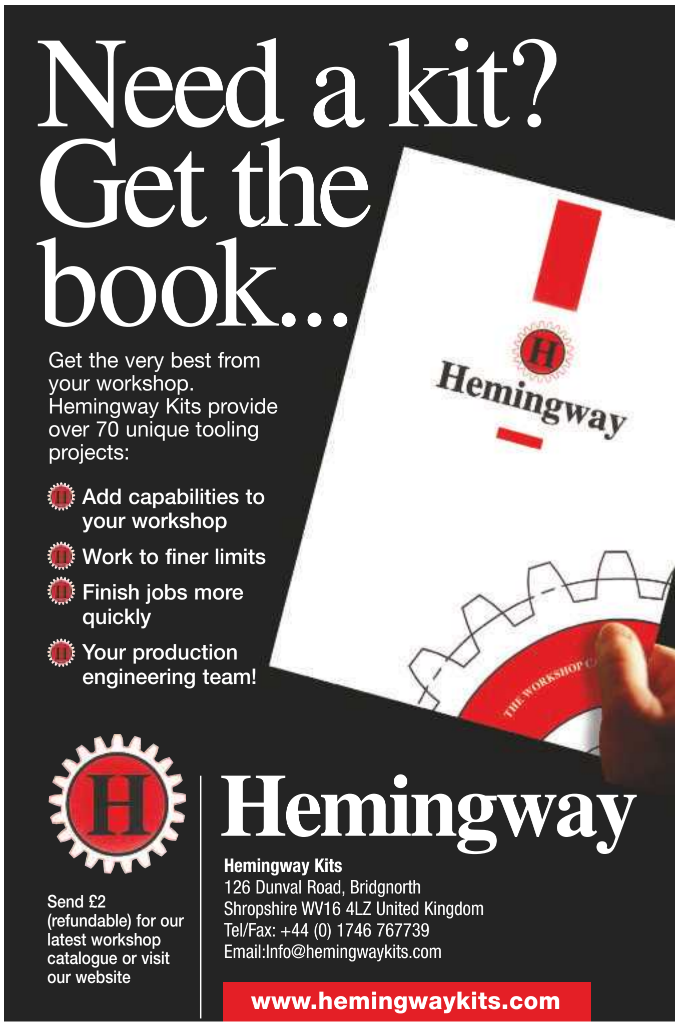

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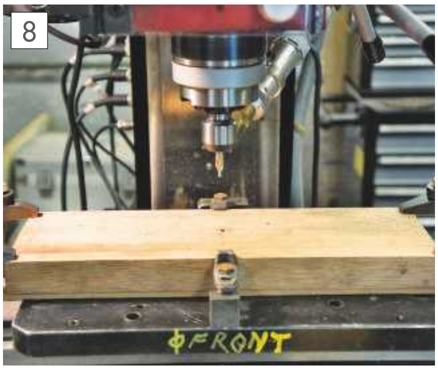
Carols, Cappuccinos and Lofted Solids Part 2

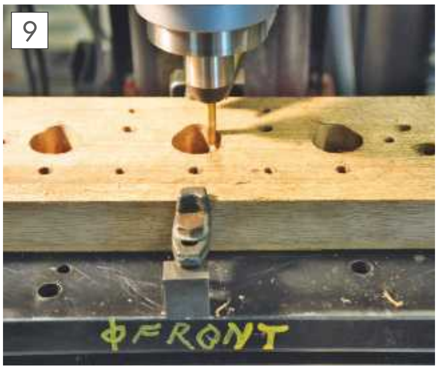
Bob Reeve tackles an ambitious task using CNC.

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!

A rare Carol.



Wooden blank on jig.



Manifold side port finishing.

Profile roughing cut.

Profile finishing cut.

When the programme had been modified to include the additional roughing cut there was first a trial cut of a single port in aluminium (mainly to check feeds and speeds) then it was time for a full size trial of the complete component. I again did this in wood, a rather nice piece of hardwood, rescued from a door frame during recent building works. Wood is a lot less expensive than aluminium as well as being more forgiving in machining trials, but in this case its use was partly with the intention of sanding and varnishing it as a reminder of what would become an insignificant component buried in the engine compartment (**photo 8**).

The machining cycle was lengthy with lots of tool changes. After all the holes were drilled, a 10mm slot drill was used to rough out the ports. This was followed by a 3mm ball ended cutter (**photo 9**) for finishing. A vacuum extract was run continuously to remove the large quantity of chips produced and to stop the cutters machining their own chips at the bottom of the deep pockets.

After the ports were machined, the profiling was done with a long series, centre cutting, end mill. Note the button head screws that attached the component to the jig while the excess material was cut away (**photo 10**).

The profiling included a finishing cut (**photo 11**) with an optional programme stop to allow the excess material to be unclamped and removed for a better photograph. Note the telescopic vacuum nozzle repositioned behind the cutter.

The final operation on the manifold side was to chamfer the profile as shown in **photo 12**.

With the component repositioned engine side up, the first operation was the chamfering, because the cutter was still in position. Then the ports were machined to the tri-lobed shape (**photo 13**).

The roughing cut appears to be cutting into a solid area but in fact there is a thin surface layer just covering the ports where the cutter did not quite break through from the other side.

As can be seen from **photo 14**, the trial was successful with only a few minor changes required to add and remove some optional spindle stops and tool changes. After sanding and varnishing the engraving was a somewhat tongue in cheek addition!

So, days had turned into weeks and then months but the time had finally arrived to machine the component. The aluminium plate was marked out approximately to ensure there was sufficient material round the profile to clamp on. The hole marking the centre of the middle port was drilled for location on the jig (**photo 15**) and the plate, positioned by the pin, then clamped, down with a sacrificial layer of 8mm MDF underneath as before.

Note that the clamps have been recessed to give more clearance for the cutter when the bottom of the pockets and the bottom of the profile were being machined (**photo 16**).

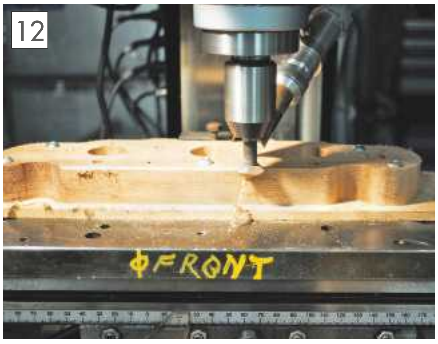
With the locating pin removed machining began with the centre drilling of the manifold fixing holes. When all the holes had been drilled it was time to start on the ports (**photo 17**).

Photograph 18 shows the last of the three ports being roughed out. Then all three ports were finish-machined with a 6mm ball end slot drill, starting with the centre port (**photo 19**).

All went as it should, except for occasional slight rubbing where the cutter shank just touched the side of the previously machined hole. Not enough to mar the finish of the ports so the machining of the tear-drop shaped ports was declared successful and profiling could begin (**photo 20**). Note that the path of the cutter will pass between the end of the left clamp and the button head fixing. I needed the confidence of the previous full size trial to do this with so little clearance!

At about halfway down the profile things went seriously pear-shaped. The programme stopped for no reason that I could see. It took an hour or so of investigation to find that one of the spindle motor brushes had worn out and so had the cutter. Fortunately I had spares for both; unfortunately, when the motor was started up again, it rapidly overheated and smoke appeared from the ventilation slots. The last rites were performed and I went in search of a replacement motor.

To make matters worse, it was now late on a Friday afternoon. Fortunately not too late to get in touch with Arc Euro Trade and talk to proprietor Ketan Swali about a



Profile chamfering.

Engine side, port roughing.

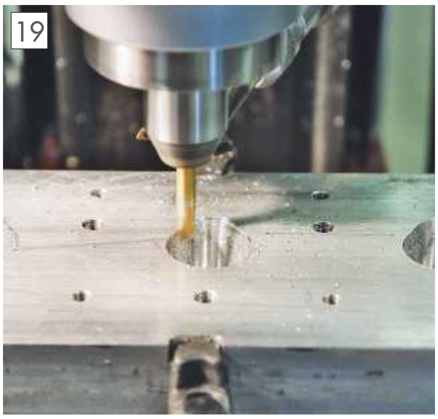
Finished component in wood.

Setting the aluminium blank.

Drilling reference pin holes.

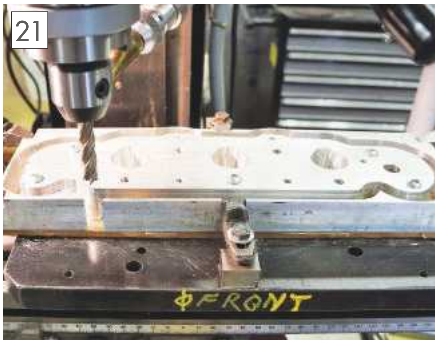
Rougfhing the centre port.

Two down one to go.

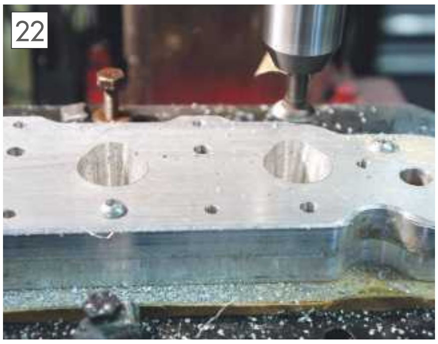


Manifold side finishing cut.

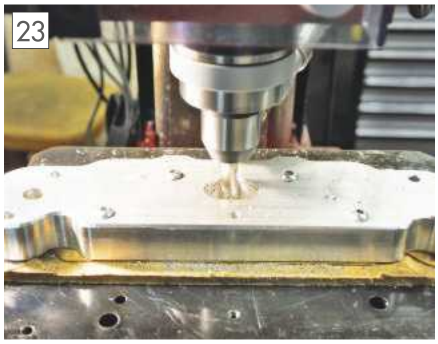
Starting profile.



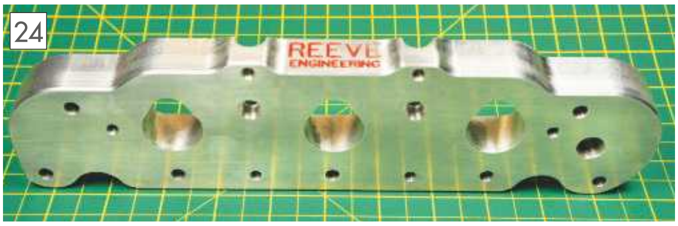
Finished profile.



Chamfering manifold side.



Starting engine side ports.



Finished component, manifold side.

Finsihed component engine side.

replacement. There was one in stock and he enquired how old the defunct motor was. We concluded that this was one of the very early brushed motors which had been replaced by a modified version. Again I was lucky that it was a straight replacement, no modifications needed. I am within driving distance of Arc Euro Trade so I was off first thing on Saturday to pick it up. It turned out to be one of the wettest drives ever, with torrential rain all the way there and most of the way back. But I did get a tour of the facilities and an in depth discussion on X3 spindle drives from a very knowledgeable source, as well as the replacement motor. I departed with some good advice, to the effect that running a hobby machine for 5 hours continuously is not to be recommended! Thanks Ketan.

By Sunday the X3 was back up and running. The work offsets were OK and all I had to do was re-set the tool offset for the new tool. Then the 'Run from Here' facility in Mach 3 enabled me to continue with the profiling. The finished profile can be seen in **photo 21**.

The last operation on the first side was to chamfer the edges. I have always thought that this is one of the things that CNC does really well. The result is shown in **photo 22**.

It was then time to turn the job over and start on the second side. Again the chamfering was done first because the tool was already set up from the last operation. Then the tri-lobed ports were roughed out (**photo 23**) and finished with a ball ended slot drill as before.

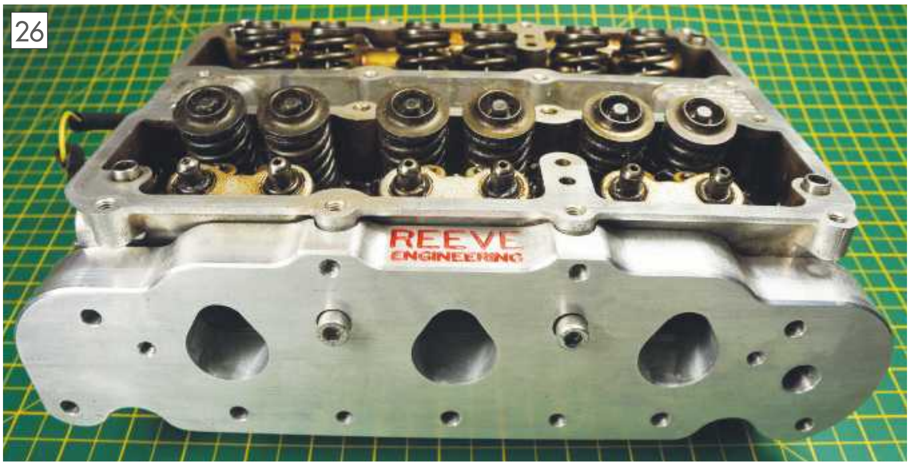
After engraving a 'maker's plate' and machining the relief for the cam box stud locations the result was as in **photos 24** and **25**. As can be seen the smooth transition from one port shape to the other is achieved within the thickness of the plate.

The last remaining task seemed to be a trial fit onto the head. **Photograph 26** shows all was well. **Photograph 27** is the adaptor plate with the six stainless studs ready to bold on the inlet manifold, plus a pipe ready for connection to the cooling system.

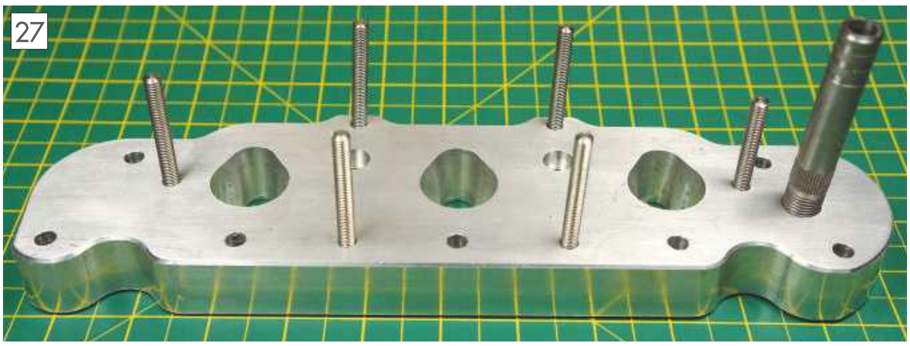
At this point the plate and its fittings were carried off by the intended recipients and I set about cleaning up the workshop thinking it was all done and dusted. About a week later I had a phone call to the effect there was another problem. It had originally been intended that the Carol exhaust manifold would be used but, as you may have guessed by now, it would not fit!

The fly in the ointment was that the exhaust gas recirculation (EGR) system could not be connected. For those not in the know, this is a cunning means of reducing the NOX content of the emissions. It works by reducing the amount of oxygen available for combustion at times when the combustion temperature is likely to be high enough to produce these emissions. The effect is to lower the combustion temperature and so reduce their formation. Typically this might be when the mixture in the cylinders is lean, e.g. on a trailing throttle. However the exact demands for EGR vary from engine to engine and there is a valve provided to control the amount admitted.

The Cappuccino exhaust manifold (**photo 28**) was now needed because of the integral connection to the EGR system. There is a cast in gallery connecting the left port to the small hole on the extreme left. Note the rather coked–up condition of this, which is one of the main reasons EGR systems suffer from unreliability.



Trial fit.



Manifold side fittings.

Cappuccino exhaust manifold.

Positioning on rotary table.

This was designed to connect with a cast-in port passing right through the cylinder head so that a connection could be made with the EGR valve mounted on the inlet manifold of the Carol. This connection can be seen poking out bottom right of photo 5. However, the adaptor plate was designed to blank off the port for exhaust gases where it emerges from the head on the inlet side.

The problem was exactly how to connect the EGR valve to the plate just produced. A straight through connection was difficult because of the proximity of the inlet manifold and its associated plumbing. A connection out sideways would be too close to the EGR valve connector. The best options appeared to be upwards at about 10 o'clock or downwards at about 5 o'clock when viewed from the inlet manifold side. With either of these there was barely sufficient material to accommodate the existing style of connector based on a hollow nut tightening on a formed end of a steel pipe.

After some head scratching an adaptor was devised that would screw into the adaptor pate (⅜ inch BSP) and have a socket at the other end that would accommodate the existing style of connector. With a little care the 10 o'clock option would just allow the existing connector pipe to be straightened and re-formed to fit the new layout.

The position corresponding to the EGR port in the head was marked out on the adaptor plate which was then set up on the rotary table. With this set up on my Thiel milling machine, the vertical spindle would produce a flat bottomed blind hole (same diameter as the EGR port in the head) then the horizontal spindle would make the cross drilling for the adaptor at the 10 o'clock position.

Photograph 29 shows the set up, with my trusty sticky pin on the end of the centre drill which will start the blind hole. Note the parallels that were to give sufficient clearance for the drill chuck when machining the cross hole. **Photograph 30** shows the cross drilling in progress and **photo 31** shows a 1 inch slot drill used to produce the flat surface which the adaptor was to seal on.

The adaptor proved more difficult than expected because it needed a 90 deg male conical seat at the bottom of a hole threaded for the hollow nut. I contemplated making a form tool, but funny profiles down small holes is what Model Engineering is all about. I machined the required form with a slim boring bar. However, in the absence of an endoscope, photographs were not an option.

After a bit of iron fighting, to straighten the connecting pipe and to re-form it to fit the new set up, all was ready for a trial fit. There were, in fact, quite a few trial fits but the result can be seen in **photo 32**. The adaptor has been chemically blacked and can be seen screwed into the adaptor plate.

The connecting pipe can be seen running from the adaptor to the EGR valve on the right. Note the cast-in port for the exhaust gas which forms the chevron shape on the end of the cylinder head.

The completed components went off to be installed in the Carol a while ago. So far there have been no further requests for assistance. Let it continue to be so!

In retrospect

This was probably one of the most difficult things I have ever machined. But I think I might use lofted solids again for shapes not achievable with conventional milling. I was particularly impressed by the smooth blending of shapes that was possible

I had not used BobCAD before and was impressed by its capabilities. However, the price tag is probably too high for hobby software and I don't expect to be getting a copy unless there are some very special offers. ■

Horizontal spindle drilling cross hole.

Spot facing.

Completed EGR installation.

One Man and his Lathe

Gary Wooding and his Chester 12 x 36 Lathe

Gary Wooding describes one of the larger imported lathes to be found in hobby workshops.

My first lathe was a second-hand Boxford 4½ inch centre height CUD, which I purchased to help create tools for making hand-made jewellery. When I retired from my full-time occupation as a software developer with a well-known computer company I joined the local REMAP panel. In case you don't know, REMAP is a national charity that designs and makes items, free of charge, for disabled people. The only caveat is that they are not available commercially. This work can be rather mundane, but, at times, very challenging. I soon found a limitation with the Boxford; the spindle bore was too small. I needed a bigger lathe.

1

The Chester 12 x 36.

2

Camlock back plate.

3

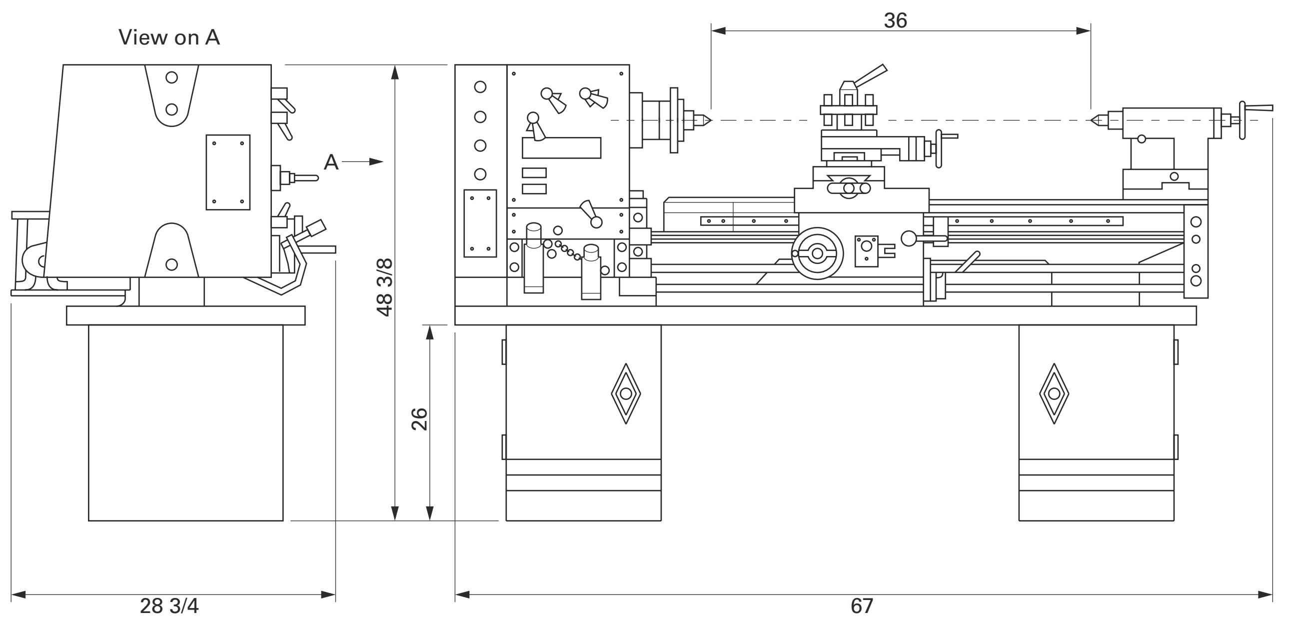
Special pool chair for REMAP.

I looked around and finally decided on the Chester 12 x 36 Geared Head lathe. It's a rather large lathe for a home workshop, with a 6 inch centre height; 1½ inch spindle bore, 36 inches between centres, and weighs 450Kg. **Figure 1** shows the dimensions.

My workshop is in the cellar. Armed with photographs and dimensions of the cellar steps I took a trip to the Chester Machine Tools' showroom. My initial thought was that, with the head and tail stocks removed, a couple of friends and I could man-handle the individual parts down the steps. This hope was dashed with the news that, if the headstock was removed, there was very little chance that it could be accurately replaced. Chester's advice was to contact a local machinery moving company to request a quote for transferring the lathe from my garage (the delivery point), around three sides of the house, through a rear door, and down the steps into the workshop. In due course a guy arrived. He examined the Chester brochure and took various measurements.

The verbal estimate was acceptable so I placed my order, only to receive, a few days later, a written estimate that was far too high for my budget. Panic set in, but, with a lot of planning, and help from my Model Engineering Club (which I had recently joined), the lathe was eventually installed into my cellar workshop. The 12x36 Geared head has now been superseded by the Crusader DeLuxe.

Fig. 1



The lathe has an Imperial lead-screw, screw-cutting gearbox, power drive to both axes via a separate drive shaft, and is very well equipped; with 3-jaw self-centring and 4-jaw independent chucks, fixed and travelling steadies, tailstock chuck, fixed centres and the usual toolbox and change gears. I also added the optional vertical slide since I didn't have a mill at the time. It also has a gap bed, which I've never actually used. **Photograph 1** shows the (well used) lathe in its present condition.

It also had an entirely different method (to me) of attaching the chuck: a D1-4 Camlock mount, which not only makes chuck changing quick and easy, but completely eliminates any possibility of it unscrewing when running the lathe in reverse. The mount consists of a short tapered flange projecting from a flat base that contains 3 sockets, each containing an eccentric cross-pin that can be turned by the standard chuck key. The chucks and backplates have three studs that fit into the sockets. Each stud has a semi-circular cut-out which engages with the cross-pin which, when turned, pulls the chuck securely onto the mount.

The 3-jaw chuck didn't come with the usual second set of reversible jaws. Instead, each jaw is comprised of two rather nicely machined parts which are bolted together and fit perfectly. One part is a carrier that is directly connected to the scroll; the other part is the actual holding part of the jaw, which can be reversed to provide the facility of reversible jaws. **Photograph 2** shows the Camlock mechanism and one of the jaws with the parts separated.

In use it turned out to be very accurate indeed. The first major task for which I used the lathe was a REMAP job: a pool chair (see **photo 3**). This was a special type of wheelchair used to carry disabled people into a heated therapy pool. Since the water was heavily chlorinated and maintained at blood heat the chair was made from stainless steel. Some parts had to be made from 1.25 inch bar and some from 1 inch, but since it was cheaper to buy one 2m length of 1.25 inch rather than 1m of each, it was decided cut the larger bar in two and turn one half down. One end was held in the 3-jaw with the other supported by a live centre. The job was then swapped end-for-end and the remaining section machined. It is a tribute to the machine that there was no more than 1 thou difference along the length and the transition between the two sections was barely detectable.

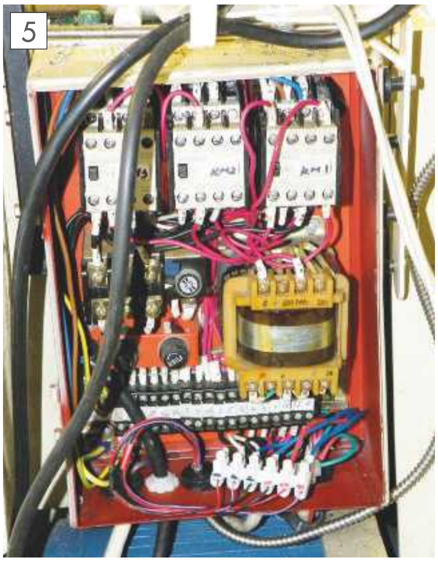
T-slots on cross slide.

I soon became frustrated with the supplied 4-way tool-post and replaced it with a Dickson Quick Change. I then started a collection of tool holders. I use a Kit-Q-Cut parting tool from Greenwood tools, and preferentially, a homemade tangential tool holder for most facing and turning. I also use the CSMT insert in a Greenwood holder. Other holders have various boring bars, form tools, and threading tools.

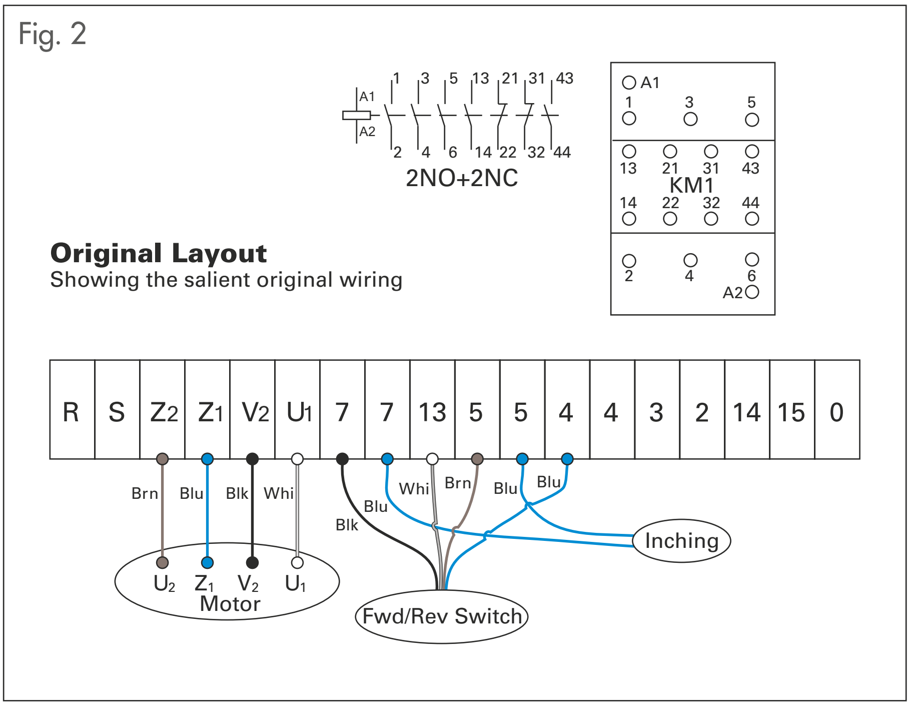
The first modification to my new Chester was to install the easily detachable BW Electronics wire DRO (Digital Read Out) system that I'd removed from the Boxford. Each sensor consists of a small box that houses a coil of thin cable that exits via a protruding tube. The box contains the electronics that measure how much cable has been unwound. It works very well. The tube guides the cable and, by snapping into a pair of standard cable clips, provides a simple method of mounting the sensor. A major problem was that the X-axis sensor extended beyond the cross-slide and fouled the rear splash guard when the cross-slide was at its maximum travel. I fixed this by making spacers to move the splash guard back; one such spacer can be seen in photo 4, which also shows the X-axis sensor and the display. I also fitted a Z-axis sensor to the bed and a sensor to the vertical slide.

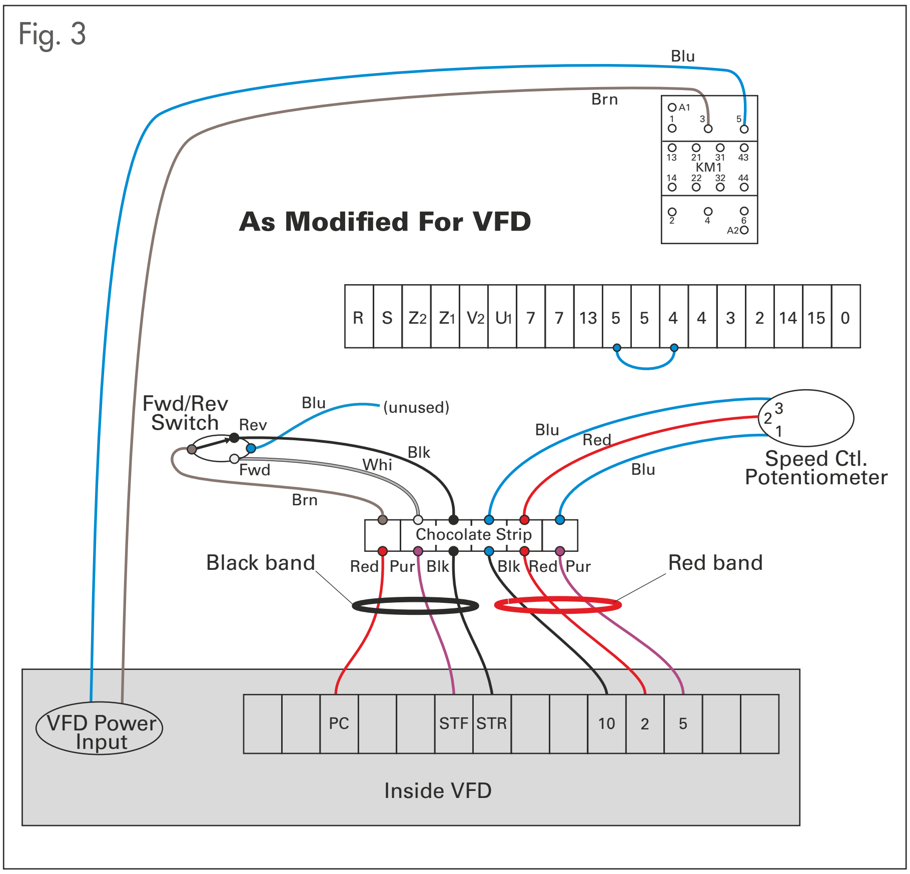
The next big alteration was to the cross-slide. I used a friend's mill to cut the two T-slots that can also be seen in **photo 4**. This made it much easier to attach the vertical slide.

For screwcutting in the Boxford I'd made a mandrel handle that gripped the interior



Inside the control box.





of the spindle bore. Initial plans were to make a similar one for the Chester, but the 38mm bore kept putting me off. Eventually I decided on a very different approach: variable speed. To this end I scoured a well-known online auction site and eventually bought a suitable 1.5hp 3ph motor and a Mitsubishi VFD (Variable Frequency Drive - also known as an inverter) at very reasonable prices. I encountered no problems in replacing the motor – it was just the right physical size, but fitting and wiring the VFD was another story. I have an aversion to drilling unnecessary holes in machinery, so I mounted the VFD on a metal cradle which was attached to the head-stock by some strong magnets. My objective in fitting the VFD was to end up with a lathe that was used and operated exactly as before, but with the addition of a speed control knob.

Using the mains switch to supply power to the lathe does nothing except make the main power button active. Until this is pressed, nothing happens, but pressing it illuminates a green light. When the green light is on, moving a saddle-mounted lever up or down energises the chuck backwards or forwards. I didn't want the VFD to interfere with this basic operation.

There is a box on the back of the headstock that contains the various relays and switches that control the lathe electrics and interlocks. The wiring diagram in the supplied manual was rather daunting, so I decided to open the box. The interior was even worse, see **photo 5**. After much head scratching I decided to use a multi-meter to trace what happened when the power button was pressed. I discovered that terminals 3 and 5 of Relay KM1 became live, and pressing the Emergency Off button turned them off again. Further tracing identified how certain terminals in the labelled strip at the bottom of the box were connected to the forward/reverse lever, etc., **fig. 2** shows a schematic of this.

Figure 3 shows the original wires from the terminals of Relay KM1 replaced by two new wires to the VFD power-in sockets. There were four wires from the forward/reverse lever but I found that I didn't need the blue wire because it was for switching the motor OFF, a function performed automatically by the VFD. The remaining three were connected to the new chocolate strip that can be seen at the bottom of photo 5. The original two blue wires from terminals 7 and 5 to the Inching lamp in the original layout were used to connect to the speed control potentiometer which replaced the unused inching lamp on the front panel. **Figure 4** shows a speed dial that I created on the computer and stuck to a blanking piece that covered the hole left by the inching lamp and supported the potentiometer. The potentiometer needed a third wire; this is the red one in the modified layout. These three wires were connected to further terminals of the chocolate strip. The last remaining modification was to connect terminals 5 and 4 of the original strip together. The other side of the chocolate strip was wired to the control terminals of the VFD, shown schematically by the strip along the bottom marked PC, STF, STR, 10, 2, and 5. Because 6 different wires had to be taken from the chocolate strip in the control box to the control terminals of the VFD, and I only had three different coloured wires, I made two groups and identified them by black and red bands of tape.

Upon completion, everything worked exactly as it did before, plus I could change the speed by simply turning a knob. In fact, it was so successful that my friend with the Crusader lathe has done the same update to that.

It was when I needed to cut a metric thread that I found my only disappointment with this lathe. The manual gives a table of the various metric threads that can be cut with the supplied gears. I needed to cut a 12x1.75mm thread, when I checked the maths I found that it was a rather poor approximation at 1.77mm, which is almost 1.2% too big. The best approximation was +0.06% and the worst was -2%. I intend to get some more convenient change-wheels. The friend with the Crusader reports that it has a superior gearbox that cuts accurate Imperial and metric threads.

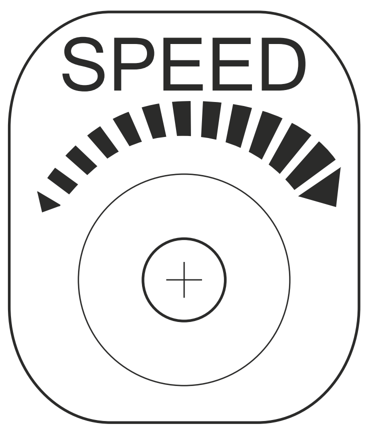
The later machines come with a 2-axis DRO fitted. As mentioned above, I transferred the BW Electronic's wire system from my Boxford, but there was a problem: the bed of the Chester was considerably longer than the Boxford's. I forgot this too many times when moving the saddle too far to the right and snapping the Z-axis cable. Repair deprived me of the DRO to which I had come to rely, plus it started to get expensive. I sold the entire system to a friend, where it continues to give good accurate results, and purchased a glass-scale unit from MACHINE-DRO.co.uk.

Fitting the scales involved the usual head scratching for deciding their placement. The Z-axis, along the bed, was relatively straight forward, requiring only careful measurements and a few drilled and tapped holes. The X-axis was a bit more of a problem. Placing it on the left of the saddle would expose it to the usual swarf and detritus from cutting metal, and placing it on the right would cover up the cross-slide locking screw, as well as exposing the scale to possible damage from the tailstock. In the end, I placed it on the right of the saddle, replaced the cross-slide locking grub-screw with a thinned hex head screw, and used spacers to offset the scale sufficiently for an open-ended spanner to operate the lock screw (**photo 6**). A simple hex head screw underneath the scale sensor acts as buffer to stop the tailstock from damaging the scale. (Incidentally, the scale fitted to the Crusader covers the saddle-lock). At this point I thought I'd cracked it; but I was wrong. I couldn't access the saddle lock properly, which consisted of a special bolt with a square head and a captive washer. Although it was not covered by the scale, there was not enough space around it to swing the spanner. The solution was to replace it with a long socket headed bolt with a captive washer half-way along (**photo 7**).

Photograph 8 shows a model of an early BRM racing car, made by a friend, for which I turned the wheel hubs, rims, and brake drums on the lathe.

It's very useful having a large lathe. The large spindle bore means that most bar stock can be turned without having to saw it into short lengths, thus minimising waste, and its mass makes it very rigid. Would I buy another one? Yes I would, but I can't deny that I'd prefer the Crusader with its superior Imperial/metric gearbox. ■

Fig. 4



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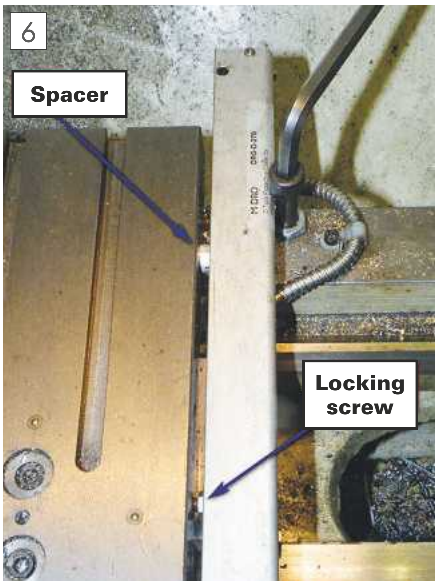
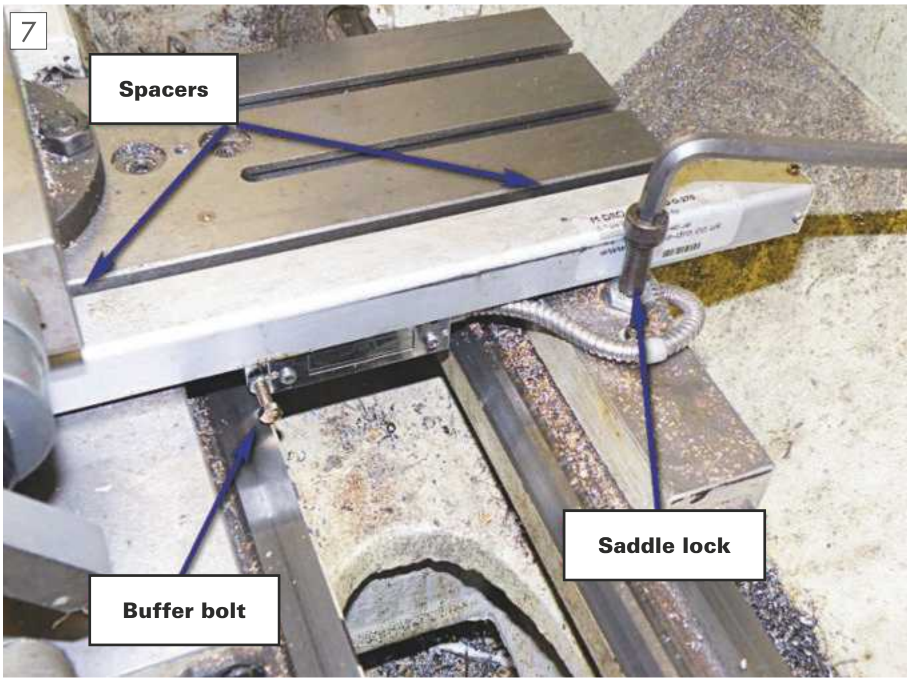


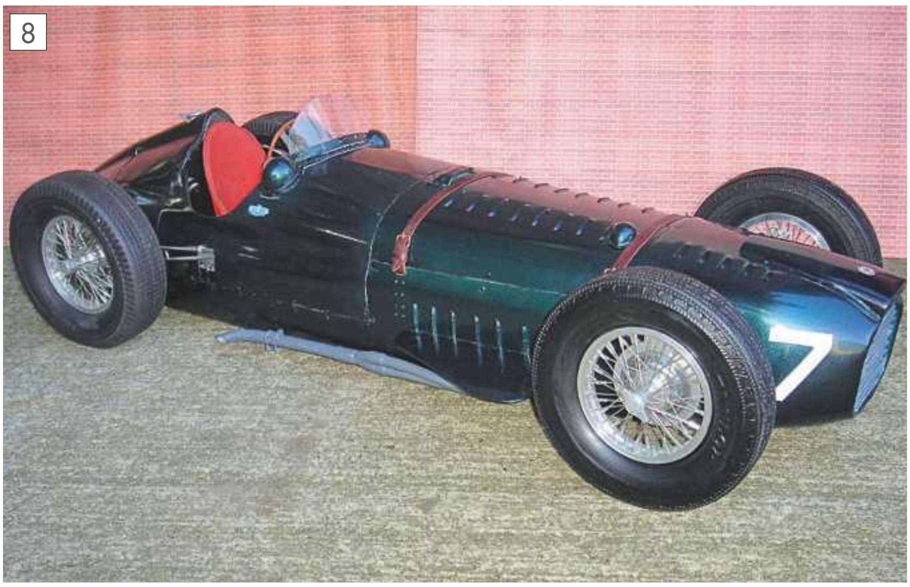
Fitting of x-axis scale.

7



Another view of the scale arrangement.

8



BRM racing car with wheel parts turned by the author.

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Scribe a line

YOUR CHANCE TO TALK TO US!

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

Myford 254 gearcutting

Dear Neil, as we outside Blighty receive our issues at a somewhat delayed time this may seem tardy.

Duncan Webster's solution to regearing his Myford for pitches not include by the manufacturers in the original design is reasonably clever and of interest to me as one of my major interests is gears and what you can do with them. I have an alternative solution which might be of interest:

Problem: Regearing the end gears from the stud to the screw gear for threads which have been put in the 'less required' category by the manufacturers.
Required ratios: 2/3, 4/3, 1/1.
Gears evidently supplied by Myford: 30, 40, 60, 90.
Additional gears used by Mr. Webster: 40, 50, 50, 60.
Drawbacks to Mr. Webster's solution: Extra intermediate stud, causing a double reverse in the train as well as an extra interface, and trusting to precision equality of spacing between 50/50 and 60/40 gear sets, which has led him to leaving the clarance adjustment alone when changing from one to the other.
Mr. Webster's 2/3 solution: 40 > 60 > 60, followed by 50 > 50..
Mr. Websters 4/3 solution: No solution offered, presumably pitches greater than 2.5 mm not frequently required by him. Perfectly acceptable approach.
Mr. Webster's 1/1 solution: 40 > 60 > 60 > 40.

Let me offer a couple of alternatives:
My 2/3 solution: 30 > 90 > 45.
My 4/3 solution: 60 > 90 > 45.
My 1/1 solution: 45 > 90 > 45.

Admitting Mr. Webster has solutions for 2 out of 3 of the required setups and already has the required hardware, my solutions have certain benefits:

- Screw gear remains the same for all setups.
- Idler remains the same for all setups. This and the one above allow one time clearance adjustment.
- Change only the stud gear, then adjust the gear clearance properly. (Yes, I know it requires clearance adjustment, a bane for Mr. Webster, but it ought not to be ignored.)
- Requires only a 5 gear set, instead of 8, additional two 45 tooth gears, readily available.
- A simple 3 gear train, no compounding, which reduces disassembly and reinstallation issues if occasion arises for some odd pitch, say TPI, BS, DP, Module, etc.
  (If you like small gears make the setups 20 > idler > 30, 40 > idler > 30, and 30 > idler > 30.)

While I expect Mr. Webster will keep his setups, as reported, I thought an alternative approach which has some benefits would be worth offering.

Anthony Rhodes, Berkeley, California, USA

Alcan's Die Sinker

Dear Neil, thank you for your help. Today, I have now donated it to the historical machinery exhibition a Tooley's Boat yard Banbury. I will send you some pictures when it is part of the display. My thanks to the readers who kindly got in touch with me about the machine.

Paul Boscott, Banbury

Readers will recall that Paul has been seeking somewhere that would conserve this veteran machine, Ed.

Tray Cool

Dear Neil, Please see the attached photo of my swarf tray solution. Spurred on by Phil Bellamy's comments regarding his swarf covering, I offer my own design to keep swarf under control. It is a length of discarded aluminium Venetian blind slat, carefully crafted to form a seal onto the cross slide.

Steve Middleyard, by email

Heading please

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

Graham Astbury, Skipton

Discussing Degaussing

Dear Neil, The Demagnetiser project in issue 234 looks to be a useful gadget reusing an existing transformer, I always like things that can be reused/recycled. However there a few safety items that should be addressed by any builders:-

Tying a knot in the supply cable is not a good idea and is not an acceptable as cable anchor in many jurisdictions. Also taking a cable through a drilled hole is also not a good idea, needs a grommet to protect the cable from chafing. However there are cable glands available which provide a rubber cushion around the cable and lock it very securely at the same time. Just drill a hole in the box and lock it in place with the nut provided. Then put the cord through it and tighten the cable locking nut which compresses the rubber liner onto the cable to hold it, easy quick and safe. These should be available from electronics places anywhere but mine come from Jaycar in Australia Cat No HP0724 (no connection except as a happy customer).

If a light bulb is used as a current limiter, a technique often used by electronics service people, the bulb should be covered to protect it against breaking (especially in a workshop like mine). Not only is the broken glass a hazard, but the wires on the end of the broken filament are live and potentially lethal, we need to keep all the Model Engineers fully functioning!

While I have not tried it, and I am short of time at the moment so can't try it now, an old fashioned fluorescent tube ballast is simply a current limiter for the lamp and should do the job. These are easily found in old fittings and have a range of wattages, so an appropriate one can be sourced. The ballast could easily be put into the box with the modified transformer and if used intermittently for short periods ventilation should not be needed.

While it is not really a serious safety issue, I would usually fix the terminal block with a screw holding it neatly in place in the box.

Lastly if anyone uses a metal box, the supply cable needs to be 3 core and the earth wire properly terminated onto an earth screw into the box wall to earth the box. Personally I think the original plastic box is a far better option, especially as eddy currents could be generated in the metal by the magnetic field.

Hope this is helpful to potential builders of a good simple project.

Arthur Davies, Canberra, Australia

Readers will recall that Mike Cox's solution for protecting the bulb was raised in our previous issue – Ed.

2016 Model Engineer Exhibition

Dear Neil, I was very interested to read about the new venue. I have been to Brooklands a few years ago and found it very interesting. I think the combination of the two will be just perfect, and I shall be there if possible. I usually visit the Bristol exhibition, which is good, I live near Exeter, so not so far to go!

Yours sincerely C. Rowcliffe

Live steam locomotives at the 2014 Model Engineer Exhibition.

Backyard Builders

Dear Neil, I am part of the casting team on a brand new BBC Two series called Britain's Most Spectacular Backyard Builds, which is celebrating Britain's most passionate inventors, makers, engineers and tinkerers.

This is a programme for anybody who loves to create their own inventions, whether that be an 8 year old science fanatic or an 80 year old hobbyist inventor, we want to find the most passionate and creative backyard builders.

Up and down the country, extraordinary things are being made, from back garden rollercoasters to homemade helicopters. They are built with passion and created with purpose and now BBC Two are delving into their world to document the most passionate and most magnificent makers in the UK! This is a celebration of engineering, invention and innovation and this is a great opportunity for hobbyist inventors, engineers and makers across the country to take part in something magnificent.

Filming for the series will take place between January - March 2016 and those who take part will only be required for between 1 to 4 days.

For those who are interested, they can email the team on makers@rdftelevision.com or visit the BBC website to download an application form http://www.bbc.co.uk/showsandtours/takepart/most_spectacular_backyard_builds

Davinia Richardson, RDF Television

Turn of the Screw

Dear Neil, you recently published a table of engineering screw threads, how about something for wood and self tapping screws? There are bewildering number available, from our old Imperial friends to the more modern self drill type. Surely it is possible to tabulate these.

I suggest:

- Head (csk, round, raised, mushroom)
- Designation (O/D threaded portion, length of plain portion, pilot drill (soft or hardwoods or plastic, for self taps metal gauge)
- Head, slotted, cross point. hex,
- Availability:- Steel, japanned, zinc plated, stainless, chromed, brass, etc.
- Head dia. (in case a wooden cover plug is to be employed.
- Spiral available, single, twin, quick thread, pointed or blunt for self taps.
- The above is not comprehensive, but I cannot think of more variants.
- A compiler? No idea, the late Tom Walshaw was considering it when he died and Harold Hall used to be good at such things.

I never got time to get it put into *MEW* or *M.E.* but would like to have seen it done if an enterprising reader could produce such a table.

Ted Jolliffe

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

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 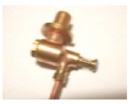    

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The Sieg X3 vertical milling machine is deservedly popular as it offers excellent value for money; it also offers many opportunities for improvement. One of these involves replacing the final drive gears with a belt in order to reduce noise and vibration. This article describes the design and manufacture of an HTD belt final drive for the X3 mill. The design stage was also an exercise in 3D CAD that demonstrated some of the advantages of this method.

The finished HTD belt drive.

David has produced 3D models of the X3 gearbox and some of the critical dimensions. Naturally these are a bit difficult to print in the magazine, so we will be making them available on the website www.model-engineer.co.uk

A Belt Final Drive for the Sieg X3 Mill

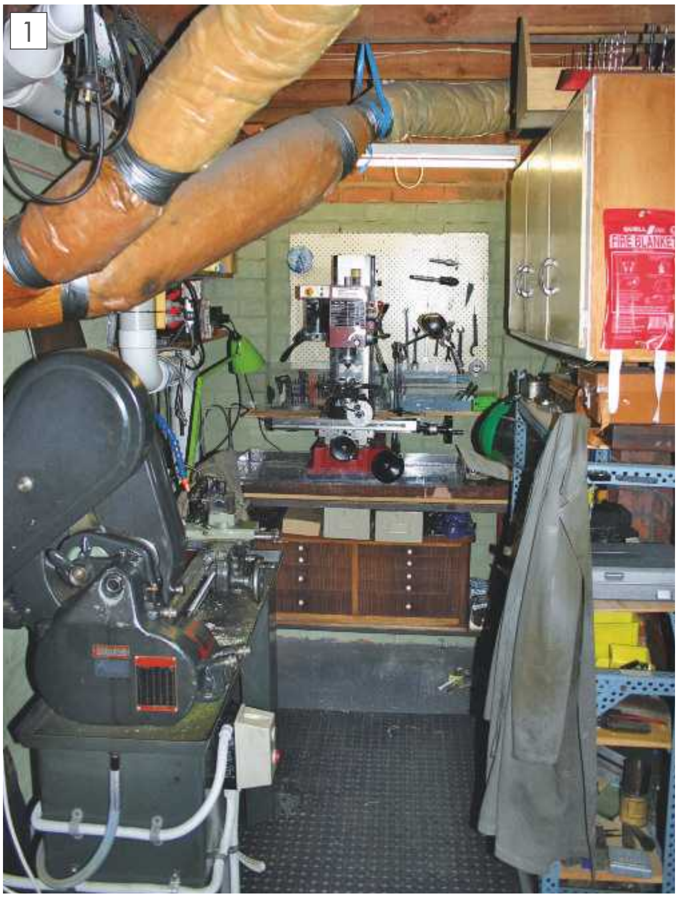
David Thomas revisits Dick Stephen's conversion of his X3 mill, published in *MEW* a decade ago.

Background

The Author's workshop (**photos 1** and **2**) is a bit less than 2 metres wide by 5 meters long and by the time the Hercus 9-inch lathe, a fitting bench and storage were installed there wasn't much room for a mill. The first machine was a homemade version of the Westbury machine (non-Dore) which provided many 'learning opportunities' in its construction but was limited in its capabilities. The available space limited the possible choices of commercial machines and my strong preference for a dovetail z-axis ruled out most small mill-drills except the X3. In a small brick-walled workshop the noise level of the mill, particularly at high speed, is significant and some of this is due to the final spur gear drive to the spindle. A search of the internet and the *MEW* and *M.E.* indexes brought up the article by Dick Stephen (*MEW* November 2005) where the author described his conversion of the gear final drive on his X3 to a High Torque Drive (HTD) belt drive which gave a significant reduction in noise and an improvement in the surface finishes obtained. The author had a few problems trying to follow Dick Stephen's approach and this article describes how these were overcome as well as giving details of the design of the belt drive.

A first attempt

Following the drawings in Dick Stephen's article, I made the two pulleys in aluminium, creating the grooves by the hole-drilling method he described, and

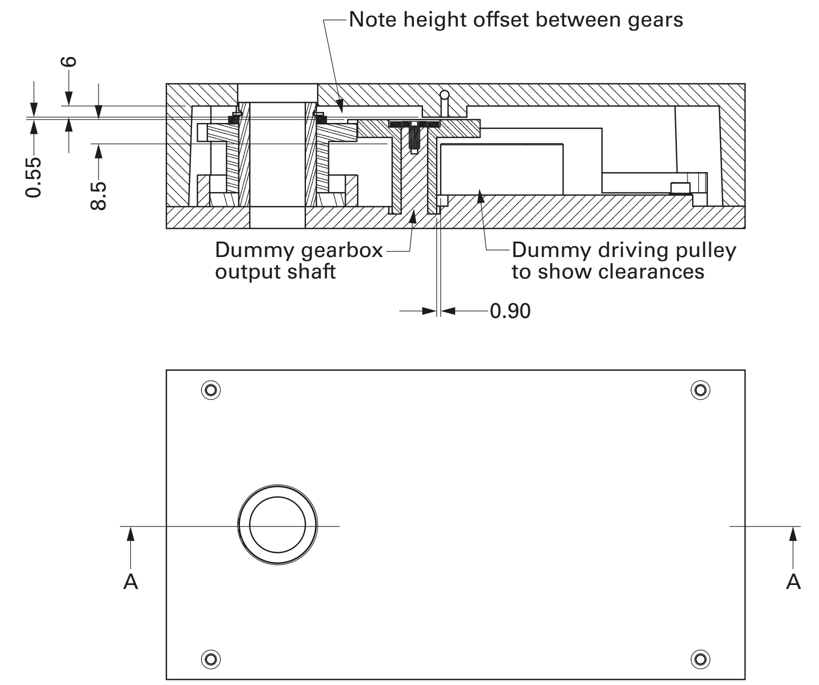


The author's workshop north end.

The author's workshop south end.

the results looked good. Unfortunately, when I came to assemble the drive the 300mm belt was clearly much too long. The same experience has been reported on the X3 forum by someone else so either that person and the author both made the same error, which is possible but unlikely, or the final drive of the X3 exists in more than one form, which is more likely. The critical details are the shaft centre-to-centre distance (which is not given in the Stephen article) and the module (or diametral pitch) of the gears. The gears on my machine have the same number of teeth (28 driving 34) as described in DS and appear to have very similar teeth so there is a bit of a mystery there. With hindsight, I should have stopped and done some proper design calculations right away but instead I set to and guessed the sizes needed and modified the first set of pulleys; not too surprisingly, this did not work.

Sketch 1



Section Of The Original X3 Head

Starting again

Having made the pulleys (particularly having cut the keyways by hand, something I find hard work and difficult to get right) I was not about to give up on the project but it was time for a rethink of the design from first principles. This was something that seemed like a good idea at the time but led to more work than expected. Perhaps this article will reduce the work for others who decide to follow the same path.

For those who want to get on with making things and don't have any need to read the rest of the text then the final version uses the same pulleys as **ref. 1** (30 grooves driving 32) but with a 280mm belt 15mm wide. Remember that this is for a mill with 61.5mm between the spindle and final drive shaft centres. If you do not use the mill at spindle speeds below about 1500 RPM then a 9mm belt is adequate and you can follow the Stephen article, for the 15mm belt version and a lot more information, please read on.

The basic idea of replacing the final drive gears with an HTD belt seemed sound so I started by studying the manufacturers literature for HTD belts (search for 'Fenner', 'Gates' or 'Optibelt' HTD belts). For the high-speed work of clock making in brass that motivated Dick Stephen the 9mm belt is adequate but for low-speed/high torque work across the full range of possible applications of an X3 mill 9mm would be outside the specified limits and a 15mm belt is necessary (see below for the calculations). A further cause for thought about the belt size is that the primary drive belt on the X3 is a 15mm wide timing belt so using a narrower belt at the higher torque end of the drive train seems odd. This is where the project began to expand well beyond the original intention. In order to fit the pulleys for a 15mm belt some modification of the X3 top cover (a substantial iron casting) would be necessary and the best way to determine the nature of the changes was to draw up the top-end of the machine in its entirety. As I had purchased a copy of the Alibre Personal Edition 3D CAD programme (now known as Geomagic Design in commercial form, or Cubify for hobby work) the project also became a learning exercise in the use of this. I hope that this article will provide readers who have not yet used a CAD package with some insight into the considerable advantages of these tools.

As I suspected that my version of the X3 might not be identical to the one in ref 1 the first exercise in Geomagic Design was to measure up and draw the top of the head of my machine, see 3D models online and **sketch 1**). I did not model the input and output shafts of the gearbox or the pulley driven by the motor in any detail but what detail is there is correct for size and allows you to assess clearances correctly. What can be seen straight away is that both the vertical and horizontal clearances around the input pulley constrain the driving pulley size. Figure 2 also shows the strange vertical offset between the two gears for which I can see no purpose but which would have been easy enough for the manufacturers to eliminate, if this is normal I would like to know why it is there. From fig 2 you can see that using a 15mm wide belt will require removing metal from the underside of the top cover, most having to come off the boss that carries the oil-way that is intended to lubricate the gears. With the belt in place the oiling has to stop anyway, in fact it is vital to blank off the oil nipple to prevent anyone in the future using it. Another 3D view available online shows the 15mm pulley drive with the original cover with interferences shown in light blue. A cross-section view of the existing X3 head is shown in sketch 1 with the critical dimensions from the author's machine included. Having accepted the need to machine the top cover then fitting the 15mm belt drive looked to be no problem so it was time to get on and sort out the correct belt length.

Belt selection

The manufacturer's literature gives a method for designing a drive for a given power and speed where both the pulley sizes and shaft centres are freely variable but for the conversion of an existing drive there are more constraints. Note that the manufacturers do not recommend the use of idler pulleys. This section will follow the recommended design process but, as will become clear, what we are actually doing is setting a limit on the lowest speed at which the mill can use the full motor power. The first step is to choose the tooth pitch and width of belt necessary for transmitting the required power. The process starts with the motor power to be transmitted multiplied by a 'service factor' that reflects the level of usage. For most modeller's workshops, the service factor should probably be 1.0 but if you use the machine more than intermittently (up to 10 hours per day) then the motor power should be multiplied by 1.2 to arrive at the 'design power' that is used for belt selection. In the case of the X3 the rated motor power is 600 W and I assumed intermittent use so it is reasonable leave this factor as 1.0. In our case the centre distance is fixed so we can estimate that the belt length is likely to be less than 400mm and we therefore have to apply a 'belt length correction factor' for belts less than 400mm which is 0.8 giving a design power of 750 W. We now have to choose the tooth pitch of the belt and here we hit the next design constraint: we are limited to using a 5mm pitch belt as the short belts that we will need are not available in the 8mm pitch that the Fenner catalogue indicates would be appropriate. The fixed centre distance also allows us to estimate that the total number of grooves on the two pulleys cannot be more than about 73 before the pulley flanges will interfere. If we are to approximate the speed ratio of the gear drive then the number of grooves on the pulleys will be close to equal and both in the low 30's. In the table of power ratings for 15mm belts the columns for pulleys of 28 and 32 grooves show that for 750 W the minimum rated speed is around 1000 RPM, for 600 W it is between 600 and 700 RPM. Based on these design calculations the full motor power may not be available (without some signs of strain) when using the drive for fly-cutting or boring operations that demand low speeds.

Now we have determined the necessary belt pitch and width, the length has to be calculated to give pairs of pulleys with 5mm groove spacing. Replacing an existing pair of gears, where the centre distance is fixed, adds greatly to the difficulty of choosing the correct length of belt. HTD belts are only available in a limited range of lengths so a usable combination of pulley sizes and available belt length had to be worked out. This was done using a spreadsheet program that implemented the formula for calculating belt length for any pair of pulley sizes. The results of this exercise are shown in **table 1** where pulley combinations that I think will be satisfactory are listed. The clearances between the flanges of some of the larger pulleys will be small and you will need to take care with this.

First time around, I chose to use a 34-tooth pulley driving a 37-tooth with a calculated belt length of 300.2mm. This looked very close to 300mm, it is only a whisker too short, but the belt is actually very tight and quite difficult to fit. This experience (a bit more thought in the first place and it would have been obvious) suggested that pulley combinations (table 1, if the centre-to-centre distance on your X3 is 61.5mm) where calculation indicates a belt length a little under a standard length should be chosen. In fact, the Fenner catalogue recommends an allowance of 1.8mm extra for fitting but this assumes that the centre distance can be adjusted to tension the belt after fitting. The final choice for pulleys was the same as in ref 1, but now I knew the process behind the selection and could have confidence that the sizes would work.

Table 1	Pulley 2														
Pulley 1	# of teeth														
# of teeth	**20**	**21**	**22**	**23**	**24**	**25**	**26**	**27**	**28**	**29**	**30**	**31**	**32**	**33**	**34**
20	223.0	225.5	227.9	230.2	232.5	234.7	236.9	239.0	241.0	243.0	244.9	246.7	248.5	250.3	251.9
21		228.0	230.5	232.9	235.2	237.5	239.7	241.9	244.0	246.0	248.0	249.9	251.7	253.5	255.3
22			233.0	235.5	237.9	240.2	242.5	244.7	246.9	249.0	251.0	253.0	254.9	256.7	258.5
23				238.0	240.5	242.9	245.2	247.5	249.7	251.9	254.0	256.0	258.0	259.9	261.7
24					243.0	245.5	247.9	250.2	252.5	254.7	256.9	259.0	261.0	263.0	264.9
25						248.0	250.5	252.9	255.2	257.5	259.7	261.9	264.0	266.0	268.0
26							253.0	255.5	257.9	260.2	262.5	264.7	266.9	269.0	271.0
27						255 belt		258.0	260.5	262.9	265.2	267.5	269.7	271.9	274.0
28									263.0	265.5	267.9	270.2	272.5	274.7	276.9
29								265 belt		268.0	270.5	272.9	275.2	277.5	279.7
30									270 belt		273.0	275.5	277.9	280.2	282.5
31												278.0	280.5	282.9	285.2
32											280 belt		283.0	285.5	287.9
33														288.0	290.5
34					Values in this region are duplicated above the diagonal										293.0
35														295 belt	
36															300 belt

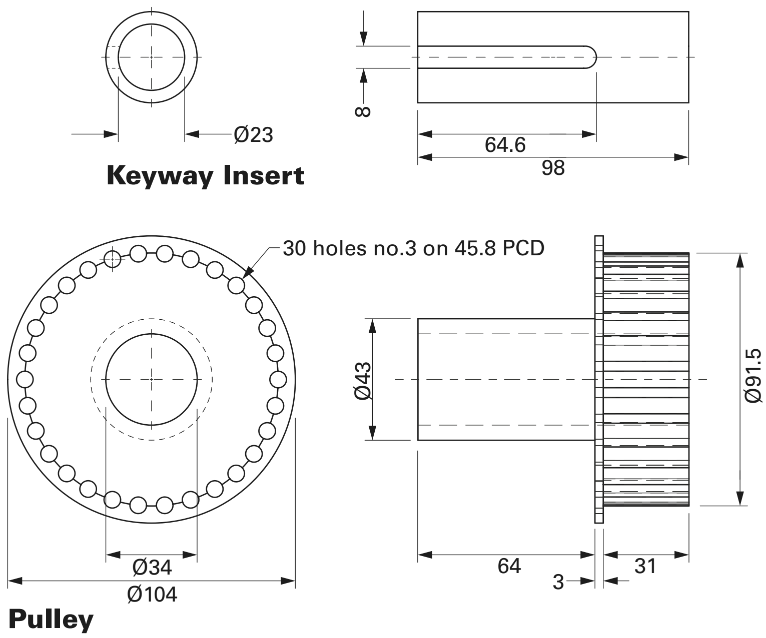
Pulley manufacture

The pulleys (**table 2**) were made by drilling holes to form the grooves rather than milling the full HTD profile although there are notes on the drawings with the correct dimensions for the pulley OD if you want to mill the grooves. An integral lower flange was included as there is no reason to make more parts than necessary. Lacking any keyway broaches (and planing the 8mm one looked like hard work) I made the keyways in inserted steel sleeves and glued these in place. If you have 4mm and 8mm broaches, a slotting attachment for the mill or a planer then you can produce the keyways by a more traditional method.

Aluminium alloy 6061 was used for the pulley bodies, mostly because that was what was in stock in the right sizes, but using a relatively soft material helps with machining. Nothing in the design demands a light material, speeds are low enough not to need any great tensile strength, and you can use whatever is to hand. **Figures 1** and **2** give the necessary details for making the 30- and 32-groove pulleys respectively.

The machining sequence is very similar for both pulleys, each starting with a length of 60mm diameter 6061 alloy cut from the stock and faced to length. If you leave the bore solid at this stage and just form a large centre then, after setting the centre of the rotary table accurately under the spindle axis of the mill, aligning the blank on the rotary table is straight-forward. The centre needs to be in the end of the blank that will later have the grooves formed in it. Reverse in the chuck, leave the outside diameter of the 17.5mm portion at the stock size at this stage (in order to have plenty of metal outboard of the holes when forming the grooves) and turn the pulley shaft to size. The diameter of this is not critical for the driven (32-groove) pulley but the clearance between the driving pulley shaft and the existing X3 gearbox input pulley is tight and the driver (30-groove) pulley shaft must not be over size.

Fig 1



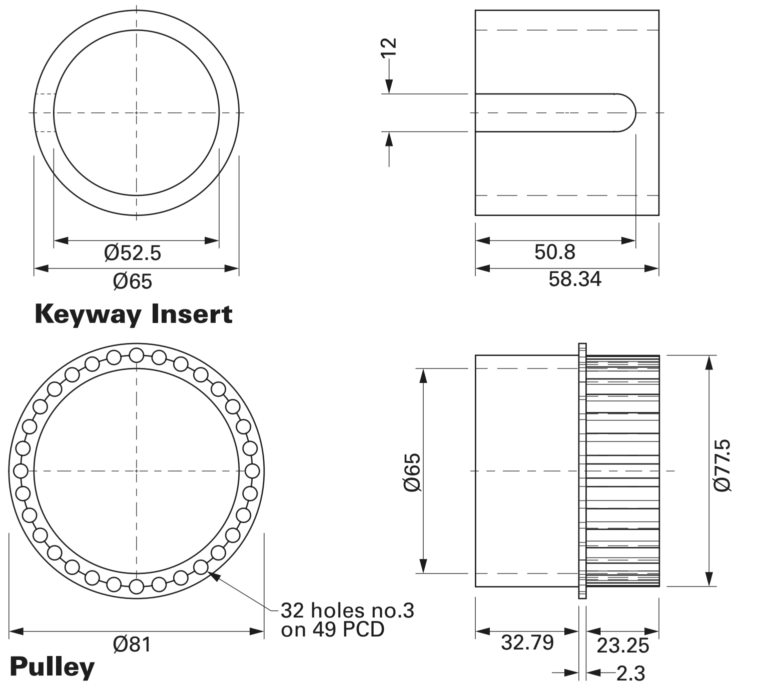
30 Groove Pulley And Keyway Insert

Table 2: Small pulley dimensions for HTD belt drives, all dimensions are millimetres

Pulley grooves	Belt Pitch diameter	Full profile Pulley OD	Hole PCD	Hole PC radius
20	31.83	30.69	29.89	14.95
21	33.42	32.28	31.48	15.74
22	35.01	33.87	33.07	16.54
23	36.61	35.47	34.67	17.33
24	38.20	37.06	36.26	18.13
25	39.79	38.65	37.85	18.92
26	41.38	40.24	39.44	19.72
27	42.97	41.83	41.03	20.52
28	44.56	43.42	42.62	21.31
29	46.15	45.01	44.21	22.11
30	47.75	46.61	45.81	22.90
31	49.34	48.20	47.40	23.70
32	50.93	49.79	48.99	24.49
33	52.52	51.38	50.58	25.29
34	54.11	52.97	52.17	26.09
35	55.70	54.56	53.76	26.88
36	57.30	56.16	55.36	27.68
37	58.89	57.75	56.95	28.47
38	60.48	59.34	58.54	29.27
39	62.07	60.93	60.13	30.07
40	63.66	62.52	61.72	30.86
41	65.25	64.11	63.31	31.66
42	66.85	65.71	64.91	32.45
43	68.44	67.30	66.50	33.25
44	70.03	68.89	68.09	34.04
45	71.62	70.48	69.68	34.84
46	73.21	72.07	71.27	35.64
47	74.80	73.66	72.86	36.43
48	76.39	75.25	74.45	37.23
49	77.99	76.85	76.05	38.02
50	79.58	78.44	77.64	38.82

35	**36**	**37**	**38**	**39**	**40**	**41**	**42**	**43**	**44**	**45**	**46**	**47**	**48**	**49**	**50**
253.5	255.0	256.5	257.9	259.2	260.5	261.7	262.8	263.9	264.9	265.8	266.6	267.4	268.1	268.8	269.3
256.9	258.5	260.0	261.5	262.9	264.2	265.5	266.7	267.8	268.9	269.9	270.8	271.6	272.4	273.1	273.1
260.3	261.9	263.5	265.0	266.5	267.9	269.2	270.5	271.7	272.8	273.9	274.9	275.8	276.6	277.4	278.1
263.5	265.3	266.9	268.5	270.0	271.5	272.9	274.2	275.5	276.7	277.8	278.9	279.9	280.8	281.6	282.4
266.7	268.5	270.3	271.9	273.5	275.0	276.5	277.9	279.2	280.5	281.7	282.8	283.9	284.9	285.8	286.6
269.9	271.7	273.5	275.3	276.9	278.5	280.0	281.5	282.9	284.2	285.5	286.7	287.8	288.9	289.9	290.8
273.0	274.9	276.7	278.5	280.3	281.9	283.5	285.0	286.5	287.9	289.2	290.5	291.7	292.8	293.9	
276.0	278.0	279.9	281.7	283.5	285.3	286.9	288.5	290.0	291.5	292.9	294.2	295.5	296.7		
279.0	281.0	283.0	284.9	286.7	288.5	290.3	291.9	293.5	295.0	296.5	297.9	299.2			
281.9	284.0	286.0	288.0	289.9	291.7	293.5	295.3	296.9	298.5	300.0	301.5				
284.7	286.9	289.0	291.0	293.0	294.9	296.7	298.5	300.3	301.9	303.5					
287.5	289.7	291.9	294.0	296.0	298.0	299.9	301.7	303.5	305.3						
290.2	292.5	294.7	296.9	299.0	301.0	303.0	304.9	306.7							
292.9	295.2	297.5	299.7	301.9	304.0	306.0	308.0								
295.5	297.9	300.2	302.5	304.7	306.9	309.0						In this region pulley flanges interfere			
298.0	300.5	302.9	305.2	307.5	309.7										
	303.0	305.5	307.9	310.2											

Fig 2



32 Groove Pulley And Keyway Insert

Aligning a pulley blank in the rotary table.

Drilling a 4mm keyway pilot hole.

Pilot drilling on the rotary table.

Drilling the 3mm holes.

Now transfer the pulley blank to a rotary table fitted for dividing and clamp securely. Carefully centre the rotary table axis under the spindle axis of the vertical mill and lock the fore-and-aft travel. Early in the project I mounted the pulley blanks between a pair of V-blocks which gives very good alignment but is fiddly to set up (**photo 3**); later I took time out to make a mounting plate for a three-jaw chuck which is a bit less accurate but much easier to use. Whatever method you use to mount the blanks to the rotary table remember that the future true running of the pulley depends on this alignment. Photograph 3 shows a 3MT centre fitted in the mill spindle nose being used to align the pulley blank with the spindle axis.

If you are going to form the keyways directly in the pulleys a method that will reduce the work of planing the keyways is to drill 4mm and 8mm holes in the pulley blanks in positions that remove much of the material. Offset the blank by the amount shown on the drawings and drill the pilot hole at 4mm or 8mm as appropriate (**photo 4**). After the pulley is bored out for the shaft the 'half hole' remaining provides a start for planing (or could even be a guide for filing out the keyways by hand).

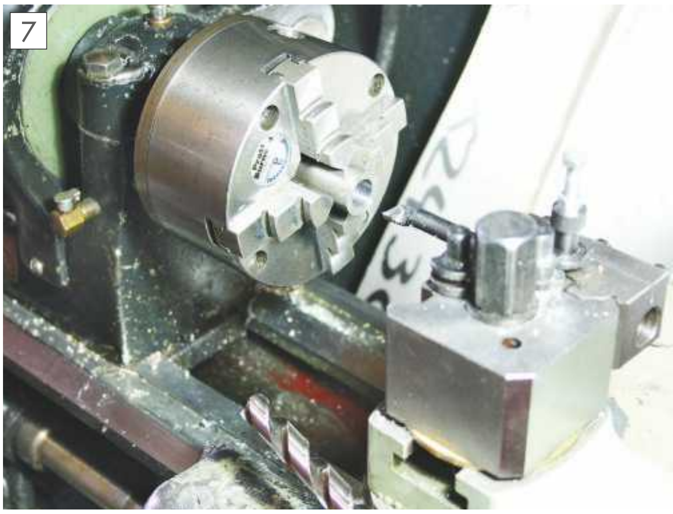
Now move the blank across to the correct radius for the number of holes. Set the dividing gear for the appropriate number of holes and index round making small pilot holes with a centre drill. This will ensure that the 3mm drill starts cleanly and serves as a check on the division plate settings (**photo 5**). When you are confidant of the settings, change to a 3mm drill and index round again drilling the final holes (**photo 6**). The alloy used is a bit prone to building up on the drill and the holes are deep relative to the drill diameter so flooding with cutting fluid is a good idea.

The method I adopted to form the keyways was to bore the pulleys oversize for the shafts and insert sleeves with the keyways milled into them. These sleeves are shown on figures 1 and 2, their manufacture in **photos 7** and **8**. One process that does need care is locating the keyway grooves centrally on the axis of the insert and here you can return the 3MT centre to the spindle and use it to locate a V-block under the spindle axis and set the V-block parallel to the table travel with a square off the table edge. When the insert is mounted in the V-block, it should be accurately aligned with the table travel and centred under the spindle.

With the inserts complete, these can be used as gauges while boring out the pulley blanks. After assembly with Loctite 603 (**photo 9**) the composite pulleys were turned between centres on mandrels to make sure that the outer diameters ran true (**photo 10**) and to reveal the grooves.

The driving pulley is secured to its shaft using the original axial threaded hole in the gearbox output shaft but the driven pulley covers the original circlip groove and could only really be held with grub-screws. In practice this has not been a problem as the drive has run many hours now without this pulley being locked to the spindle sleeve and there is no sign of it moving up the shaft.

Two small components are needed to complete the project: an upper flange for



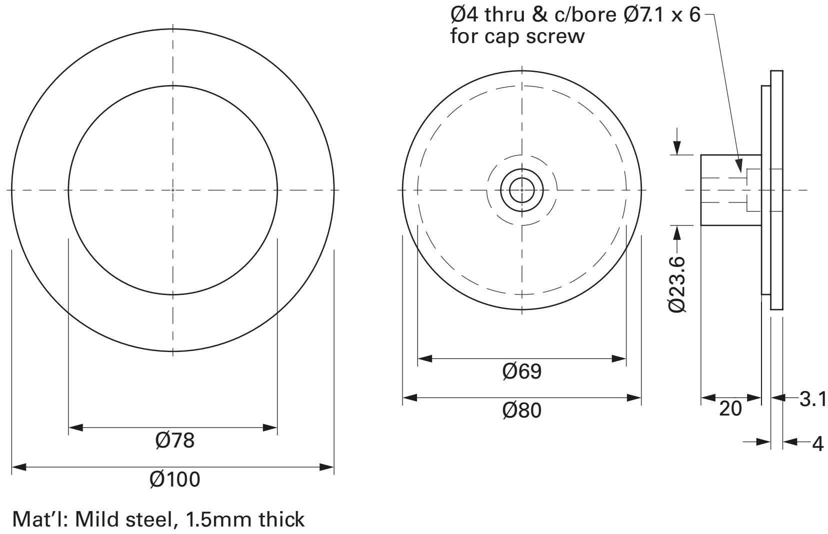
Boring a keyway insert.

Milling the 4mm keyway in the insert. A V-block is clamped to an angle plate and the insert held down into it with a bar through the central hole.

A pulley ready for final machining. The 3mm rods were for a final calliper check on the hole PCD.

the 30-groove driving pulley and a retaining collar to hold this down and secure the pulley to its shaft. The retaining collar (**fig. 3**) has a counter-bored hole for the fixing screw in order to clear the head cover. The flange (also fig. 3) is just a large washer in 1.5mm (or 1⁄16 inch) steel and **photo 11** shows the hole being bored out in the mill with a sacrificial piece of plywood to protect the mill table. The outer surface was roughed out from the sheet with a hacksaw and turned to size on the outside of the jaws of a 3-jaw self-centring chuck.

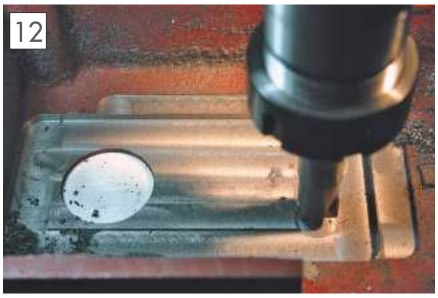
Fig 3



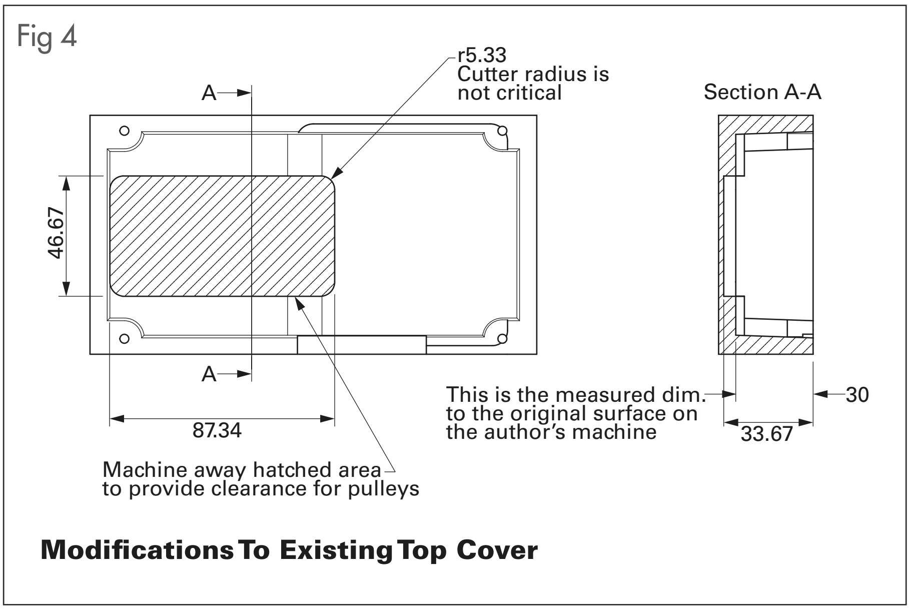
Flange And Retainer For 30 Groove Pulley

Turning a pulley on an expanding mandrel to reveal the grooves. The lower flange is formed at the same operation.

Boring a pulley upper flange.



Machining the extra clearance in the X3 head cover.



Head cover modifications

In order to accommodate the 15mm wide pulleys it is necessary to remove a few millimetres from the inside of the top cover. The dimensions for this are given in **fig. 4** and the process is illustrated in **photo 12** where a 16mm inserted tip end-mill is being used to remove the metal. The top of the cover is already machined all over and is a good reference surface for clamping to the X3 table with a sheet of thick paper in between (I still have a stock of 8 by 4 inch file index cards which are idea for this). The cast iron proved to machine easily and was free of chilled areas or porosity.

One further essential modification is to blank off the oiler apparently provided for lubricating the final drive gears. This lubrication is only 'apparent' as it does not look likely that any oil from this will get to where it is needed and the inside of the top cover had a line of dirty oil that had simply been thrown off the top of the turning gears. With a geared final drive this weakness doesn't matter, with the belt drive it needs to be avoided at all costs.

Further work

An alternative to the complications of finding a workable combination of pulley sizes and belt length would be, despite the manufactures instructions, to devise a way of fitting an idler wheel. This is not ideal, and space will be a problem, but it would free up the possible choices of pulley sizes and allow a wider choice of speeds. A much better method for driving the spindle would be to replace the motor with a more powerful one and eliminate the two-speed gearbox and this is the only argument I can see for buying the Super X3 rather than the basic model. The replacement motor could also be a three-phase unit with variable-frequency speed control or a DC motor and speed control (ex-treadmill for instance) and this is what I will consider next.

Most noise is generated when there is an interrupted cut and a device for clamping the splined drive to the spindle would be worth experimenting with, this might also improve the surface finish where the cutting is continuous. The major things I learnt were the strengths and weaknesses of the X3: the finish on the machine is good where this is needed but there simply is not enough cast iron in the structure. In particular, the column is much less robust than it appears with the sheet-metal cover in place, for the machine to perform well the column needs stiffening.

Conclusion

After all the work the project needs to be evaluated: was it worth it? As a learning exercise it was certainly worthwhile, for the practical results, possibly not. The reduction in noise is noticeable but not great and, for the type of work I do, no real improvement in surface finish is noticeable. The X3 is very good value but has some inevitable weaknesses; I still think it was worth the money and will persist in working on improvements. ■

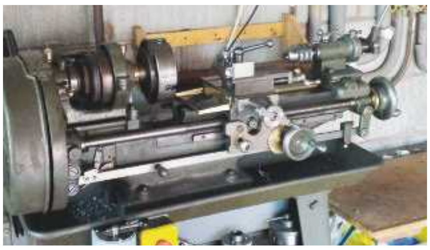
REFERENCE

1. Dick Stephen, Modifications to the X3 milling machine, *Model Engineers Workshop*, No. 110, November 2005

In our Next Issue

Coming up in issue 237

On Sale 31st December 2015



Geoff Walker has shared several Drummond M projects, now he shares the full story of his machine for One Man and His Lathe.

Gold-star work with Marcus Bowman and CNC in the workshop.

Richard Gordon shows you how to make this handy set of precision parallels.

Part 2

From ARC to MIG

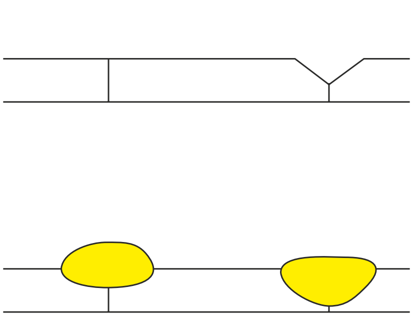
In the second and final part of this series, Neil Wyatt recounts his experience of putting mig welding into practice.

Like many *MEW* readers, I have had a basic arc welder for several years. I don't claim any great proficiency with this technique but I have managed a few useful jobs. Now I've decided to take the plunge and try out MIG welding in the hope of getting better results.

My arc and MIG welders side by side.

Last time I described the differences between my simple old arc welder, and my new Clarke MIG145 Turbo from Machine Mart (**photo 18**). I went through the various safety gear used for welding so now I'll take it as read that you will have this equipment, but may I just cover a few more points. Obviously, welding creates a very hot workpiece, but it also throws showers of hot sparks in all directions. Make sure that the area around where you are working is free of any combustible materials, in particular watch out for oily rags. Another thing to watch for is galvanized sheet – welding will evaporate the zinc coating, and breathing zinc fumes causes a very unpleasant condition called 'fume fever'. This can give you nasty flu-like symptoms that may take a few weeks to wear off.

Fig. 1



It's also important to let people know not to walk in on you when you are welding, and why – and to keep pets away as well. Dogs and cats can get arc eye too!

Prepping

Just as with arc welding, MIG welding benefits from good preparation of 'prepping' of the joint. This is not as onerous as preparing for silver soldering, partly because welding has much greater gap-filling properties. Essentially there are two things you need to do: make sure the material is clean and that the joint will allow the metal to flow right into it.

This is not an article that will go into the details of joint design, but it is worth remembering that the penetration of a welding bead is limited. This means that if you want to join thicker material the joint will be much stronger if you grind a bevel on edges to be joined. This allows weld to be built up from the base of the groove, creating a much deeper cross section to the joint. **Figure 1** gives an example to show how this can greatly improve the penetration of weld, although ideally in this example you would want to weld from both sides to get complete penetration.

First Attempt

So after all this, we are finally ready to start welding. In my case I decided to start with some practice beads on some small pieces of scrap. I cleared a space outside as it was a windless day, and I have a very sheltered spot enclosed on three sides that I use for brazing. I donned my gear, set up a pieces of 3mm steel and dialled in the suggested settings of wire feed 7, gas flow at about 7 and the lowest power setting.

In principle, the welder worked straight away – out came the wire, it sparked and drawing the torch along created a bead. However, my first attempts were very 'sputtery' and inconsistent. I didn't seem to be getting good penetration and the weld was more a series of 'blobs' than a real continuous bead (**photo 19**).

My first test piece with the MIG, note the blobby weld.

The rusty coating should have told me the gas wasn't getting through.


21

Damage to the shroud caused by slow wire feed.

John quickly buzzed down a weld with one of his big machines; two things were obvious – the 'sizzling bacon' sound of the weld forming, and the 'hiss' of the shielding gas as soon as the trigger was pulled.

Naturally I tried various settings for the power, gas and wire feed, but it didn't make a great deal of difference. A bit disappointed I packed everything away and looked for more advice. The 'rusty' appearance of the welds (**photo 20**) suggested that there wasn't enough gas getting through, although I had the gas turned right up at the end. Was my 'sheltered spot' actually too exposed? I had managed to make a bit of a mess of the nozzle shroud, and the reason for this was almost certainly that the wire feed was too slow allowing the arc to travel right up into the torch (**photo 21**).

Getting a helping Hand

I decided it was time to take some advice, so I arranged to take the welder and my kit over to see John Stevenson at the legendary Bodger's Lodge. Now one of John's specialities is building up worn shafts with MIG weld and some of his welds are almost a work of art (**photo 22**). Standing at a proper welding bench showed some obvious advantages of just having the work at a comfortable height. John whizzed an angle grinder over the thick metal surface of the bench, so with the earth clamp attached, work could simply be dropped down and placed in a comfortable position for welding. A weld bench isn't essential for success, but easy access to the work is a big advantage when you are learning.

John quickly buzzed down a weld with one of his big machines; two things were obvious – the 'sizzling bacon' sound of the weld forming, and the 'hiss' of the shielding gas as soon as the trigger was pulled. I had a go, and found it nice and easy to get a passable bead on a flat metal sheet. But the object of the exercise wasn't for me to play with a top-end professional machine, it was for me to get the hang of using my machine, which is aimed more at the hobby or occasional user.

So, we set up the Clarke MIG 145. How would it compare to the much more sophisticated machine? The first thing John noticed was the lack of gas coming out of the torch. It turned out that I hadn't fully pushed the tube into the regulator and in my enthusiasm to get on hadn't realised the hissing sound was coming rom the wrong place. John was able to get a reasonable weld almost instantly, but he had a play around with the wire feed and power controls and soon had the machine working well (**photo 23**).

The Clarke MIG145 has two power switches – min or max and 1 or 2 (**photo 24**) as well as the wire feed speed and gas settings. We found that for 0.8mm mild steel wire a feed rate of 7-8 with a power of low 1 or a higher feed rate of 9-10 with power of low 2 both gave satisfactory results. The 'high' settings would clearly be suitable for 1mm wire, and smaller 0.6 wire would probably need to be used on Low 1 with near maximum wire feed. Naturally, there may be some variation between machines, but these settings are probably a good starting point. The gas setting isn't critical – as long as enough is getting through to shield the work.

Into action

Now I could have go with the machine knowing it was perfectly able to lay down a neat bead of weld, so I set too with a


22

A pump housing welded up at the Bodger's Lodge (John Stevenson).


24

The control panel of the MIG145.


23

John laying down a bead with the MIG145.

My new test piece, experimenting with techniques and settings.

Wire feed too fast - the weld sits on top of the steel.

A passable weld, that would tidy up nicely with the grinder.

A rather uneven attempt at big fillet.

This lap joint would be okay, if I hadn't missed a bit.

Going back to a flat plate was easy, after trying to weld in corners.

slightly larger pile of scrap and started learning the best way – by practicing. It really wasn't difficult at all to create a half decent bead, with the settings above (**photo 25**).

With the federate too low, or the power to high, the wire melts and creates a bead, but it doesn't penetrate the work fully, and it sits on top looking like a sort of 'worm' (**photo 26**). If the feed rate is too high, then you feel the wire push back and get a less well formed, broken, bead – accompanied by sputtering and sparking. The result to aim for is where the wire feeds into a small 'pool' of molten metal that you draw along with the torch, and this gives the steady 'bacon sizzle' sound.

As I continued I started to feel the wire 'pushing' the torch away from the work even at the initial settings. Dropping the feed a little improved things again, and I suspect this was the feed mechanism running in and getting a little freer and faster.

Eager to run before I could walk I used a magnetic clamp to hold some decent sized sections of square tube together, and practice some actually joints. This was only 2mm steel so penetration wasn't an issue, and the tube corners were rounded creating a good 'target' for the weld. I then upended my construction and welded the end of a tube onto a flat sheet.

My first attempts gave mixed results, but they improved with practice (**photo 27**). I rapidly discovered that unlike stick welding, where you nearly always have a great view of the weld, it is quite easy to find the MIG torch spoiling your view. It took me while to realise that the weld bench made it easy to reposition the work and get a much more comfortable view of the weld.

John saw these first fillet welds, he suggested that it would be good practice to go over them again 'weaving' the torch to create a broader fillet, and also said that using both hands to guide the torch would help. It was quite surprising just how large a fillet I could produce in this way, although I need plenty more practice to get an even result (**photo 28**).

I then decided to try a lap weld, this is where two thick sheets overlap and you fill the two resulting right angles with the bead. My first bead wasn't brilliant, but I turned over the work and although it isn't perfect the resulting weld is certainly starting to show some progress (**photo 29**).

By now I was happy with the settings and far more comfortable with handling the torch, so I finished off my practice session by trying to lay down the best straight beads I could across a steel plate. The work was propped up at 45 degrees and I allowed the shroud to drag on the work ahead of the bead to help me keep nice and steady.

The results are in **photo 30** and though I say it myself, given my relatively limited experience, I think that the three bottom ones made at the higher power with faster wire feed, are a satisfying result. I won't pretend that this experience has made me into a coded welder, but although my practice welds aren't perfect, they are certainly neater than the results that I had been getting with my stick welder. I can also be confident they are good and clean, without the slag inclusions left by arc flux.

I'm happy that the Clark 145MIG will meet all my foreseeable needs in the workshop, and I'm already putting together a mental list of jobs for it. For a start I need to make a two-wheeled trolley and I have a big sheet of 1mm steel to make a bigger splash back for my lathe.

Coda

My brother rang me up to wish me a happy birthday and I mentioned I'd been trying welding. Oh, he said, I've got a spare MIG welder at Dad's if you want it, it's been there for years... ■

Readers' Tips

We have £30 in gift vouchers courtesy of engineering suppliers Chester Machine Tools for each month's 'Top Tip'.

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

Giant Height Gauge

When marking out the frames for Rob Roy I had a lack of height on my marking gauge. I drilled and bolted the gauge to a substantial angle plate as per photo adding 5.905 inches to my calculations.

The height gauge is a Mitutoyo and is a joy to use, it cost £20 at a car boot sale. The surface plate cost £40. The giant angle plate measures 9 x 12 x 16 inches and I can't lift it. I paid for it less than it would fetch for scrap. If nothing else the collapse of our industry has certainly helped model engineers by offering so much equipment onto the model engineer's market.

Paul Lynch

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