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A CNC Toolchanger

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On the Editor's Bench

Welcome Back Diane and Welcome Aboard Martin

Many readers will be aware that since the end of 2017, Diane Carney has been on extended sick leave, putting Model Engineer temporarily in the capable hands of Martin Evans, former editor of Engineering in Miniature.

I'm please to report that Diane is now back and in great form, although she has decided that editing two issues of ME a month is more than she wants to keep doing. Equally Martin, having previously 'retired' was wary of taking on the full-time role. A happy solution has been agreed where Martin has become the new editor of Model Engineer, supported by Diane as Assistant Editor. I'm sure all readers will wish them well and look forward to the 120-year-old magazine continuing to prosper.

The Exhibition Season is upon us!

This month's On The Wire brings news of two more Exhibitions happening later in the year. A few week's ago, I went to the Doncaster show (a.k.a. the National Model Engineering and Modelling Exhibition, but that hardly trips off the tongue...) Car troubles meant I ended up taking the train, which was actually quite convenient aside from the fact I only arrived at 12:30 on the Sunday! I kept up the tradition of wearing a brightly coloured T-shirt, which I'm sure helped me meet a lot of old friends and some new ones!

Many interesting conversations were had, not least with Peter Nicholson on the Society of Model and Experimental Engineers stand. His recently commissioned Prusa i3 from the latest kit attracted a constant stream of interested visitors throughout the exhibition, but what was remarkable was the absence of other 3D printing examples there. This is in curious contrast to the Bristol Exhibition last year where there were many examples on display.

Personally, I'm sure the future of exhibitions – and our hobby – is going to increasingly involve such new technologies as well as robotics and embedded electronics. Younger hobbyists (and many older ones) aren't waiting for us to embrace these technologies, they are bringing them, along anyway.

A good example is this month's PID controller article by Chris Gabel, which features many 3D printed parts that are totally incidental to the main subject of the article. On a personal level, my 3D printer continues to get regular use – just yesterday evening I spent twenty minutes revising a part for my astro-modified DSLR, and it happily printed out on its own this morning while I got on with the magazine.

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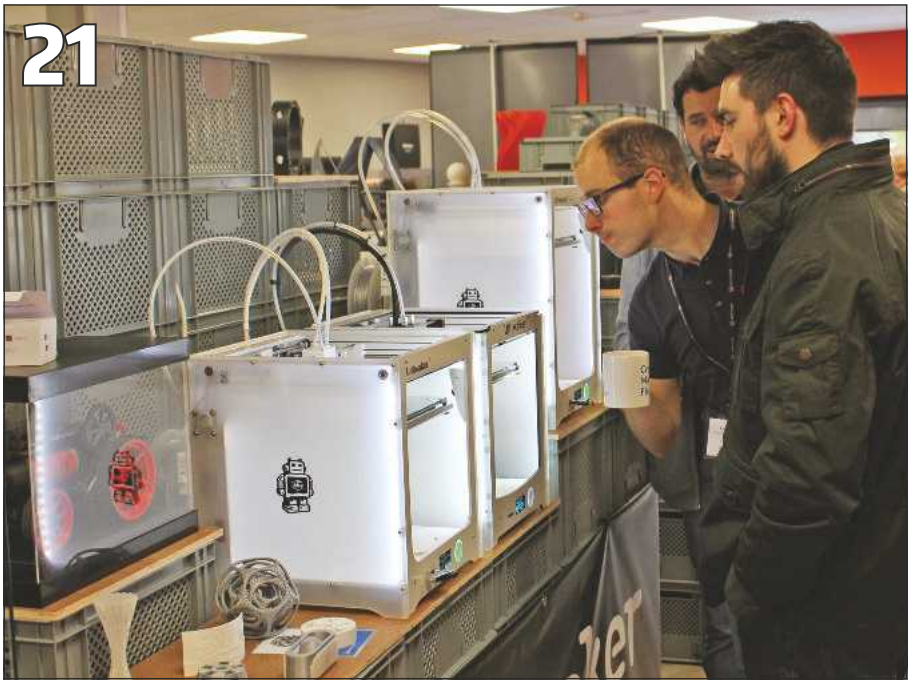

See page 52 for details.

Coming up...

in our next issue

Coming up in our next issue, MEW 270 another great read.

Regulars

ON THE COVER

This month's cover features Simon Davies' automated CNC Toolchanger fitted to his Unimat lathe and featured on page 9 of this issue.

HOME FEATURES WORKSHOP EVENTS FORUMS ALBUMS

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THIS MONTH'S BONUS CONTENT

Log on to the website for extra content

This month you can find Martin Johnson's program for the thermal design of model boilers https://www.model-engineer.co.uk/boilerdesign Please note this is a guide to optimising the performance of boilers, not the strength of the boiler. A series of articles top accompany this program started in issue 4584 of our sister publication Model Engineer.

Any questions? If you are a beginner and you have any questions about our Lathework for Beginners or Milling for Beginners series, or you would like to suggest ideas or topics for future instalments, head over to **www.model-engineer.co.uk** where there are Forum Topics specially to support the series.

So, why not come and join one of the busiest and friendliest model engineering forums on the web at **www.model-engineer.co.uk?**

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- What is a good size of air compressor to run steam engines for a demonstration?

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A Stepper Motor Driven Toolchanger for a Small CNC Lathe

In this new series, Simon Davies describes the development and construction of a CNC toolchanger for his Emco lathe.

Introduction

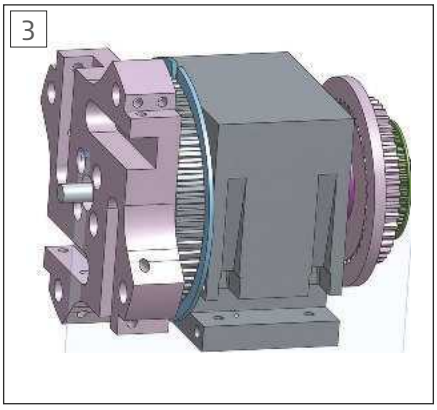
The following description of a toolchanger for a CNC lathe is unashamedly designed for and is constructed largely using CNC machinery. The solution is a combination of pure mechanics allied with electro-mechanicals, electronics to drive them and two layers of software to initiate and control the tool change process at the required moment.

My description will descend into sufficient detail to allow the construction of a similar solution, but it is not going to offer a blow by blow build log but rather a discussion of the concepts and reasons behind the solution and the blocks contained within it. Drawings are supplied to allow the reader to understand how it is constructed and I will be very happy to supply my more detailed (albeit cruder and unfinished) working copies if required. Similarly, whilst this is neither an electronics journal nor a software magazine, the components used and their integration with the two software systems are key to the solution as a whole. Therefore, I have explained the electronics chosen and the underlying concepts as well as the general workings of the main software program and that associated with the CNC platform.

My Emco 5PC in normal form

My expectation is that someone can use the ideas contained here to build a similar

The Emco with the toolholder installed and ready to go



Main mechanical components modelled in 3D

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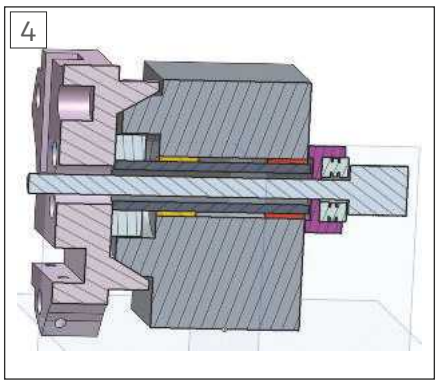
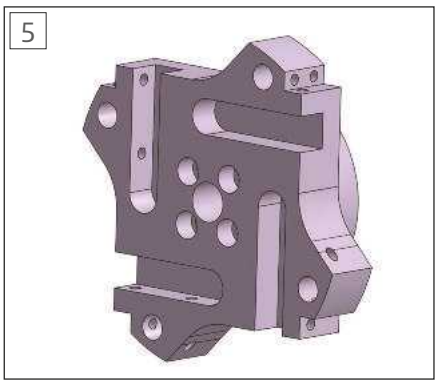
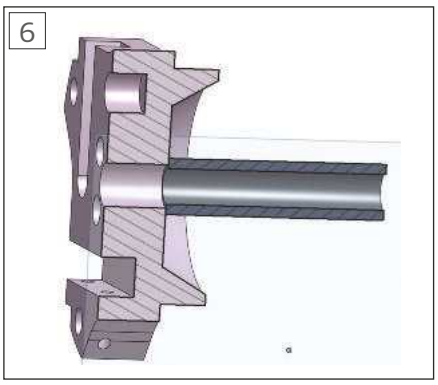


Toolholder and block sectioned to show the way that the through bolt pulls them onto their cones



Toolholder plate from the front - note 4 tool positions plus 4 axial holes for drills etc



Toolholder plate sectioned showing the through shaft

Serious lumps of steel - more or less as delivered

Creative use of the bandsaw to cut to size

toolchanger or, as happened to me, to use the control and drive methods to automate other requirements. As an aside, I have also explained some of the failures and dead ends in the hope that the process will be of use to others experimenting on other projects.

Background

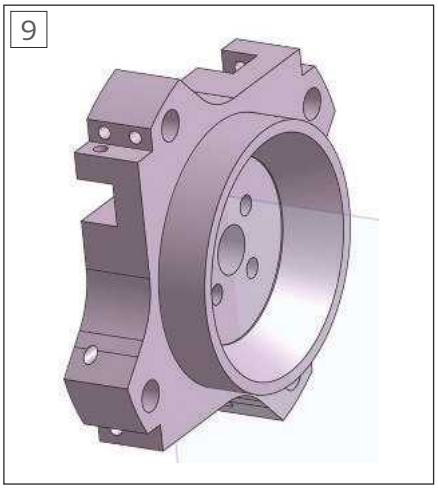
I purchased a second hand Emco 5PC about 3 years ago, **photos 1** and **2** after having had some experience in converting a BF20 mill (similar to a Sieg X3) from fully manual to full CNC control. Having a CNC lathe seemed to be the obvious next step and when I had the opportunity to buy a virtually untouched model, I jumped at the chance.

I have to say that I found the learning curve between the two forms of CNC to be rather larger than I had expected, and a number of different concepts had to be absorbed.

The 5PC dates from the late 1980s and is a version of the 65 mm centre height Emco Compact 5 lathe with a more substantial cross slide saddle and 5-phase stepper motors driving ball screws. A quantity of electronics and electrics is hidden in the back of the cabinet and the whole was expected to be driven by DOS based software driven via a printer port connector. There is a well-documented conversion that allows direct use by a modern PC using Mach3 and also a more recent version using LinuxCNC. I swiftly followed the former having previous experience with Mach3 on the CNC mill.

Mach3 Turn is a rather less friendly solution than the mill version and gives a feeling of being a poor relative of the latter but it is adequate for the purpose.

Once I had got beyond the basic steps of facing and turning to size, I started to apply some improvements. Chief amongst these was the addition of Home Reference optical switches to ensure that the lathe tool could always be referenced against a known point. After this I started to discover the next issue. The lathe is supplied as standard with a beautifully made quick change toolholder block along with....one tool holder. Once machining processes advance beyond the capabilities of a single tool, the restrictions rapidly became clear. Equally clearly, I was not the only one with this issue since the cost of second hand toolholders are, in the words of one of my friends, cubic money. I eventually bought an additional four and made two more although these lacked the



A rear view of the toolholder plate showing the cone clutch face

This may be more than it was designed to cut!

Toolholder plate faced and then drilled through

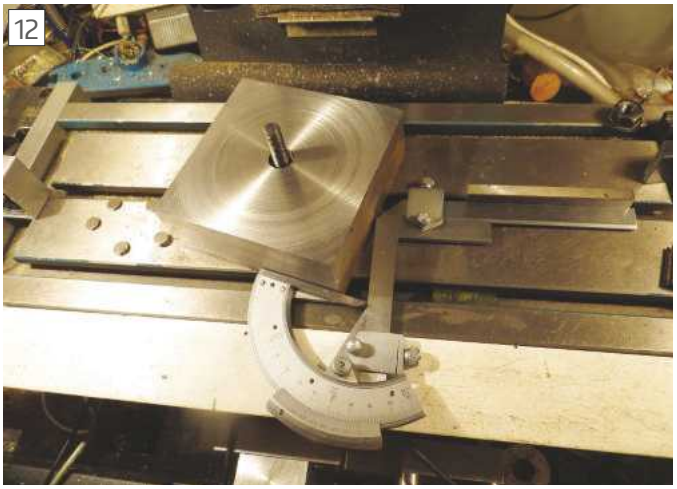
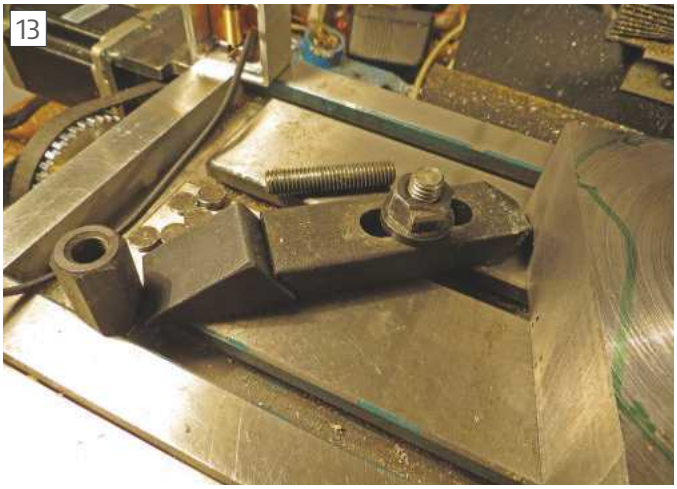
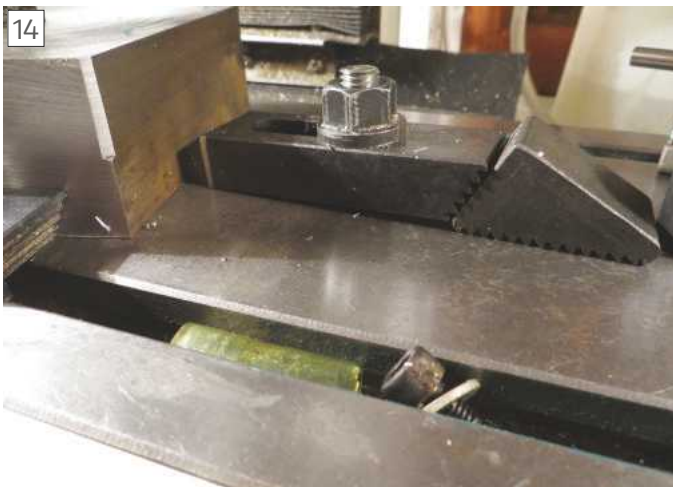


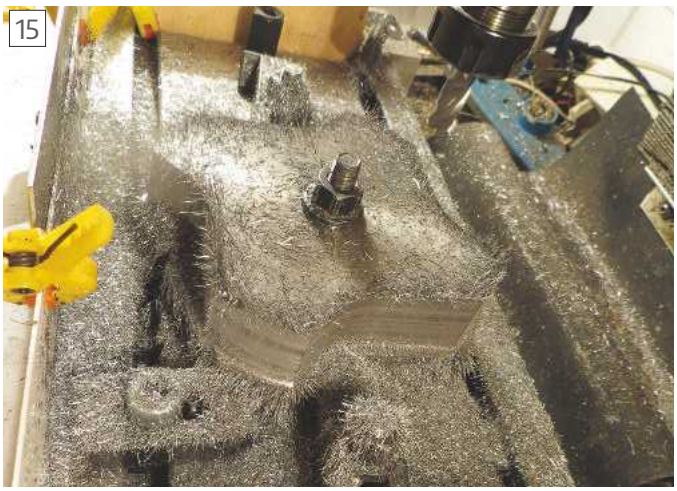
Plate mounted skew on the mill to minimise waste



Hold down clamps using wedge principles



Clamps on the other side of the plate



Hairy look caused by using a magnet on the plate to limit swarf distribution

hardened and ground all over finish of the real ones.

At this point the CNC process became more logical and Mach3's tool tables which allow tool X and Z positions to be referenced against a master tool (itself referenced against the Ref All opto switches) came into its own. This allowed me for instance to make some tens of screws for a clock project by:

- Undo chuck and move barstock to position set by static lathe tool
- Start motor and launch Mach3 programme which faces then uses knife tool to turn down to thread diameter
- Programme stops and awaits manual toolchange for threading tool
- Motor speed changed and programme restarted to cut thread, then stops awaiting manual change to parting tool
- Screw then parted off and programme stops awaiting replacement of knife tool and then moves to zero position for next piece of bar stock

This method produced a good collection of identical screws and a lot of tedium switching toolholders.

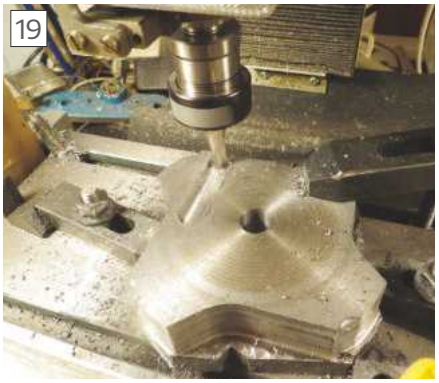
My next step was to look at an automated tool changer or ATC. Emco supplied these for this lathe and the larger 6CNC and they are as rare as the proverbial hen's teeth and correspondingly expensive. In fact, they may be worth their weight

›

Cleaned up and ready for the slots to be cut. Note the position of the clamps

Another view of the part finished plate - the reason for angling the part on the bed is clearer now

The cuts just visible at the corners will be further machined to give access to the tool clamping bolts



First tool slot being cut - note the additional hold down clamp

Slots finished and just the bolt holes for securing the plate to the main shaft to go. Note this is a CNC bore routine rather than drilling with the final size drill

in gold given their substantial size, but I may be guilty of exaggeration here. I investigated further and discovered that these ATCs and other similar ones used the concept of a rotating toolholder plate with 6 or 8 tool positions allied to a motor which rotated the plate to the desired position and then reversed it against a pawl to lock it into position. As I understood it, the motor turned the plate with glacial speed and the pawl method required that the tools be setup very carefully to ensure accurate centre height.

At this point I resolved to build my own version...

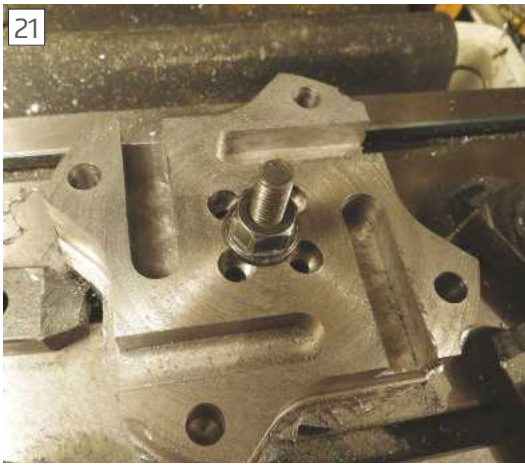
Concept

I wanted to avoid the pawl locking method which seemed to require a great deal of accuracy to construct and at the same time to restrict how the tool plate was used. Similarly, a faster speed to select the next tool was a requirement. My final design is based around a mounting block mounted on the cross slide which has the tool plate freely mounted on a shaft through the block, **photo 3**. Two stepper motors are mounted on the block. One rotates the tool plate and the other tightens and loosens a bolt running through the centre of the shaft. This pulls the plate onto the block to grip the two together. To enhance this grip and to ensure repeatability of positioning, the block and the plate have mating cones machined into them at such an angle that the cones will align, add additional grip but will not auto-lock like a Morse taper, **photo 4**.

The stepper motors are driven via modern drivers and controlled by an Arduino single board computer which issues the step commands and monitors two opto sensors to determine the states of the locking and rotating mechanisms. On start up the tool plate is unlocked and rotated to locate a defined zero/index point, rotated again to tool 1 and locked in position. At this point a signal to the Mach3 interface indicates the unit is ready to receive position change requests. Manual changes and status information are also available using the control button and LCD display on top of the electronics box.

The manual control also allows the user to jog a tool to present it at true centre height without recourse to shims. This revised position is recorded in the non-volatile memory of the Arduino.

Much of the development centred around the combination of making the steppers tighten the bolt firmly enough, undid the bolt when asked to and also how



All milling and drilling in this plane now finished - back to the lathe to deal with the rear face and cone

Motor torque	128	Ncm	(from datasheet)
Motor to drive wheel ratio	2.867		43 :15 torque multiplication
Thread pitch	0.07	cm	
Cone Inner radius	4	cm	
Cone Outer radius	5	cm	
Thread efficiency	5%		From various sources for a 60° thread
Cone angle	60	degrees	
Steel: steel friction coefficient	0.60		Midpoint from published tables

From Wikipedia on "Screw_(simple_machine)"
F_out = T_in *2 * pi * efficiency/lead pitch

Torque into nut (torque multiplied motor)	367	Ncm
Force on shaft (from Wiki above)	1,646	N

From : **Roymech.co.uk/Useful_Tables/Drive/Cone_Clutch.html**

Cone clutch resisting torque T = F * μ * (r_o + r_i) / 2 * sin angle

Torque resisting movement (from above)	3,849	Ncm
Resisting force at 8cm radius at tool tip	481	N
Imperial equivalent	108	lbf

the Arduino determined at what point the bolt was actually tight. Of this, more anon.

As part of the sanity check, I carried out some rough calculations as shown on next page (the figures have been updated to the final gear and torque ratios):

I decided that some 500 N resisting the inclination of the tool to move was going to be sufficient for my purposes – assuming my rough calculations don't have too many errors within them – happy to hear any corrections though.

Mechanical details

There are two principle components, the toolholder and the block to which it is attached. The remainder consists of the stepper drive supports, the toothed pulleys and the housing for the electronics as well as sundry fittings and bearings. I have tried to use off the shelf items wherever possible to speed the process and to focus on the end result.

Tool holder

This, **photos 5** and **6**, and the main block originated as two colossal lumps of steel offcuts weighing 24kg and delivered through our post office– each wrapped in a single layer of unhappy looking bubble wrap, **photo 7**. Fortunately, I had no other deliveries from this van but I do wonder what effect my steel had on the other more lightly constructed parcels skidding around on the van floor. The material is XC48 corresponding to EN8 I think and was as tough as old boots. The front part of the toolholder has slots and holes for the tools whereas the rear side incorporates the cone to allow it to be locked onto the main block, **photo 9**.

I started by squeezing it into the trusty and long suffering bandsaw and cutting out a square slightly over the toolholder dimensions of 140 x 140 x 37mm deep, **photos 8** and **10**. This was then firmly mounted in the 4 jaw and faced, drilled and bored to a nominal size to give a centre reference. This hole would later be enlarged to allow the locking bolt to pass through, **photo 11**.

The next step was to move it to the mill where it was mounted at 15° to the X axis to allow the tool slots to be orthogonal to the mill bed axis. **Photograph 12** shows a sophisticated protractor being used – but a plastic one would probably have sufficed! The hole was centred and then held by some clamping blocks used in a 'creative' manner similar to the purpose made clamps described by Harold Hall in MEW 171, December 2010 as well as the centre bolt, **photos 13** and **14**. Concerned about the amount of spare material available as well as the setting up, I roughly mounted a marker pen in the chuck to confirm that the entire block was going to be machined. I subsequently removed the block and hacked most of the surplus material from it with the bandsaw before returning it to the table and re-setting it up.

The mill is my own CNC conversion but hacking through this stuff even with

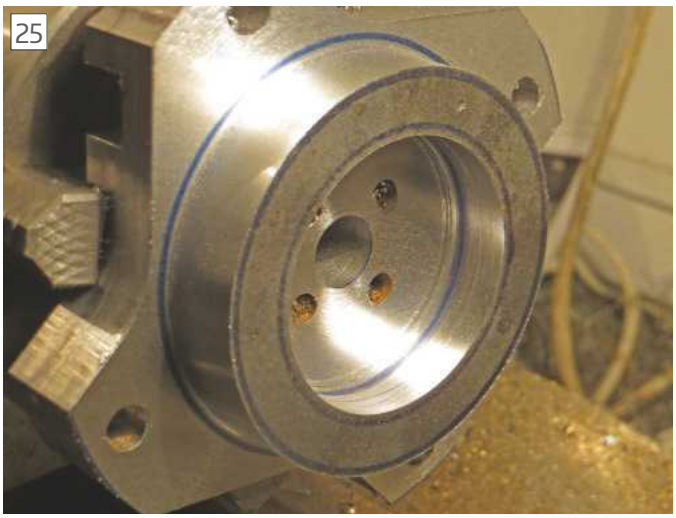

22

Part way through machining - the blue line is the target point - roughly


23

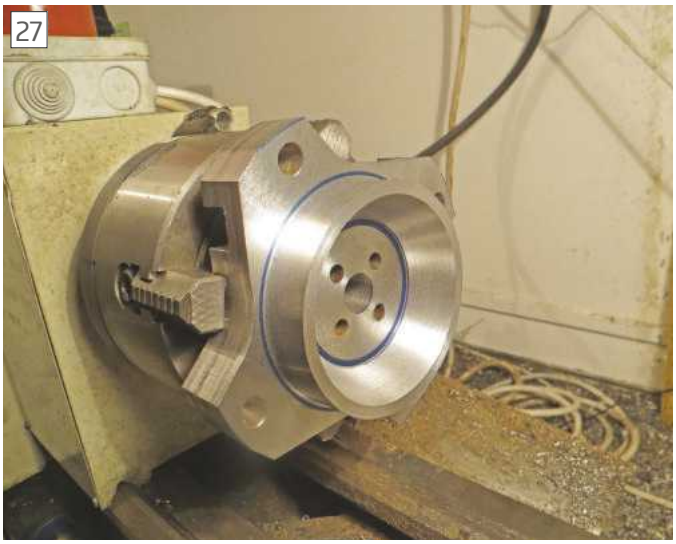
Boring the centre hole ready for the cone which will be machined between the two lines on the unmachined face

Seriously hot swarf once I had the courage to push the carbide tools and lathe far beyond what I thought was reasonable. I had to install serious shields to stop being assaulted by this stuff



Bored and ready for the cone to be cut

Cone cut although the surface finish leaves something to be desired



The finished version of the plate and cone

carbide tooling was not easy. I struggled to find a combination of feed rate and speed but eventually bit the bullet and pushed it far harder than I thought possible. The end result is seen in **photo 15** before the magnet and needle like swarf was removed and in **photos 16** to **18** after cleaning. There is a certain satisfaction watching the machine carve complex shapes exactly as originally drawn on the CAD screen (my apologies to the non-CNC people at this point!) Next task was even harder on my stock of brand new slot drills which was to cut the 4 tool holding slots to a width of 14mm and a depth of 13mm, the first cuts being shown in **photo 19** and the end result, masked slightly by the mill cutting recesses for the socket cap fixing screws, in **photo 20** and finally in **photo 21**.

After this exercise, it was time to give the mill a rest and return to the lathe to machine the cone on the rear of the toolholder.

The front was held in the 4 jaw and aligned centrally using the centrally bored hole and the serious work commenced. The initial steps can be seen in **photo 22** and the final result in **photo 23**. On the way, the swarf came off in short coils that were either blue or straw in colour and in such volume that I had to rig up temporary protection to operate the auto feed lever, **photo 24**. After this, the centre was bored out to the carefully calculated diameter, **photo 25**, and the topslide pressed into use to cut a nominal 30° taper. **Photograph 26** shows work-in-progress and **photo 27** shows the results with the best finish I could achieve with this material and any number of different settings.

A final trip to the mill was then made to drill and tap the M5 tool fixing holes – resulting in the loss of one tap which took umbrage at being asked to work in such steel. Some brutal chiselling and a brand new tap soon cured the problem. **Photograph 28** shows some finished holes as well as the slot drill used to machine a flat on the sloped edge for the tapping drill to cut cleanly and the broken tap. At this point the toolholder was put to one side and the main block became the next target for lathe abuse!

● To be continued

Drilling and tapping ther tool fixing bolt holes - not the very 2nd hand tap awaiting disposal

Indexing Modification for a Tailstock Turret

Six equally spaced dimples.

Mick Knights makes a rapid indexing modification to Alex du Pre's design.

When the free plans for a tailstock turret, designed by Alex du Pre, appeared in MEW issue 253 I thought they looked to be a workman like set of drawings and so I kept them for future use if and when the need arouse. The opportunity presented itself recently when I was waiting for some components to come back from the platers and so faced with a few non-productive days to fill I decided to machine what would hopefully become a useful addition to the workshop armoury. Luckily, I had all the necessary material to hand and so the only item to be bought in was the MT2 shank.

After studying the plans in more detail, it occurred to me that it would be a relatively easy operation to incorporate a positive and quick indexing system to the turret by using a couple of sprung loaded ball bearings in the reverse face of the turret which would locate in six dimples on the top face of the back plate, thus providing

Two sprung loaded ball bearings.

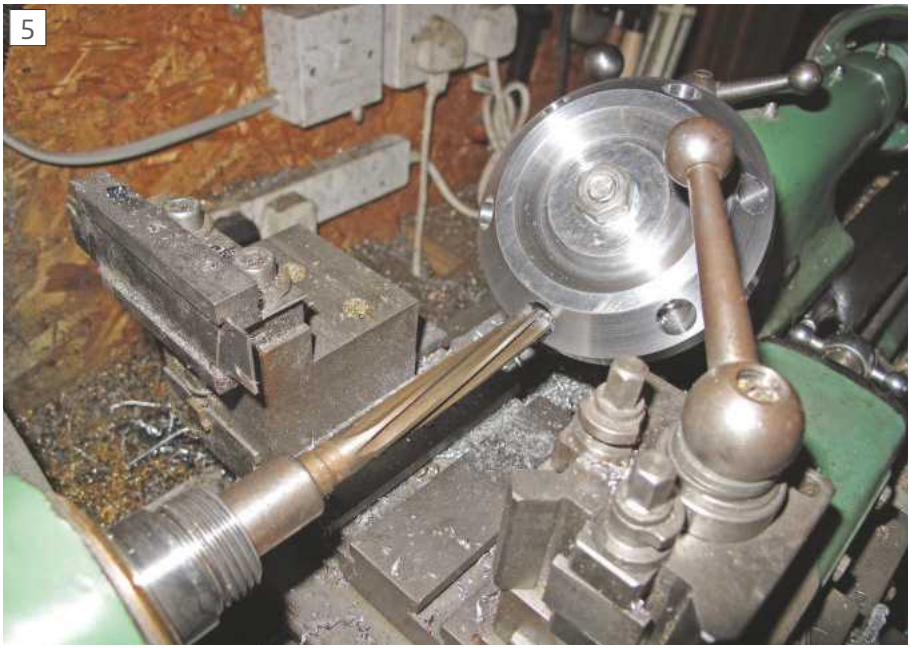
Pilot drill.

11.7mm reaming drill.

a quick clicking indexing move to the next tool position. Using two ball bearings would also provide a positive indexed position with no side ways movement. In all other respects I'd follow the plans, which can be downloaded from the ME web site **www.model-engineer.co.uyk/tailstockturret**.

Having over the years accumulated plenty of 'it'll be useful one day' pieces of material including quite a few pieces of bronze I decided to use a suitable disc to make a bearing bush between the turret and the base plate which would make for a smoother action between the two as well as providing a surface for the ball bearings to rotate on. This is of course an optional extra and the indexing would work perfectly well without it.

With the turret and backplate machined I pitched out the six dimple locations using a 6mm ball nose cutter. The depth of the dimples is only 1.5mm as this is plenty to provide a positive location to the sprung loaded ball, **photo 1**. Two 6mm diameter holes were drilled in the back face of the



12mm ream.

Grub screw holes.

turret on the same PCD as the dimples and to a depth of 12mm. The springs only need to be long enough to hold the ball bearings clear of the back face of the turret and to allow the ball to compress below the surface when assembled, **photo 2**.

With the turret assembled the tool location bores were machined as per the original, but with the benefit of positive location at precisely 60 degrees. The temporary clamping nut needed only to be slightly slackened to enable positive indexing to the next position. **Photographs 3**, **4** and **5** show the process, finishing with a 12mm reaming operation.

I used M5 grub screws for clamping the tool holders, these hole positions were established with the turret set in the dividing head to give the correct orientation, while the individual holes were again drilled by indexing the turret against the sprung loaded balls, photo 6.

Now for the turret tooling itself, which basically follows the original, with a centre drill, stub drill and countersink. Stub drills

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Tail stock turret with M8, M6 & M4 taps in tool holders.

Tap holder in the home position.

Fully extended 25mm travel.

are by far the best option for this particular application, as jobber drills, being longer, might tend to judder when starting the drilling operation. Jobber drills can of course be reduced in length by grinding, but as the length reduces so the web increases, which would also require thinning.

The only application for the turret in my shop, that I can currently think of, would be for internal threading operations, which means that several simple sliding tap holders would also be required.

Most popular machine tap holders have an independent head in which the tap is clamped, this is because as the tap reaches the end of its travel the driving dog disengages allowing the tap to spin freely in its holder so it can be withdrawn using reverse spindle rotation. This is a bit too complicated a holder to be trying to produce, so a simple holder that allows the tap to feed into the work piece to the required depth then to be withdrawn using reverse spindle rotation has to be the way forward. After giving the problem a bit of thought I came up with a suitable quick and easy method, **photo 7**.

In describing the method and dimensions involved the approach has to be generic, as it all very much depends on the size of tap being used and the diameter of its shank, either metric or imperial.

M4 & M3 taps bonded in sliver steel sliders.

The method is quite straight forward, after turning the 12mm location diameter drill and ream the tool holder body to the diameter of the tap shank and to a depth that accepts most of its diameter. This will ensure both diameters are concentric. If of course the tap body is approaching the 12mm location diameter, say 10mm, then drill a pilot hole right through, reverse in the chuck or collet and drill and ream 10mm stopping short of the location diameter shoulder. I used 16mm diameter mild steel for the tool holder body, but this would need to increase along with any larger tap sizes. With the turning complete transfer to the dividing head, or whatever indexing device is available and cut two slots at 180 degrees. These slot widths need to be smaller than the diameter of the shank in order to leave as much reamed location for the tap as possible, for example, for the M8 tap I used M4 grub screws and so the slot width was machined to allow the grub screw free movement along the entire slot. I made the length of the slots the taps cutting flank length plus one screw diameter, making the over all length 29mm. which obviously gives 25mm of travel. Of course, this length can be extended to suit individual applications, **photos 8** and **9**.

The sliding clamping ring can be produced from any convenient diameter stock available, but the section needs to be thick enough to allow a positive threaded location for the two grub screws, I used 25mm diameter mild steel. Lightly knurl the outside diameter, then drill and ream to suit the tool holder body diameter and part to length. Drill and tap two holes at 180 degrees for the chosen grub screw. If only a few grub screws are required, then I find Amazon the cheapest option with UK delivery usually taking three working days. A quick polish with emery tape may be required to ensure the slider ring passes smoothly along the tool holder body, then simply use the grub screws to clamp the tap's driving square. One sliding tap holder.

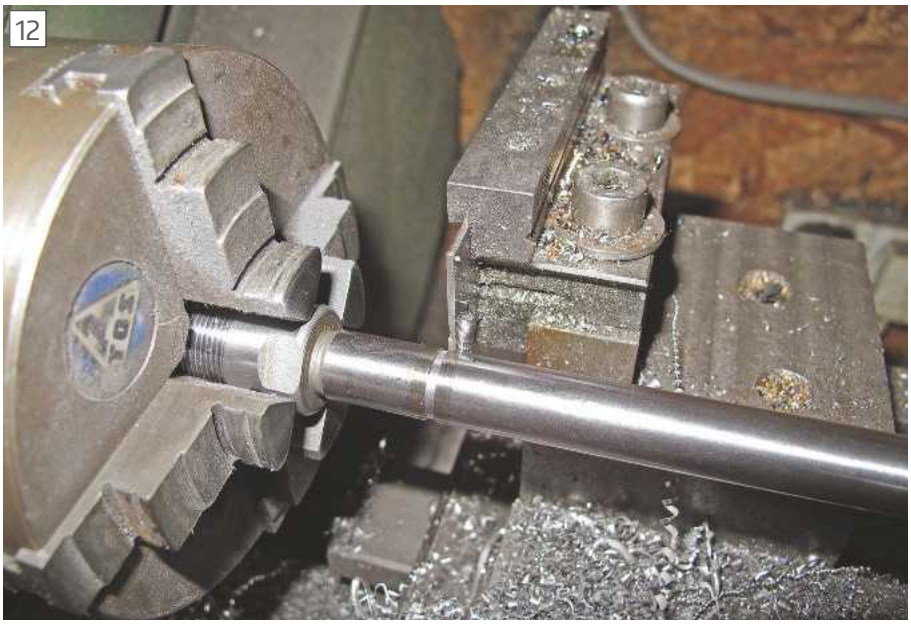
For smaller tap sizes I used a piece of sliver steel to suit the location bore in the tool holder and drilled it to the tap shank diameter, then permanently bonded the two together leaving the drive square exposed. This way the tap can still be used for manual tapping if required, **photo 10**.

There may well be occasions when tool holders need to be produced for individual drill sizes, but for general use there's a cheep and quick alternative, by using an ER 16 extension tool holder with a 12mm shank, **photo 11**. A suitable tool holder and ten collets, which cover the range 1mm to 10mm can be sourced for very reasonable cost.

The ER 16 tool holder shanks are usually 100mm in length but are not dead hard and can easily be parted, supported by a live back centre, to a length suitable for the turret location bore, **photos 12** and **13**.

The end result is a tool turret which is versatile and quickly adaptable for different components. ■

ER16 tool holder.



Parting tool holder to length.

Ready for mounting in the turret.

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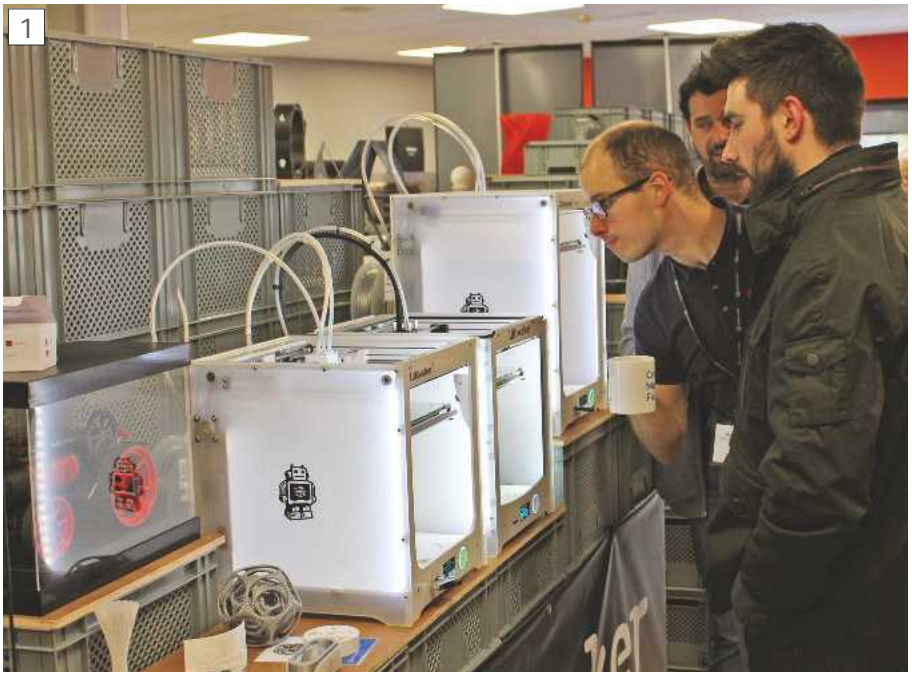
Exploring the latest 3D printing technology at the recent GoPrint3D – Mintronics Workshop

Mark Noel comes face to face with the latest advances in 3D modelling and printing

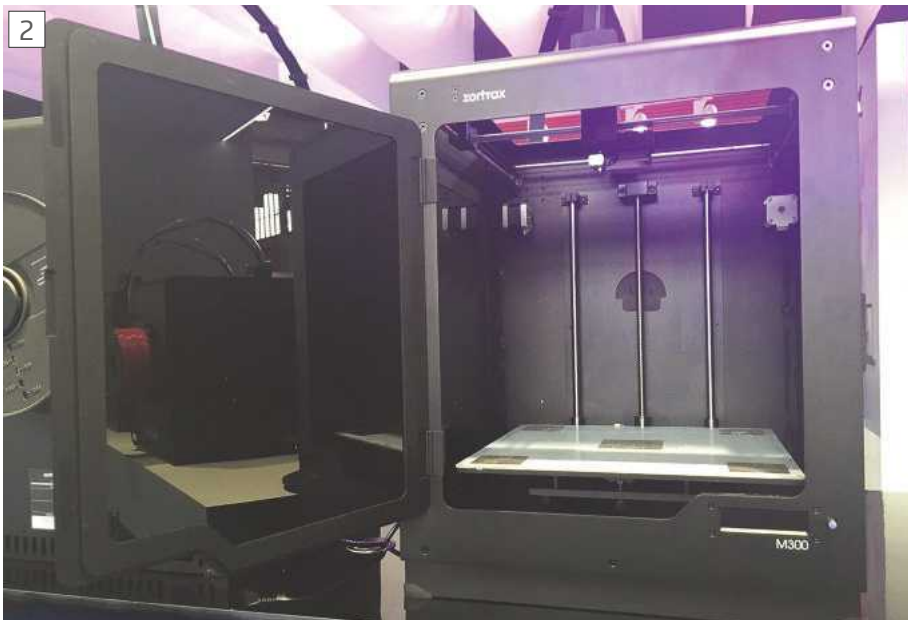
Conjure up the image of the typical home workshop and most of us will picture a chilly shed or garage at the heart of which will be a prized lathe and milling machine. Both of these tools are designed to whittle away material from an initial billet to yield the desired part, be it a complex loco wheel or a simple knurled knob. The file, saw and chisel perform similar tasks in that they all perform 'subtractive machining', to use the modern term. Indeed, identical processes have been the focus of our creative endeavours since the earliest times, whether it be chipping away flint to create an axe, shaving a pole to make a spear or carving bone into a fish hook. In contrast, the craft of 'additive manufacturing' involves the exact opposite - creating an object by applying new material to build volume and shape an object; this shift in technology probably began when the first artefacts were moulded in clay soon after 30,000 B.C.

The discovery of metal ores, with their smelting and casting during the late prehistoric period, began the revolution in additive machining which today has culminated in the mass production of die-cast and injection moulded components which equip our lives. Today many engineers would agree that a third revolution is gathering pace with accelerated developments in rapid prototyping brought about by the invention of new processes, materials and software. As hobbyists we should all take an interest in this field since there is the real possibility that in the not too distant future our chilly sheds will be replaced by cosy laboratories where small machines will be humming away conjuring precision parts seemingly out of thin air. Oily brown coats will give way to white surgical gowns and plastic overshoes, and we will all be wearing hairnets.

I had a chance to glimpse this future following an invitation to join an event at the HQ of GoPrint3D, leading providers of 3D printing solutions. The workshop was jointly hosted with Mintronics, specialists



An array of Ultimaker FDM printers working away in the demonstration area.



Zortrax M300 FDM printer from Poland.

James Blackburn of GoPrint3D holding a complex 3D scaffold produced by the Form 2 SLA machine behind him.

in solid modelling and reverse engineering software that includes the Alibre Design Suite. Inside their unit on the College Business Park in Ripon, GoPrint3D had set aside a lecture room and display area where a dozen of the latest rapid prototyping machines was beavering away throughout the day, with many finished parts also on show.

After an introduction by James Blackburn (GoPrint3D) and John Minto (Mintronics) we were guided through the design of a simple machine fixture in ABS plastic by Alibre specialist David Jupp. Once completed, the part was copied into an array of six and wired as an STL file to one of the machines next door to begin work, the results of which were inspected during the coffee break. David's presentation demonstrated the power of Parametric History-Based Modelling, as embodied in Alibre, explaining how this architecture enables any changes made to an initial sketch to ripple through the design, maintaining the scale, form and constraints that were embodied in the model. In this regard Alibre provides tools that are usually only found in costly high-end programs such as Solidworks or Catia.

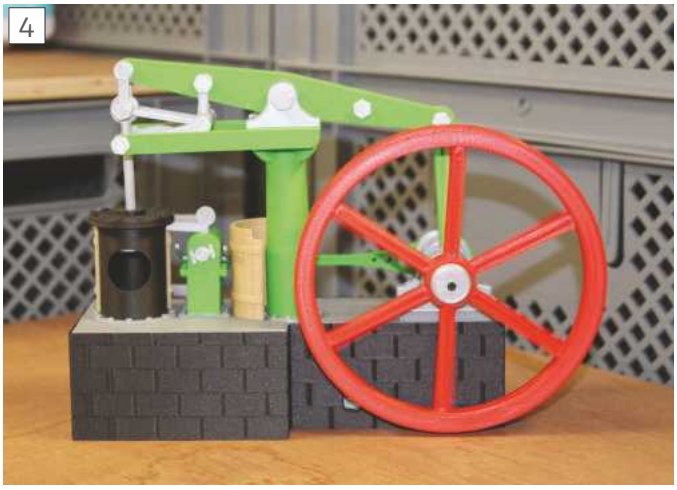
Next, we heard GoPrint3D gurus Kevin Askew and Darren Ayres outline the strategy needed to obtain optimum parts from a Filament Deposition Modelling (FDM) machine. These use the method of extruding a thin molten fibre to build up layers that create the part - the technique that is most often seen in hobby 3D printers. The physical properties and surface finish of FDM parts depend critically on the width of the filaments, the layer thickness and the orientations in which they are deposited. Not all FDM parts are layered as complete solids but may have larger internal volumes filled with a sparse mesh of filaments forming a less dense matrix of 15 - 20% that of a solid fill. This saves both on extrusion time and valuable material, but care must be taken to ensure that the final part has the desired stiffness where required, with minimal sag to any thin skins that overlie this matrix. Sagging can also be reduced by instructing the software to increase the surface layer density over the fill. The gurus also pointed out that it is best not to try printing a screw thread, since the outcome is generally very weak. Instead, print a hole into which is pressed a threaded metal insert. My article in MEW 225-227 described the use of threaded inserts and how they can be hot-inserted into plastic parts. Another tip given was that holes will be stronger when printed in the build (Z) direction, since otherwise any forces in an assembly will tend to split the filament layers.

Drawing on their extensive experience, Kevin and Darren explored in depth the way in which the factors of print time, material cost, shrinkage, fill configuration and part orientation in the printer can be married and optimised to obtain the best result. Much of the focus was on the best ways to incorporate support scaffolding into the design to ensure that thin walls maintain their shape as hot filament is laid down. The latest software, such as Cura and Z-Suite, creates scaffolding intelligently but we were shown how an experienced operator can make adjustments that minimise the extent of scaffolding and the resulting scars to the surface of finished parts once it has been removed.

In this context what was particularly exciting was our introduction to the new Ultimaker 3 FDM machine which uses two nozzles to layer the print, **photo 1**. These are fed by two separate spools of material, one of which can be installed as water-soluble PVA and programmed to use as the scaffold. Once the 3D print is finished the part is soaked in warm water to dissolve the PVA, leaving the model free of any surface scarring. Among the Ultimaker 3 parts on display were a ball in a cage and three nested dodecahedrons, all with parts that became freely moving once their PVA scaffolds had been dissolved. Very impressive and a major innovation for the FDM printing scene.

In the display area alongside the Dutch Ultimaker machines were a pair of Zortrax FDM printers from Poland. These claim to have a very high print accuracy, a view supported by their more robust carriage mechanism. Unlike the Ultimaker machines the Zortrax are enclosed at the front which may make them better suited to the school classroom. On the other hand the more inquisitive might prefer getting up close to the Ultimaker mechanics to witness the belt drive mechanism and ingenious rotating guide bars. One of the delegates did tell me that anyone planning to regularly use PVA in the Ultimaker would be advised to fit some sort of shield at the front, otherwise this material will splatter everywhere.

During a lunch break kindly provided by the sponsors we had time to examine the machines, talk to the other visitors and question experts from Mintronics and GoPrint3D. At the same time multiple prints of David Jupp's fixture had been finished and could be inspected together with many other parts produced by a range of processes. To me the most astonishing were objects produced by the Form 2 desktop stereolithography (SLA) printer, **photo 3**, which claims to be the 'most advanced



Stationary steam engine model printed by the FDM process.

Traction engine combining parts from an FDM printer, with soft tyres made in the Form 2 machine.

Motorcycle handlebar lever in stainless steel created by one of the new generation of metal printing machines.

desktop 3D printer ever created'. Quite a promise, but after seeing the results this was hard to dispute. In the SLA process the part is again constructed in layers, but rather than stacking molten filaments the printer uses a laser to scan and solidify a thin film of liquid resin. After each layer is hardened, the newly created surface is lifted and wiped to re-oxidise the resin in preparation for the next; the build platform is then lowered in the tank and the laser performs another scan. SLA has several key advantages over the FDM process. Firstly, printing an array of multiple parts is much faster, since the laser scan of the surface always takes a fixed time irrespective of the complexity. Secondly, the SLA material has isotropic properties, i.e. the strength is identical in all directions, because there are no filaments influencing the modulus. Next, an SLA print is air tight, since there are no voids as do exist between the filaments in an FDM part. Finally, and most significantly, the SLA print requires little or no surface finishing and can be glassy smooth with the right choice of machine settings. (As a caveat, one of the delegates told me that a porous FDM part can be sealed by painting or – with ABS – by carefully spraying with acetone to partially melt the surface).

While FDM printers store their material on a spool, the Form 2 holds the special resin in a cassette which fills the build chamber automatically and minimises waste. Once a print run is completed the resin tank can be capped to keep the material fresh for up to six months. A wide range of resin colours are available, both translucent and opaque, and we were told that some people even experiment by adding their own dyes! Of course the deciding factor is cost: the Form 2 costs £2,800 plus VAT. To complete the STL workshop you would need to add a gadget that removes excess resin from the part with isopropyl alcohol (Form Wash, £445 + VAT), then another to cure and harden the print in blue light (Form Cure, £625 + VAT). Doubtless, there are readers who could save on this added expense by adapting an ultrasonic bath to do the washing, while I am told exposure to daylight can cure the resin. The choice of desktop SLA printers is not however confined to Formlabs products - there are printers with smaller build volumes that can be purchased for under £1,000. See the resources list at the end of this article.

Many hobbyists have already built their own 'Reprap' and other filament printer kits (including our Editor) for under £300. Others might justify buying a ready-to-run FDM machine, arguing that the price (Ultimaker 2 is £1,125 + VAT) is comparable to that of a good hobby

lathe, while providing potential for creating objects that would be difficult to make by subtractive machining. Mr. Wyatt even uses his DIY printer to make complex patterns for 'lost plastic' casting. He designs and prints a plastic master, with an allowance for metal contraction. This master is encased in Plaster of Paris and baked in the domestic oven, thus melting the plastic to leave a void into which the metal is poured. Results are reported to be pretty good, although I am told that the melting must be timed to coincide with the family being out of the house because of the pong from molten plastic!

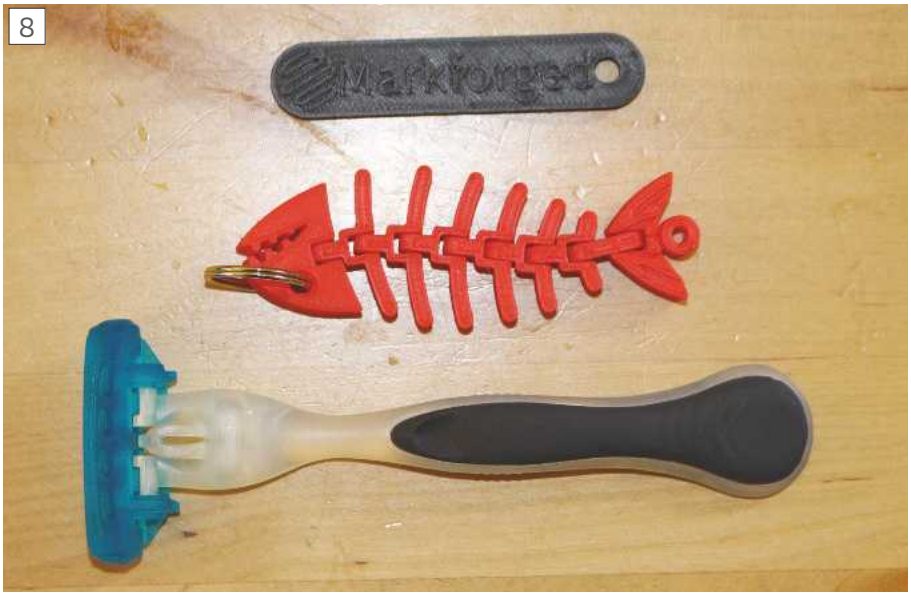
Photograph 4 shows a model that will appeal to all of us - a stationary beam engine assembled from parts printed entirely with FDM technology. The traction engine in **photo 5** combines rigid Ultimaker parts with softer tyres printed using a pliable black resin in the Form 2. Of course, the metal chain and screws are stock items, although they could today be made using one of the latest metal printing machines which, at around £100,000 are probably out of reach of most of us. GoPrint3D are soon to take delivery of a metal printer and we were shown an example of what can be achieved with this new technology - a handlebar lever in stainless steel that was finely perforated, and required no additional finishing straight out of the machine, **photo 6**. Other metals and alloys can be printed, although I also discovered that metal-filled filament is available for the Ultimaker which produces objects with a sheen closely resembling true metal. The downside, however, is that the metal power in the filament is abrasive to the print nozzle which must therefore be replaced frequently.

Some FDM printers can be configured to lay down composite material using glass or carbon fibre enriched spools, **photo 7**. The result is a vastly enhanced flexural modulus in a specified direction - in other words the direction that the filament has been deposited. With this potential comes the added requirement for the designer to consider where that extra stiffness is required. This is governed by the orientation of the part on the build platform and the structure of any open matrix filling void spaces in the model. Fortunately, GoPrint3D are happy to offer advice on these complexities in the quest to obtain the optimum result when using your printer.

Markforged 3D printers which can extrude composite material.

At this point in the day I was feeling so excited about the possibilities revealed during the workshop that my wallet was starting to itch. But which way to go ... and when is the best time to adopt any of these technologies? Obviously, I would have to sell both my kidneys and a cornea to pay for a metal printing machine and would prefer to conserve my integrity and wait until they become more affordable. How about a Markforged, Zortrax or Ultimaker toy, and can the investment be justified? Perhaps the more sensible alternative to an outright purchase is to focus on developing one's skills as a 3D designer in Alibre or software with similar capability, such as FreeCAD. Then send the file off to one of the folks on 3DHub who offer printing services using spare capacity on their own machines. That way I could devote time to becoming good at one thing, rather than being perpetually unskilled at too many things. Perhaps this comes down to a declining number of brain cells. Hand me the hair net!

We each left Ripon clutching a goody bag containing samples of what is possible with the technology seen on the day. Take a look at **photo 8** and doubtless you will also be excited by what lies ahead in the Model Engineers' Workshop. ■



From the goody bag: top carbon fibre reinforced name tag from the Markforged; centre articulated key ring printed by FDM; bottom shaver prototype composed of three resins made in SLA.

Resources

Printers and software sales, plus contract 3D printing: GoPrint3D
www.goprint3d.co.uk

Alibre 3D software suite:
Mintronics **www.mintronics.co.uk**

Ultimaker printers **www.ultimaker.com**

Zortrax printers **www.zortrax.com**
3D printing & slicing software: **www.all3dp.com/1/best-3d-slicer-software-3d-printer**

Affordable desktop SLA printers **www.all3dp.com/1/best-resin-dlp-sla-3d-printer-kit-stereolithography**

3D Hub for 3D printing services
www.3dhubs.com

Milling for Beginners

PART 5 - CUTTING TOOLS, MARKING OUT AND MEASURING TOOLS

This month Jason Ballamy finishes looking at cutting tools and discusses Marking out and Measuring Equipment

Taps

The mill also makes a good tapping guide as the tap can be used while the spindle is directly above a previously drilled hole. The tap can be guided with a male of female centre held in a collet or the drill while being turned using a tap wrench. If your mill is equipped with an electronic tapping feature, then it can be held directly in a collet and driven in and out under power. We will have a better look at taps in a later instalment when we come to use them, **photo 47**.

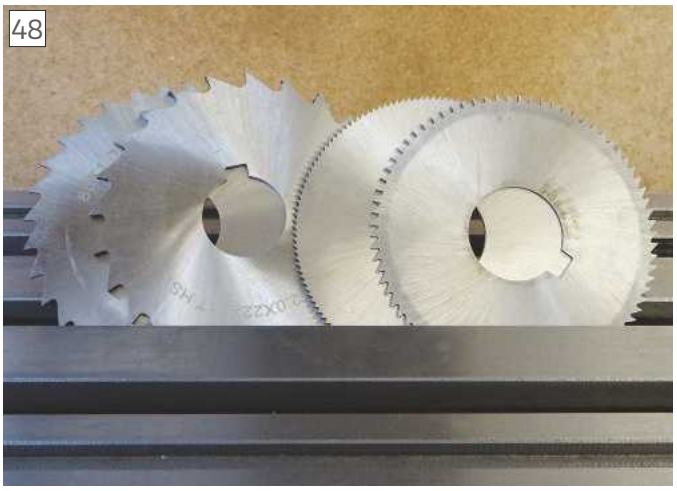
Coarse and fine pitch taps

Slitting saws

These circular saw blades can be used to cut a narrow deep slot in a surface where a milling cutter would be too long and slender, cut slots in screw heads or simply to saw a piece of metal into two. They come in a range of diameters and widths to suit the job in hand and in two tooth pitches. The fine pitch ones should be used where the cut is shallow such as slotting screw heads or where cutting through thin material, the coarse blades have less teeth which means a large gullet between them which will not fill with swarf on deep cuts with there risk of jamming the blade, **photo 48**.

Hole Saws

Where a large diameter hole is needed particularly in thinner material a hole saw can be a quick and efficient way to remove the material without having to generate masses of swarf. A hole saw is in effect a short length of tube with saw teeth on one



Coarse and fine pitch slitting saws

Hole saws and Arbors

end and the other closed off with a disk that is threaded for an arbor and in the larger sizes also has holes for drive pegs. You will need an arbor to hold these cutters of which two sizes are made, one for the smaller diameter cutters and one for the large, **photo 49**.

Trepanning tool

Another way to cut a large hole in thin material is to use a trepanning tool which consist of a shank with an arm at right angles to it, a tool holder that can be positioned along this arm to set the radius required and an HSS cutting bit.

MEASURING AND MARKING OUT.

Basic hand tools

The most basic measuring tool that you will need is a steel rule, one of 150mm/6" length will do for most small models and projects and a 300mm/12" one if you plan to work on larger items. The narrower more flexible ones are a bit more versatile than wide rigid rules as they can fit into tight spaces or against work still held in the mill.

> Keep your square in a draw or cupboard rather than mixed in with clutter on the workbench as once they get knocked out of true they can muck up a lot of subsequent work...

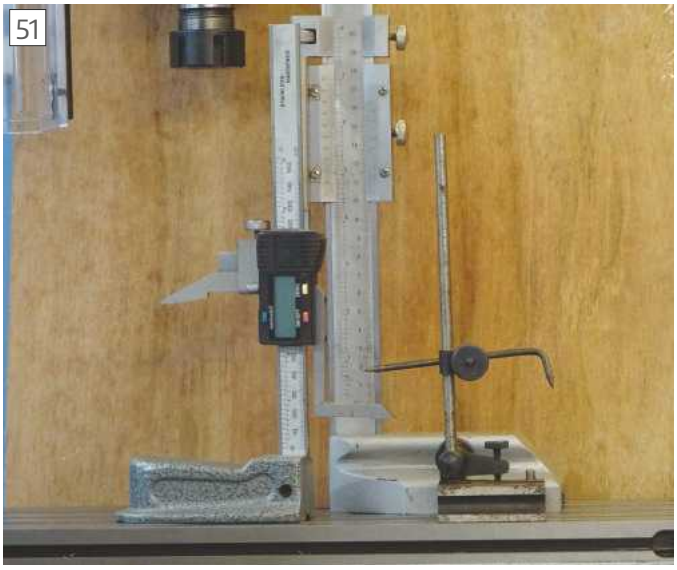
Selection of marking out tools, Rule, Scriber, Auto Punch, Square, Dividers and odd leg callipers

To mark out any measurements on your work will also need a scribe which has a hard, sharp point that scratches a line on the surface, you can make things easier to see by first coating the surface in marking out blue (not engineers blue) or a wide marker pen will do a similar job but can wash off more easily with some cutting lubricants.

A tri-square allows for marking lines at 90 degrees to a surface and should be used in preference to scribing with a rule held against the work unless marking at angles. The Square can also used to set up work across or vertical to the mill table. Keep your square in a draw or cupboard rather than mixed in with clutter on the workbench as once knocked out of true they can muck up a lot of subsequent work until you realise they have gone out of truth.

Scribed lines can be used to mark out the position of holes which should then be marked with a punch to make them easier to locate when machining and a drill bit will not wonder over the surface if it has the crater of a punch mark to locate into. Simple punches that are hit with a hammer will do or an automatic punch that has a sprung point can be pushed against the work until it "hits" the surface to make a mark.

A pair of dividers which are like a screw adjusted compass with two points are useful for marking out circles and curves as well a stepping off multiples of the same dimension. Odd Leg or "jenny" callipers have one notched leg that will run along the edge of a work piece and the other scriber point leg is used to mark lines parallel to that edge, **photo 50**.



Scribing Block and Digital & Vernier Height Gauges

Digital Callipers

Scribing blocks and Height Gauges

A scribing block holds a scriber at a height which can be set against your steel rule and is used to mark lines parallel to a surface they are a lot easier to use than trying to hold a straight edge against marks while you scribe a line by hand.

The next step up is a height gauge which has a hardened steel blade that is positioned either with a Vernier scale or has a digital readout of the height above the base. These are a lot easier to set accurately than the scribing block but are not an essential item when you start out so can be added to the tool kit as and when you feel the need for them.

To use these items, you will need a flat surface to work from, cast iron or granite surface plates can be bought but are quite costly to start out. Alternatives are granite chopping boards or the glossy porcelain tiles that are popular at the moment have adequately flat surfaces for most work and are what I use, **photo 51**.

Digital and Vernier Micrometers

Digital, Dial and Vernier callipers

The calliper is probably the most versatile measuring tool and in this day and age a digital one is likely to be the usual choice due to ease of reading and the fact that one tool can show results in Metric, imperial and fractional inches. The mid price range callipers are generally more than adequate now so a brand name is not a must but some of the very cheaply priced ones can leave a little to be desired. A 0-150mm (0-6") size would be a good all rounder though the smaller 0-100mm ones can be handy for taking vertical measurements of work in the mill as they fit in better under the head.

The calliper can be used to measure lengths, both internal and external diameters as well as depths by means of the blade that comes out of the scale. They do take a while to get the right feel to ensure you are measuring at right angles across the part and not at a slight angle which will give a false reading but will give accurate enough results for most work, **photo 52**.

Micrometers

Like the calliper these are available with either the traditional vernier scale or a digital readout, I prefer the vernier type as the digital ones can be a bit big and bulky which can be a problem in restricted spaces and they take a bit more getting used to holding correctly onto the work. Unlike the calliper they cover a shorter range of measurement so you will need one for each size group you are going to work in such as 0-25, 25-50, 50-75, etc. but to start off with 0-25mm will be the most used and probably more so for measuring turned diameters on the lathe than thicknesses on the mill. separate ones with different anvils will be needed for external and internal measurement, **photo 53**.

Depth Micrometers

These use a similar method of measurement to a regular micrometer but have a flat base that is held against one surface and a protruding anvil that is adjusted until it touches another and the measurement taken. Again, available in digital and vernier versions they often come with interchangeable anvils so one tool will cover several measurement ranges. The wider base makes them easier and more accurate to use than the blade of a calliper which can be hard to keep perfectly perpendicular to the surface, **photo 54**.

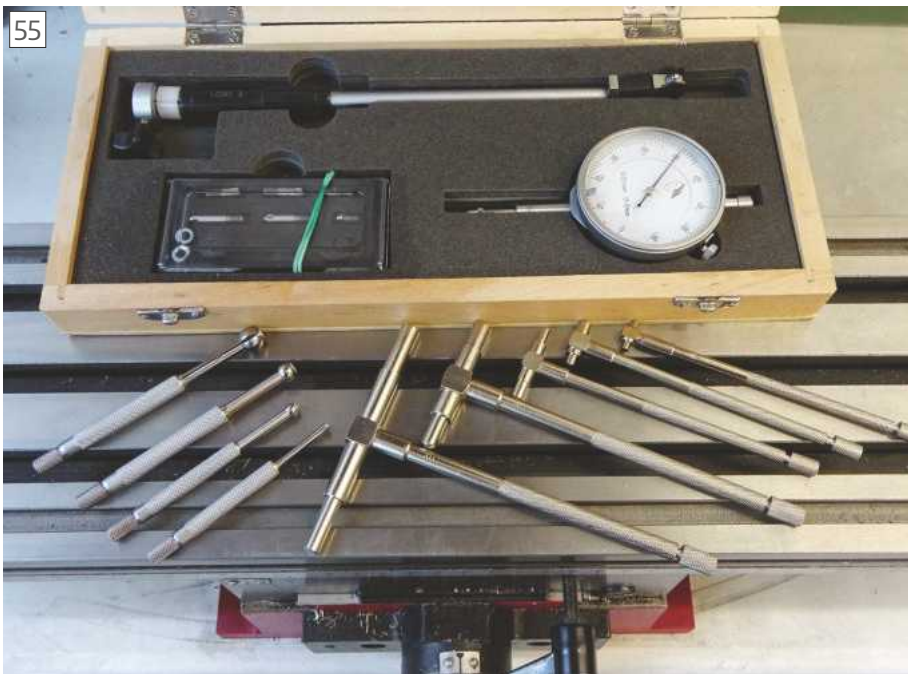
Digital & Vernier Depth Gauges

> I prefer the vernier type as the digital ones can be a bit big and bulky which can be a problem in restricted spaces and they take a bit more getting used to holding correctly onto the work.

Bore Measuring

Probably of more use on the lathe but useful when using a boring head on the mill there are a number of tools available to measure the internal diameter of a hole particularly if you want to measure a fair way down. For small holes you can get small bore gauges that have a split ball on the end that is expanded by a wedge until it touches the sides of the bore, this can then be extracted and measured with micrometer or callipers. For larger diameters telescopic gauges are used which consist of a telescoping shaft on a handle, the sprung shaft is compressed and slid into the hole to the point of measurement where a screw on the end of the handle locks it's length then like the ball gauge it is removed and measured, **photo 55**.

Dial and micrometer bore gauges have a means of reading the actual size of the hole or how much below (or over!) the desired size it is making it easy to know how much more metal needs to be removed. These are getting a bit specialist and will not be wanted until you have progressed quite far into the hobby.



Dial, Ball & telescopic Bore Gauges

Edge finders

A lot of the time you will find it easier to use the mills hand wheels to position the spindle relative to the edges of the work piece, this is especially so on mills equipped with a DRO. There are several tools that can be used to find the edge of the work, the most basic is to hold an accurate round shaft in a collet, something like a 10mm diameter HSS tool blank would be a good start, this can be brought up to the edge of the work and when it touches the spindle is half the diameter away from the edge. A step up from this is an edge finder, these can either be a magnetic one where the main shank is held in a collet and the end brought up to the work while spinning, as it touches the work the end will move sideways and at the point it moves you are once again half the diameter away from the work. A similar method is used by the "wobbler" type finders which have a range of interchangeable different ended tips which will run along the edge when half the tip diameter from an edge. Electronic edge finders will light up and/or sound as the end touches the work, **photo 56**.

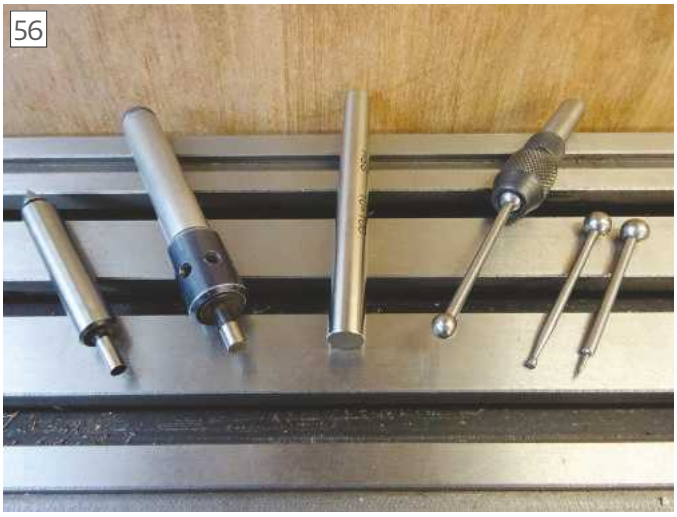
> A lot of the time you will find it easier to use the mills hand wheels to position the spindle relative to the edges of the work piece...

Dial Test Indicators (DTI) and Dial Gauges

These can have either a plunger or lever that moves a needle against a dial when it is run along a surface and will show very small amounts of movement. The plunger type are referred to as Dial gauges and the lever type as Dial Test Indicators. They can be used to check the alignment of the mill and also set tooling and work parallel to a mill axis very accurately. You will also need something to hold them with, a magnetic stand is very versatile and a means to mount them in the spindle is useful for machine set up and also locating round work, **photo 57**.

Co-axial indicator

This tool is held in the spindle and has an arm to stop the dial from rotating that needs to rest against a fixed object. One of the various arms is mounted in the other end and set to run around the edge of a round work piece. Then with the



Edge finders

DTIs, magnetic Stands and Holder

machine running very slowly the table is moved in the X and Y direction until there is no movement of the dials pointer at which time the spindle will be central to the work. A fitting is also supplied to fit into a punch mark so that can be also be located. Their only downside is they do need a fair amount of room between work and spindle so may not suit very small mills or large work pieces in which cast the DTI with a suitable holder can be used, **photo 58**.

Angle measurement

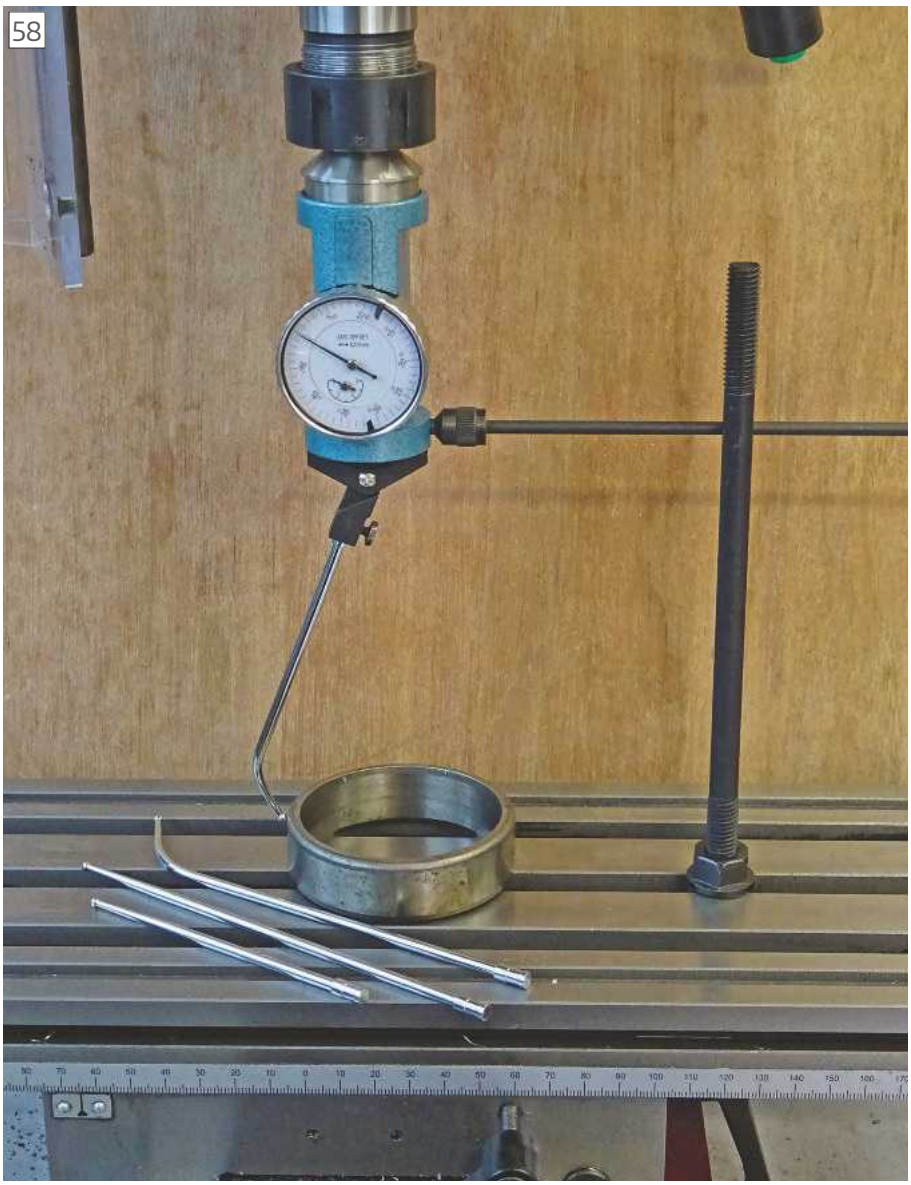
For marking out and measuring angles various protractors can be used ranging from a simple pivoted arm to a precision protractor. The latter consists of a quadrant marked in degrees and a blade that can be moved around it using a fine adjustment wheel; a vernier scale allows for quite accurate settings.

In recent years various digital tools have become readily available and allow for quick and easy setting up of work at various angles the most common being the small magnetic angle boxes which can be placed on the work while it is set to the desired angle aided by their magnetic base. They can be zeroed in on the table, so it does not matter if your machine is not sitting perfectly level, **photo 59**.

DRO (Digital Read Out)

A DRO is used to display the actual amount of movement the table or tool moves and can therefore be more accurate than using the machines hand wheels due to backlash in the screws and nuts. As with most things they come in different price brackets and you generally get what you pay for. I will take a more detailed look at these later in the series as they are not essentials to getting started and making swarf. ■

For a full list and links to the items featured which are available from Arc Euro Trade, **http://www.arceurotrade.co.uk**, who also sell the X series of mills see the accompanying thread on Model Engineer Forum **http://www.model-engineer.co.uk/forums/postings.asp?th=131318**



Co-axial Indicator

Precision Protractor and Digital Angle Gauge

Drip Feed for a Lathe

Jos Corbeau and Henk Salij in the Netherlands have passed on this unusual idea.

Henk starts the story: I think I have an interesting contribution for MEW, it is from a member of my Model association, called in Dutch NVM afd. Rotterdam or in English NVM region Rotterdam.

NVM is Nederlandse Vereniging Modelbouwers. (English- Dutch Assotiation of Modelengineers).

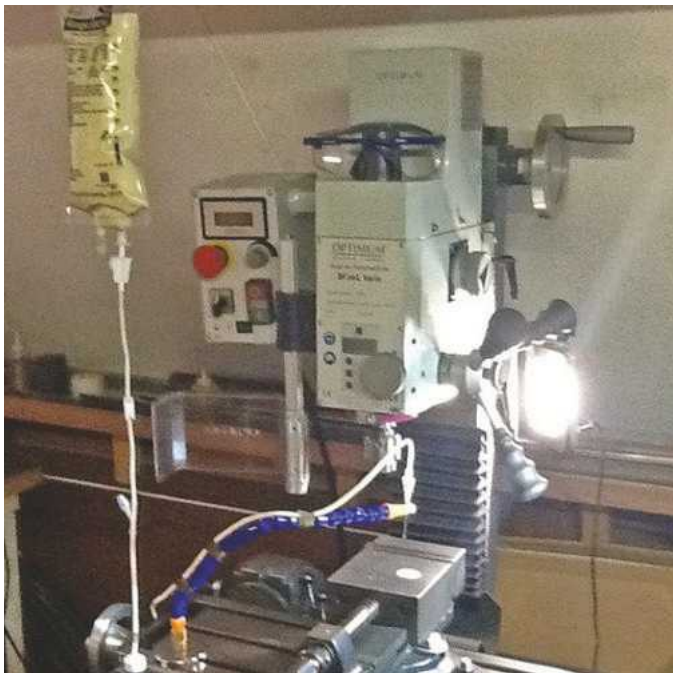
Jos Continues: during a short stay in a hospital and when I was connected on an infusion I got an idea to use the bag for my hobby. With the agreement of a nice nurse I could take the infusion to my home.

I filled it with lubricating/cutting oil and hung the bag about 1 1/2 metres above my lathe.

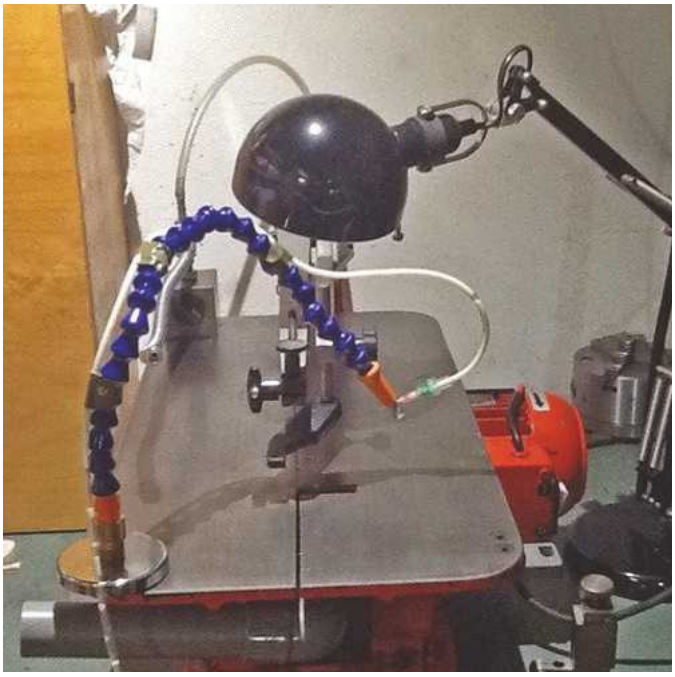
The hose with special valve, on which I mounted at the end a small outlet pipe, was connected to a magnetic stand.

Now I can cool my milling, turning and saw work drop-wise. ■

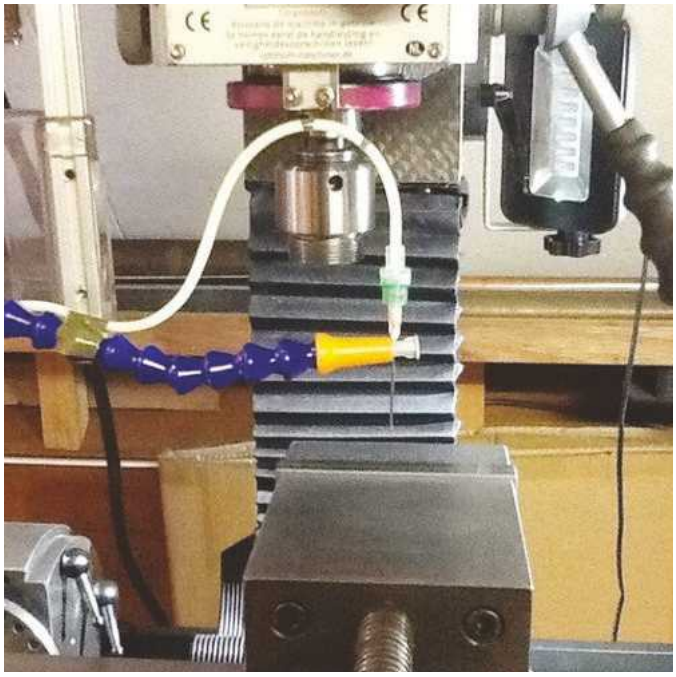
The bag filled with cutting oil



Used with the mill.



On the saw table



A close up of the nozzle

The John Stevenson Trophy 2018

A large number of readers and forum members generously contributed to a trophy in memory of John Stevenson, a contributor to MEW but best known for his larger-than life presence on the Model Engineer forum. The cup is engraved "John Stevenson, 1948 – 2017, Remembered by his many friends" with "Awarded for Excellence in Practical and Useful Workshop Equipment" on the plinth.

The John Stevenson Trophy is presented for just that, a well-made and usable piece of tooling, a modification to a machine or an accessory for a tool where the fact it works well is more important than making it look good.

Unlike traditional judged trophies, we decided on a different approach to reflect John's reticence about traditional competitions. After a call for nominations, a small panel of judges selected a shortlist, on which there would be a public vote.

The nominations for the competition were:

1. John Ashton's **Screw Modification Fixture** which appeared in MEW 250.
2. Gary Wooding's **Bandsaw Blade Repair Jig** from MEW 252.
3. Alan Wood's **Laser Centring Tool** which featured in MEW 253.
4. Mike Cox's **Ball Turning Tool** in issue 259.
5. Richard T. Smith's **Tooling System** which featured in issues 255 and 266.
6. Warren Jacobs' **Easy Quick Change Toolpost** in MEW 250.

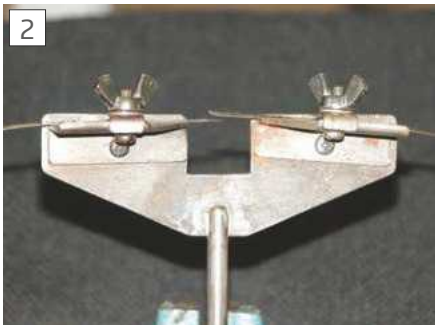
The winner: John Ashton

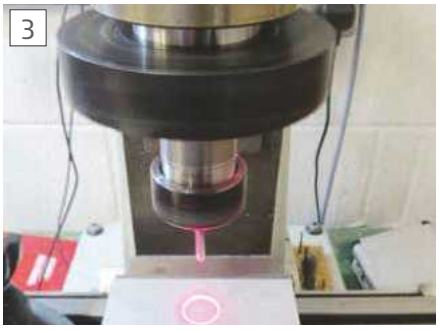
A vote was held allowing MEW readers and forum members from **www.model-engineer.co.uk** to choose the winner. In the end there was a very clear winner, John Ashton and his neat screw modification fixture with 27% of the votes cast. In second place was Alan Wood's Laser Centring Tool. The remaining entries were bunched so closely together it would be pointless to put them in order, so congratulations also to Gary, Mike, Richard and Warren.

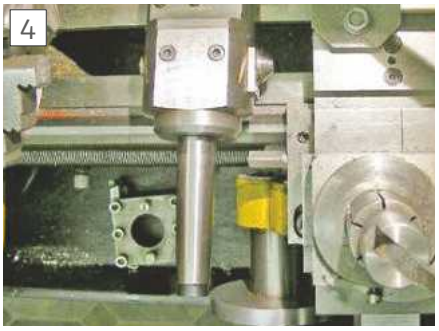
Unfortunately, John Ashton was unable to get to the Doncaster show for the presentation as he was on holiday, but we will be meeting up with him to hand over the trophy soon.

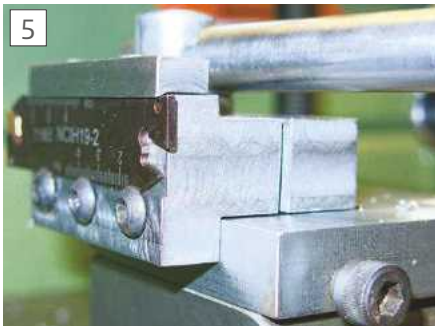
We learnt a few lessons from running the competition, mainly that no matter how simple you think it will be, in practice it's a lot more complicated and takes longer than you expect. We will be making a few changes for next year, but please be assured the one feature we will keep is making sure the winner is decided by a popular vote.

Thank you to everyone who entered the competition, to everyone who contributed to the fine trophy and to everyone who voted. ■









Scribe a line

YOUR CHANCE TO TALK TO US!

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

Cutting Fluids

Dear Neil, I am an old(er) learner, still teaching myself and learning by mistakes. One of the issues I have is what, if any, cutting fluid to use and how to use and when to use.

There is a minefield of personal opinion and information on the forum and on the web generally. I have read about soluble oils going rancid after a few weeks and from those who say theirs is 3 years old and they have no problems and only use their machines infrequently.

I think an article on cutting fluids and there use from an expert would be invaluable to those without the benefit of having worked in the industry. To include types, pros and cons, cost, ease of use, health & safety particularly the bacteria associated with soluble oils, etc.

I am particularly interested in the bacteria angle as I am immune suppressed and have to be very careful with such.

Peter Caswell, by email

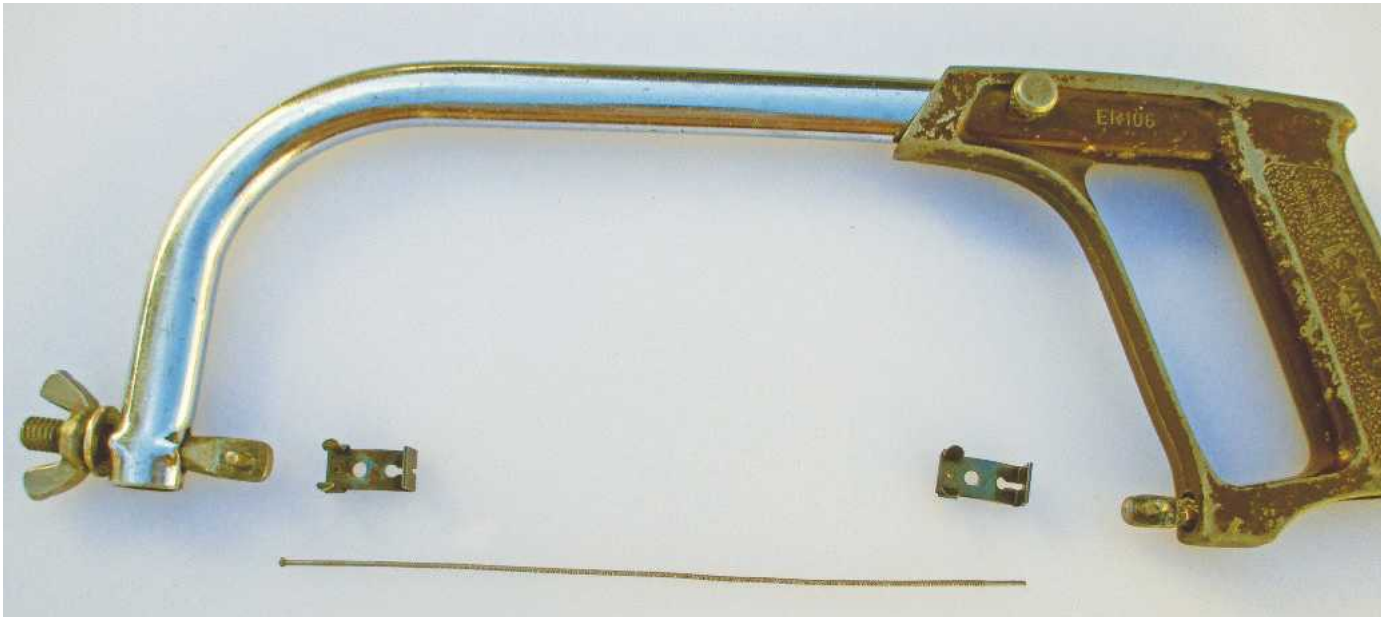
Could any readers who may be able to contribute an article on this subject, please get in touch – Neil

Abusive Behaviour

Dear Neil, I would like to express my gratitude to Mr Lodge for his letter in No 268 expressing his concerns for the well being of the SX2.7 mill supplied by Arc Eurotrade. I can assure Mr Lodge that all the photos so far in the series have been carefully posed for photographic purposes and no mill tables have been hurt in their production. I quite agree that during use it is good practice to protect machine surfaces from accidental damage be they the mill table or lathe bed. I usually have a piece of MDF on the mill table as can be seen in my build threads such as the one in the following link but felt it better to present the tools on the mill rather than an oil stained scrap of board.
http://www.model-engineer.co.uk/forums/postings.asp?th=114711

Jason Ballamy, by email.

Eclipse Round Hacksaw Blades



Dear Neil, You may not be the right person to receive this request, if not please pass on?

For some time now I have been using the attached blade for fine cut outs and now down to the last one.

I have tried throughout Australian stockists for replacements, I'm told Eclipse no longer make them if so, is there a similar version available and how do I go about procurement ?

By the way I have been buying Model Engineers Workshop for the past 15 years and enjoy.

Richard Cains, Australia.

Earthquakes Down Under

Dear Neil, perhaps Mark Noel can be persuaded to write that article on seismographs? Since 4/9/2010, we have had 23,430 'quakes within 150km of Christchurch NZ as at 11-00 am 8/5/2018. The 4/9/2010 was a 7.1 11km down – I therefore have a rather more than 'passing interest'.

On 22/2/2011 a 6.34 only 5.95 km down in the South-East of the City wrecked it, ground acceleration was about 2.5 x gravity – it threw me across my office into a wall and then back to meet a cupboard falling over. The office was a mess of overturned filing cabinets and other furniture and scattered computers / screens. Over the next few months there were 4 over 6, two whilst I was driving and fighting to keep the car under control – a LARGE coffee was required both times! One was as I was driving around a roundabout in the right hand lane with a road haulage tractor on my nearside with a 40' trailer carrying a large boat – he was 'jack-knifing' both ways and the trailer wheels were lifting off the road – the 'shock ripples' running across the road could easily be seen (we were about 2km from the epicentre).

The 4/9/2010 R7.2 was during the night, and we are more or less in line with the fault ('Greendale') and about 15 km from it. I was thrown across the 'family couch' waking my wife, we headed an erratic course through the house to get out as it was heaving, rocking and shuddering – the pictures were banging on the walls - books falling off shelves – the cat regarded it as 'our problem' and complained loudly. The most interesting was a steel spiral staircase I had built in the workshop for access to the then new upper storey – we could hear a weird whining noise. This was the vertical baluster bars supporting the handrail, they are of three different lengths on each step – their lengths must be multiples of the frequency / wavelength of the 'quake and were vibrating in sympathy. We have named it our 'Tectonic Harp' – it only does this for 'quakes of R 6.0 or over.

People do get used to earthquakes – about 2 – 3 months later when in a supermarket in a local town, there was a smallish earthquake and a small child was panicking – its mother said "Oh don't make a fuss, it's only a '4'"! with the 10's of thousands that we have experienced now, most people don't even take any notice – I have attached a photo of what one does to the ground.

Peter King, New Zealand

Angling for a Disaster?

Hello Neil, Was browsing through issue 264 which was passed onto me by a friend and was reading your part 3 of Lathework for beginners "CUTTING TOOLS".

You state " For metric threads the 60-degree tool is used, whilst 55- degress is used for imperial threads." I would like to point out that statement is far from correct as U N F (NF) @ U N C (NC) which was used widely on English motor vehicles are both 60-degree imperial threads and replaced B S F over time.

However, as a retired diesel mechanic and a home machinist I value the info and ideas that are presented in "Model Engineers Workshop" and look forward to the copy being passed onto me.

Ally Stephens, Napier, New Zealand.

Hello Ally, in my defence the UNF and UNC standards aren't greatly used in the UK these days and they aren't strictly 'Imperial' as the USA were one of the partners who adopted the standard for interchangeability of wartime production and where these fixings are most commonly encountered – Neil.

Arbor Presses

I have recently caught up with your magazine No 264 to see my letter to you concerning the BA thread in print. It is always nice to see something I have written to be considered worthy of publication. Only one little problem you are Neil, and I am Alan. No solicitor's letters involved. I realise that editing any magazine is no small task and errors do occur.

I use a number of arbor presses in my hobby work. The handles of these things can come down at inappropriate times causing minor injuries. I have solved my problem using two methods. Where possible I fit a magnet above the press to secure the handle. The other solution is to fit a spring from the top of the plunger to a shelf or the roof above. This can either balance the press movement or cause the handle to stay up out of the way when not in use.

Your issue No 265 should be available shortly so I will keep a watch on the newsagent.

Alan Middleton, Australia

My belated apologies, Alan! - Neil

Rotary Table Indexing

Dear Neil, I would like to take this opportunity to thank Howard Lewis for the updated HV6 index table which he placed on the website.

I walked into the trap myself about 2 years ago using the HV6 table to index 40 teeth for a gear. I then calculated and corrected the settings for the 40 index after spoiling 2 wheel disks. I did not then check all the other info in the table.

When I downloaded the table done by Howard I realised that there were more than one error in the table. I can not understand how a firm like Vertex could publish faulty information.

I now spent some time calculating some of the other missing divisions in the table and found that 44 divisions can be done with index B-33 and 2 + 6/33 divisions.

Likewise 84 divisions can be done using index C-49 and 1+14/49 and index 88 can be done with B-33 and 1 + 3/33.

Please publish this info in MEW for the benefit of other HV6 users. I did not change Howard's table on the website.

Dirk Du Plooy, Nelspruit, South Africa.

A High Speed Engraving Attachment

Keith Johnson made this device to fit his CNC Wabeco 1210 Vertical Milling Machine, but it would suit most other CNC mills of similar capacity. Part 3

From the underside fit M8 Pronged Tee Nuts, I do this with a piece of allthread screwed into the nut, thread this through hole, place a large thick washer onto the thread, followed by an M8 hexagon nut, with a ring spanner pull the Pronged Tee Nut into place, **photo 20**.

Place onto milling machine, clock along guide bar, setting the sub table true to machine axis, and secure down, **photo 21**. The blank to be engraved is now placed in contact with the guide bar and flush at the bars left hand end. Clamp in place using threaded holes in the pronged tee nuts.

Using an edge finder against end and edge of the guide bar that easily locates the chosen origin position, at the top left hand corner in this example.

Pronged Tee Nuts

Spring Loaded Toolholder – fig. 7

When CNC engraving the entire workpiece must be precisely positioned at the same height above the machine table. Any variations will show as varying line widths on the finished work.

The current method to overcome this problem is to use spring loaded tool holders for controlling the depth of cut and visually the line width.

The drawing details a typical holder that is simple to make and works well.

It consists of a concentrically turned and double milled slot steel body, with an accurate 14mm diameter x 40mm deep flat bottomed hole at the front. Do not forget to drill the 2mm diameter vent hole (this prevents the toolholder sticking due to trapped air).

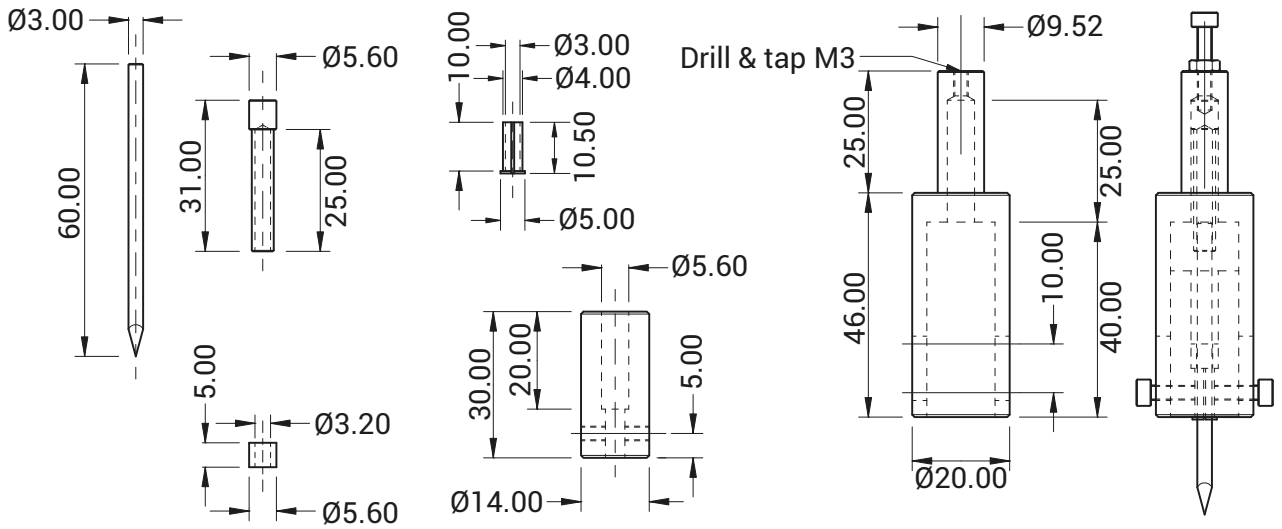
Clocking Sub Table

At the opposite end an M3 tapped hole takes care of spring preload adjustment. The 3mm diameter HSS engraving cutting tool, is double clamped with M3 cap screws pressing on a split brass sleeve, this sleeve is pushed into the front end of the 14mm diameter x 30mm steel tool holder.

On assembly the M3 cap screws pass through the 3.2mm x 10mm slots that are milled in the body. This arrangement provides both clamping and drive to the spring-loaded cutter.

The steel compression spring 44.5mm long x 5.5mm diameter is contained between two brass end caps which locate in drillings within the body and tool holder. The lower (approximately 5mm long) brass spacers length is finally decided when all other parts have been made.

Fig.7



Spring Loaded Tool Holder

Steel compression spring - 44.5mm x Ø5.5mm, rate 0.23N/mm
Supplier - RS Components, pt.no. 821-346

To check required length of spacer, hold completed body without pre - load adjusting screw in left hand, slide in upper spring adjuster and spring followed by the tool holder only. Keeping the items upright everything should now be supported on the spring.

Gently press the toolholder down, watching it return due to spring pressure.

Measure from the front edge of the body down to the tool holder. Add 1mm to this measurement to establish the little brass spacer overall length.

Re assemble with the spacer in place and the tool holder should now be 1mm proud of the body. With the M3 cap screws in place the tool holder should be flush with the body front end, we now have a touch of pre - load applied to the spring in the starting position.

Screw an M3 x 25mm preload adjusting screw with a lock nut into place, check the pressure required to compress the spring as more pre - load is applied with the adjusting screw, **photo 22**.


22

Spring Loaded Tool Holder

Alternative Purpose Made Work Spindle – fig. 8

This drawing details a spindle I intend to make, using easily available standard metric ballraces, with all other parts machined to size and left in the soft condition. However, before starting this spindle I must totally focus on completing my current project, a Congreve Clock with the well-known rolling ball table escapement.

I can then put the Alexander spindle back in the pantograph machine and advertise it for sale. I could really do with gaining a bit of space back in my workshop, this will help.

3 Facet or Triangular Pyramid shape HSS Engraving Cutters - Tool Details **fig. 9**

The majority of my engraving is onto brass sheet with the odd piece of aluminium or steel as required. Brass is engraved dry, Aluminium always lubricated with turpentine from a brush prior to starting, and Steel with a drop of cutting oil again applied with a brush prior to starting.

I only use HSS tools ground with 3 facets at 120 degree spacing, the half angle of the flats is chosen, depending on line width required, from 4 options as detailed in the table see fig. 9. This produces a cutting-edge half angle again as detailed in fig. 9 at this stage all my tools are ground to a sharp point and removed from the cutter grinder, although at this stage of making these tools will not cut.

To complete the cutter and achieve the required clearance angles I use my 30-degree sharpening block placed on a small piece of MDF. Working on the bench, place a lap plate against the 30 degree angle block, set and clamp the cutter into a vee block with one cutting edge centrally uppermost, now in plan view angle the vee block and tool are at 30 degrees to the lap plate. Note this angle must be in the correct direction to suit cutter rotation. Slide the tool point across a fine grade lap plate/oilstone to truncate the pyramid and produce the required cutter geometry, it only takes 2/3 passes to complete. This method works well, but the tip width produced is a bit of a lottery as to its actual dimension.

Engraving to Numbers

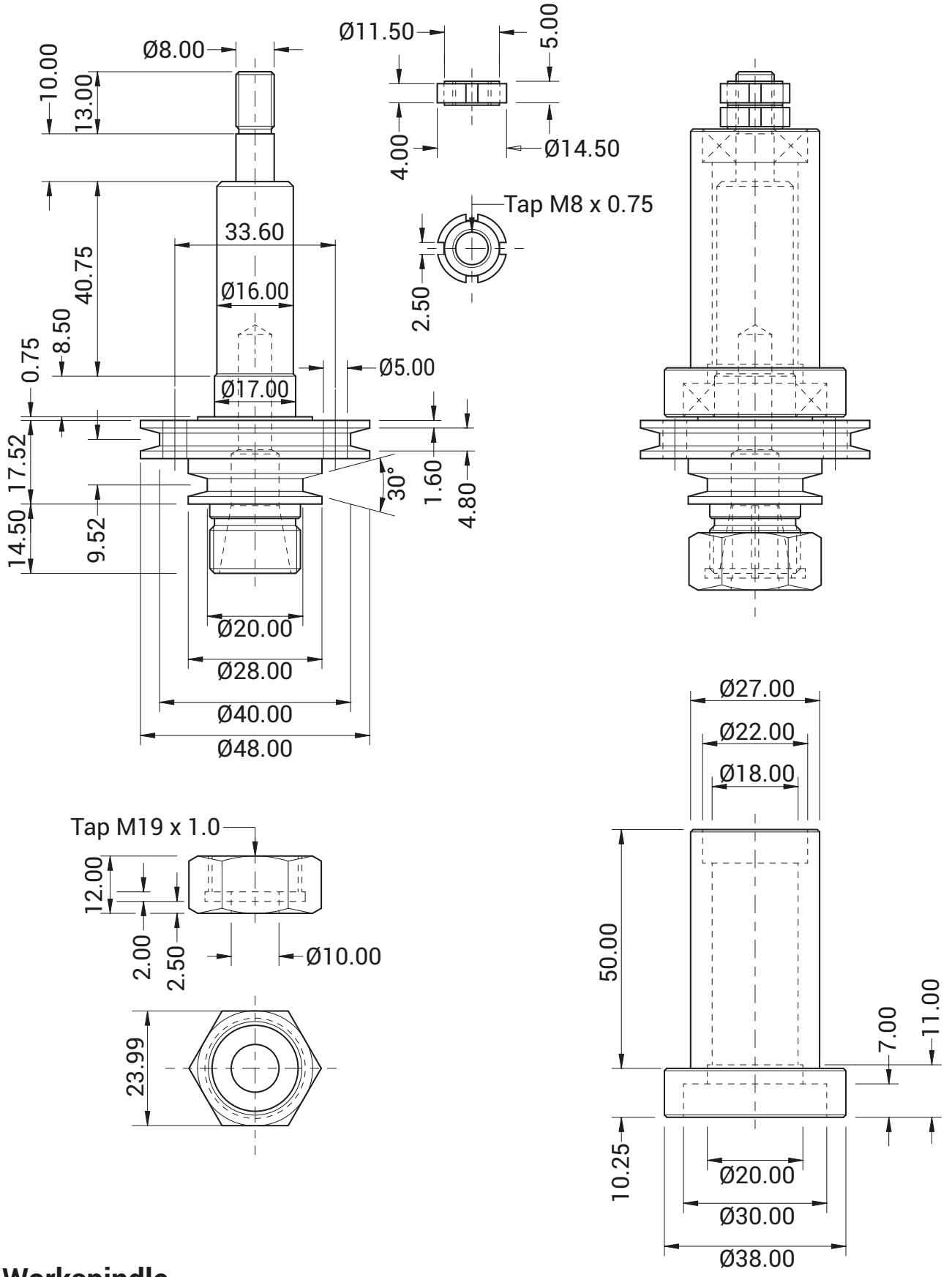
This is my most accurate method, giving total control and repeatability of all dimensions from design to finished job. I always visualise engraving cutters in the minds eye to be like small fly cutters, having a single rotating cutting point that must have clearance in all directions to allow side and end cutting. Since making this attachment and thinking about controlling the tip width of cutters more accurately I have improved and simplified the method used, completing all operations on the cutter grinder.

Start by grinding the three flats at chosen half angle and spaced at 120 degrees, when all flats meet, forming a sharp concentric point stop grinding.

Zero all relevant dials, now working on one flat only grind away material, checking on the graduated dial until the reading equals the desired "grinding distance" this

›

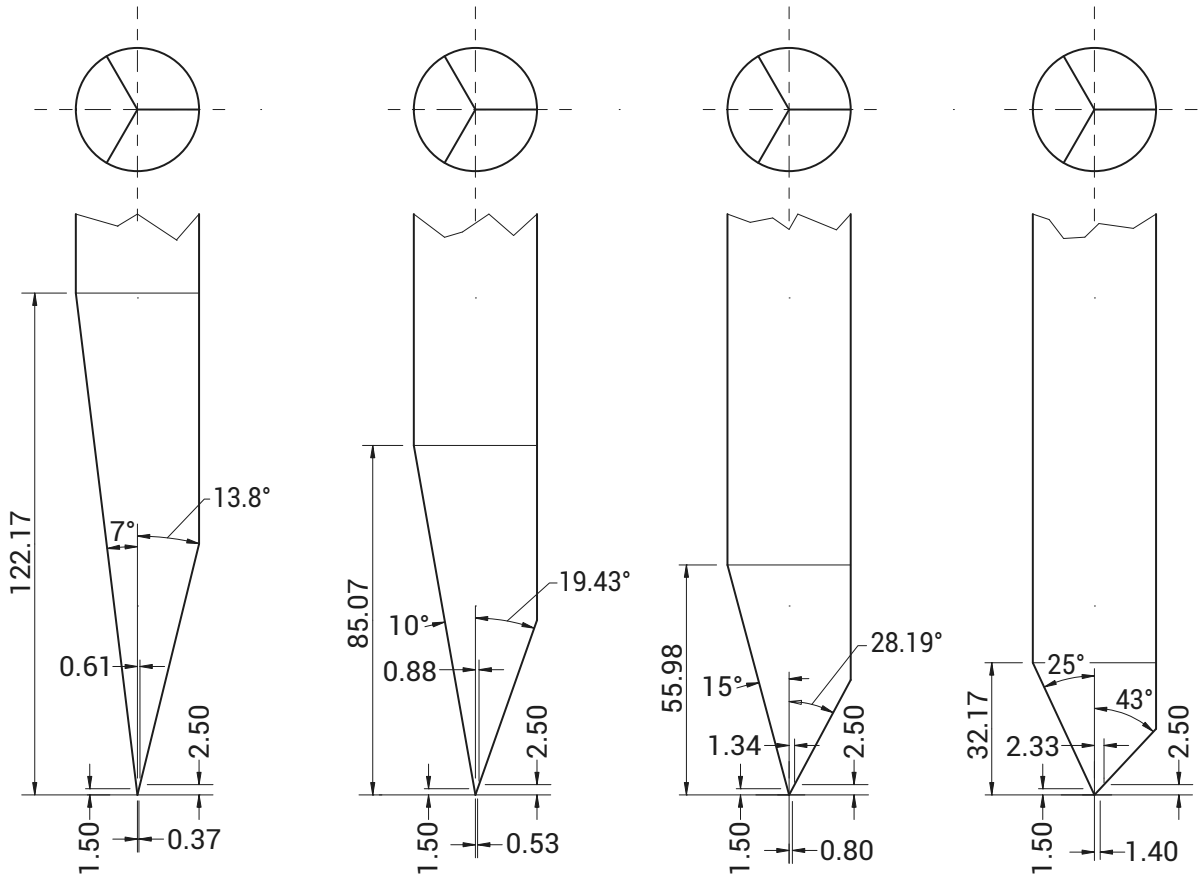
Fig.8



Workspindle

Fig.9

Note all tool drawings 10x full size for clarity



Pyramid face grinding angle	7°	10°	15°	25°
Pyramid edge cutting angle	13.8°	19.43°	28.19°	43°
Angle width @ 0.15 deep	0.037	0.053	0.080	0.14
Angle width @ 0.25 deep	0.061	0.088	0.134	0.233
Angle width @ 0.30 deep	0.074	0.106	0.16	0.28

Note all dimensions in this table are actual sizes

Tool Details

dimension produces the tip width required fig. 11 shows all details.

This last stage of grinding has produced an eccentric single point cutting tool, when spinning will cut at twice the tip width. Typically, cutters use tip widths from 0.1mm upwards. For engraving larger work with wider lines, grind cutters at larger half angles, again using similar tip widths as already described.

The recommended depth for standard engraving is 0.15mm, but work that needs to be filled with either / paint / wax / epoxy resin / etc, a depth of 0.25mm or 0.30 is the usual standard. Line widths and character height can be quite accurately measured using a digital caliper gauge, assisted with good magnification and lighting.

Cutters made as above are much stronger than other types, cutting well to produce burr free finished work.

Line Widths – Measured on the work Top Surface

It is necessary before starting any engraving to decide the style, type and height of the characters that will be cut into your work and give a pleasing appearance when finished. Another important dimension is the line width in relation to a character's height.

With single line work as produced on pantograph engraving machines, the usual method of calculating line width was to divide the character height by 8. For a heavier look to the work using wider lines, divide by 7. Tables were also published by all machine manufacturers, listing heights and recommended widths but all were based on the above factors. Looking at one such list it starts (1mm high, line width 0.125mm) increasing in half a millimetre steps up to finally (24mm high, line width 3. 00mm).

With CNC engraving the above factors for single line work are still valid keeping all characters in proportion. However, when engraving True Type fonts, I halve the line widths used so that the inner and outer lines do not appear overpowering, with a feeling of more line than letter.

A typical set of numbers to single line engrave 12mm high characters (0.30mm deep for filling with epoxy resin) would be as follows

From the table in Tool Details, fig. 9 select the 15-degree grinding angle, now look in the column beneath the tool drawing for angle width at 0.30 deep. This is 0.16mm per side.

● To be continued

On the Wire NEWS from the World of Hobby Engineering

Midlands Model Engineering Exhibition

A major event in the annual calendar, this year's MEX runs from Thursday 18 to Sunday 21t October at the Warwickshire Event Centre, sat nav CV31 1XN.

The exhibition showcases hundreds off models from societies and individuals for visitors to enjoy along with a wide range of outside attractions, workshops and lectures.

The show is supported by around 50 specialist suppliers with displays by over 40 clubs and societies, With upwards of 1,000 superb models on display.

See **www.midlandsmodelengineering.co.uk** or call **01926 614101** for full competition details, further details of the show. Online tickets at discounted prices are available via the website. Full price tickets are available on the day from the ticket office

International Women in Engineering Day (INWED)

On 23 June this year, International Women in Engineering Day 2018 (INWED18) will be encouraging participants to show the world how they are 'raising the bar' in pursuit of more diversity in engineering. This global awareness campaign, coordinated by the Women's Engineering Society (WES), aims to increase the profile of women in engineering worldwide and focus attention on the amazing career opportunities available to girls in engineering and related industries. In 2018, INWED aims to inspire even greater participation across the globe, both online and through physical activities, by individuals, schools, colleges, groups and organisations. The theme will be supported by the hashtags #INWED18 and #RaisingTheBar.

Bristol Model Engineering and Model Making Exhibition 2018

The Bristol Society of Model and Experimental Engineers claim that "year on year the Bristol Model Engineer Exhibition has rivalled the best in the country". It certainly is a big and varied exhibition and well worth a visit covering all aspects of model and hobby engineering as well as many other related hobbies including woodturning and radio control modelling.

The Exhibition is from 17 to 19 August at Thornbury Leisure Centre, near Bristol, use postcode BS35 3JB. Ticket and further information is available from www.bristolmodelengineers.co.uk.

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Tools from Trash: The Whisk-a-Shine and the WhiskerShine

Mark Noel converts two discarded appliances into handy polishing tools.

Kenwood Mini hand mixer converted into the Whisk-a-Shine polishing tool.

I am sure that many readers, like me, are often faced with the tedious task of polishing metal parts to add that finishing touch to a mechanical marvel. In my case this job also includes hours spent buffing tarnished alloy wheel hubs and engine cases on my classic motorcycle - probably more time than is actually spent riding the machine! The buffing kit comprises Scotchbrite, cotton rags, Solvol Autosol and Brasso, applied using elbow grease and liberal perspiration. However, on a trip to our local amenity site I retrieved two appliances on route to the incinerator, which I snatched from oblivion to begin new lives as polishing tools in my motorcycle shed and workshop. This article describes the steps that were followed to accomplish the conversions, **photos 1** and **2**.

One device was an ancient Kenwood Mini hand mixer (Model A345), of the type my mother used to make fluffy omelettes and yummy cakes, **photo 3**. Although coated in greasy food debris, the mixer was in good condition and appeared to be little-used judging by the negligible wear on the motor's carbon brushes. The second item was a mint Philips mains-powered electric shaver in its original case, **photo 4**, perhaps having been discarded by an owner who had opted to grow a beard and become a hairy scruff like me!

I dismantled both machines out of curiosity and to begin planning the modifications. The Kenwood Mini was found to have a 145-Watt fan-cooled motor that drives the contra-rotating paddles via a nicely engineered wormwheel gearbox, part-filled with grease, **photo 5**. This motor-gearbox was continuously rated and had been designed with sufficient torque to knead a stiff dough, implying that it would be up to its new task of spinning a pair of polishing discs on metal. In contrast, the shaver's internals were more lightly engineered but beautifully made, **photo 6**, with a clever dog clutch arrangement between the

> ...it seemed that the shaver could only be adapted to brief and light polishing tasks,

detachable cutter head and the driving spindles. Since the whole shaver assembly is enclosed in an airtight case, it seemed that the motor was not continuously rated, there being no need for a gentleman's shave to last more than a few minutes. Therefore, it seemed that the shaver could only be adapted to brief and light polishing tasks, which nevertheless would compliment the more arduous work that should be possible with the converted Kenwood Mini.

Philips electric shaver converted to become a light polishing machine.

Conversion of the Kenwood Mixer

I started by thoroughly cleaning all the mixer parts in a paraffin bath to remove old grease and carbon dust from the

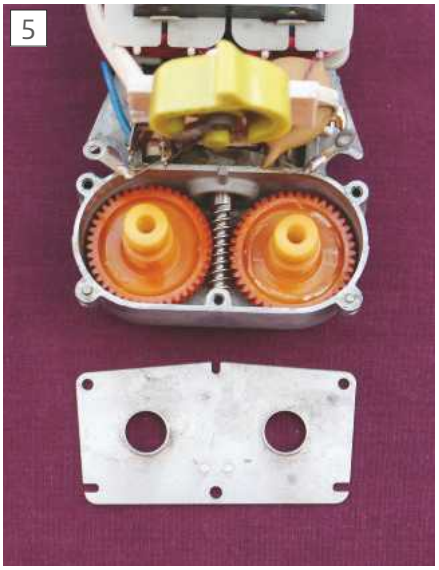
The Kenwood Mini as found at the Amenity site.

Philips shaver saved from the amenity site.

motor brushes. The gearbox was then reassembled and regreased, and a drop of light oil added to the motor bearings. A rotary switch on the motor frame enables the speed to be altered from OFF to maximum in three steps: the brass contacts were cleaned up and the wiper bent back to its proper position to improve the electrical contact.

The mixer's paddle blades are welded to 5mm diameter chromed steel shafts with a tang that locks into a spring catch inside each wormwheel. A button on the mixer handle can be pressed to release each paddle so that cake mixture can be licked off by a small child (remember?). The shafts were sawn about 10mm from the paddle, turned to identical lengths on the lathe and the ends threaded M5 for 20mm. A pair of pad carriers were then turned from 25mm diameter aluminium and tapped M5 to fit the modified shafts. Finally, a pair of lock nuts were made from 7/16" AF hex brass bar to secure the pad carriers to the shafts.

Kenwood engineers had designed the

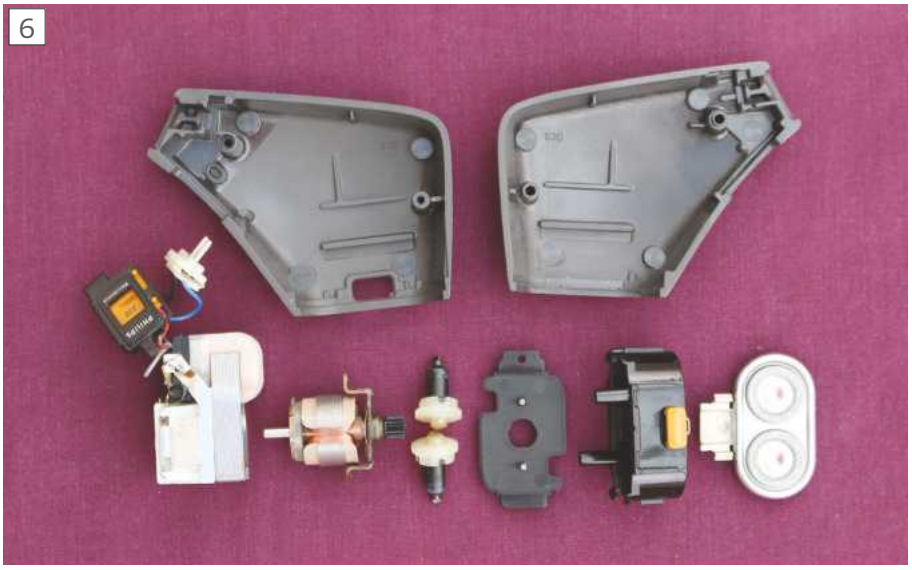


Wormwheel gearbox and speed control of the Kenwood Mini.

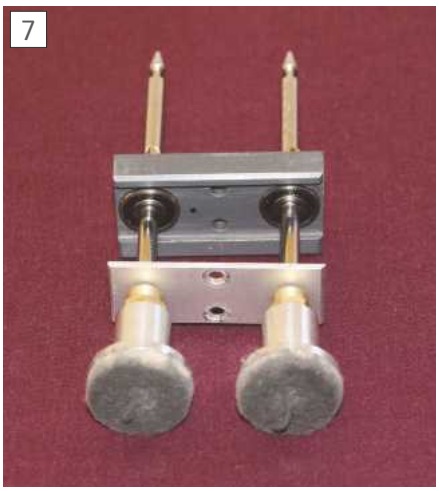
Mini's gearbox bearings to handle the forces involved in whirling stiff cake mixes. It would probably have been enough to complete the project at this stage, but I wanted to be sure that the stronger lateral forces involved with polishing did not increase wear in these Nylon bearings. To counter these forces, I added a 10mm thick PVC plate to the bottom of the mixer with recesses carrying a pair of 5mm bore sealed ball bearings. These are a snug fit to the paddle shafts and now take most of the sideways load, **photo 7**.

Circular, self-adhesive felt pads in a wide variety of diameters and thicknesses are available on Amazon, eBay and hardware stores to act as protective feet for items of furniture. I bought a pack of 25mm wide 3mm thick fluffy pads from Amazon, which fitted the aluminium carriers - these are so cheap that they can be peeled off and replaced whenever they wear out during polishing. The final stage in the mixer conversion was to replace the old brittle

Kenwood engineers had designed the Mini's gearbox bearings to handle the forces involved in whirling stiff cake mixes .



Internal mechanism of the Philips shaver.



Close up showing the ball bearings and felt pad carriers of the converted mixer.

mains cable and to add a logo in rub-down Letraset, protected with a layer of self-adhesive book cover film as seen in photo 1.

This 'upcycling' project was completed in less than a day and the re-invented machine immediately put to work buffing up the engine of my Jawa motorcycle, **photo 8**. The Whisk-a-Shine is certainly up to the job, with no signs of overheating in the motor, and the stick-on pads lasting about 20 minutes of continuous polishing with Autosol on aluminium.

Conversion of the Philips Shaver

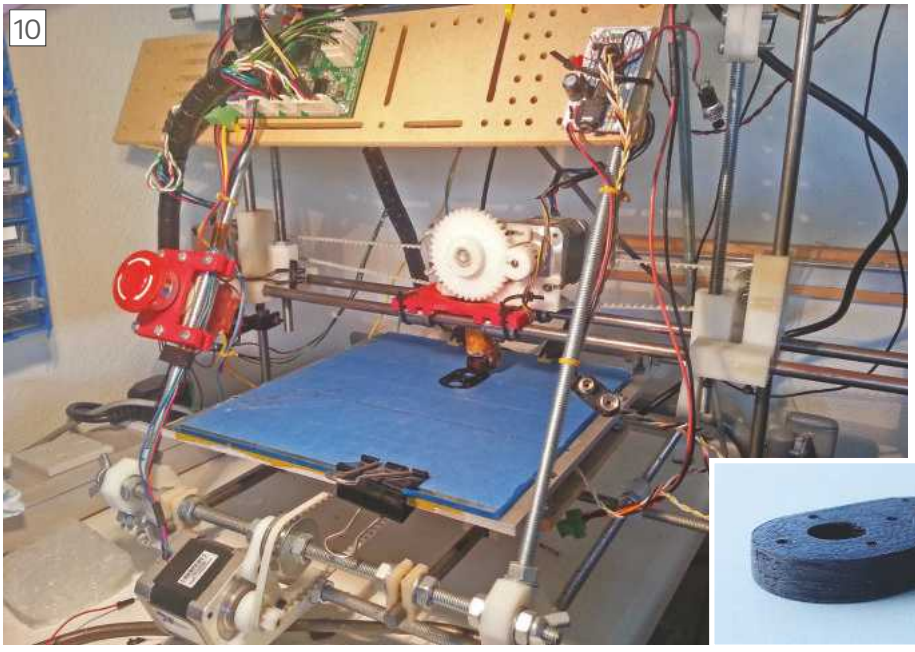
Repurposing this device presented more of a challenge owing to the weediness of the motor, the small scale of the drive mechanism and because I wanted to allow the possibility for it to revert to a shaver. This called for an adapter that could be exchanged for the cutterhead, and with shafts engaging as a dog-clutch with the driving spindles. The original peg-and-notch clutch in the original design is only

The Whisk-a-Shine buffing up a motorcycle engine.

2mm in diameter and formed by precision steel forgings that result in negligible free play and thus a 'Luxury Shaving Experience'. The more I contemplated this problem the more I marvelled at the huge investment in tooling that must have been involved in manufacturing an appliance that most would take for granted.

After several experiments with cold forging and winkling with Swiss files, I discovered that the only workable solution was to create a 'notched' end to a round shaft by pressing in a slotted steel insert of the right diameter to fit the shaver's driving tang, **photo 9**. Each brass shaft in the new polishing head is a simple turning, threaded M4 at the working end and passing through a 5mm bore shielded ball bearing. The pair of bearings are carried in a plastic part that was designed in Alibre to follow the organic contours of the shaver body, exported as

Slotted inserts in the shafts of the 3D printed shaver unit.

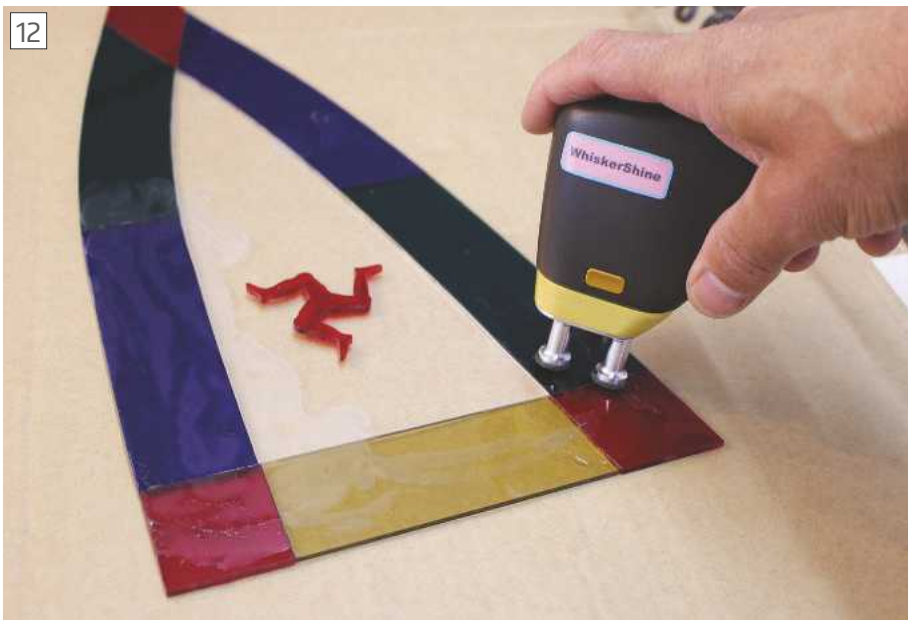


Reprap 3D printer building the shaver bearing carrier. Insert shows the finished printed part.

an STL file, then 3D printed by my friend John Oddy on his homemade RepRap Prusa machine, **photo 10**. Layer steps in the part were smoothed with Milliput putty, then painted with Humbrol enamel. A cap plate retains the bearings, while an M3 thumb screw from the scrap box engages with a threaded insert pressed into the shaver to hold the bearing module in place, **photo 11**. Two pad carriers were turned up from aluminium, similar to but obviously smaller than those fitted to the Whisk-a-Shine, and on these are fixed a pair of 10mm diameter self-adhesive felt pads again bought as a multipack from Amazon.

Tests have shown that 10mm felt pads are about the largest that the shaver can drive without the motor labouring, and that Brasso metal polish is better suited to the light duties this machine can endure. Nevertheless, I have used

Completed shaver bearing carrier, with self-adhesive polishing pads.



The WhiskerShine removing blemishes from an acrylic window.

my new WhiskerShine to do real work - for example buffing out scratches and glue runs from the 'stained Perspex' window shown in **photo 12**.

I derive great satisfaction in giving new life to old appliances, many of which are discarded due to changes in fashion, domestic habits or the drive for 'upgrading'. Every visit to the tip presents me with new ideas and opportunities. All it needs is a little imagination and the time to resurrect and repurpose the flotsam of our wasteful society. ■

References

Ball bearings: Large size Part No. 6253RS; Small size Part No. SMR105ZZ from Arc EuroTrade Ltd, **www.arceurotrade.co.uk**
RepRap 3D printing machines and community: **www.reprap.org**
A wide range of Perspex and other plastic materials: **www.thepasticshop.co.uk**
... then if you are *really* interested:
History of the Philishave shaver: **www.90yearsofdesign.philips.com/article/90**
History of kitchen mixers: **www.timetoast.com/timelines/the-brief-history-of-cooking-and-baking**

In our Next Issue

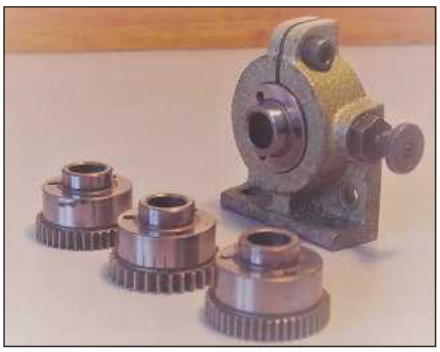
Coming up in issue 270
On Sale 13th July 2018

Content may be subject to change

The August issue, number 270, of Model Engineers' Workshop celebrates its three-quarter turn with more great articles:

Bernard Zaegel explains his technique for making clock springs.

Geoff Pointer's tiny Ajax Horizontal Mill



Terry Gorin's Unimat Indexing Head.

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A Temperature Controller for the Home Workshop

Chris Gabel explains how to use a PID Controller to Control Muffle Furnaces, Ovens, Kilns, and Temperature Baths

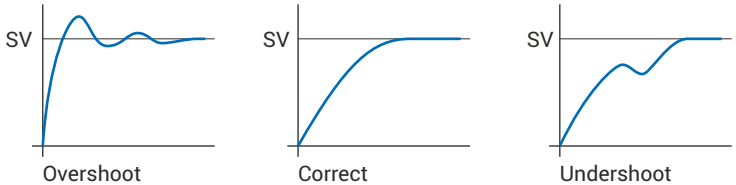
Controller in use

Proportional-Integral-Derivative is a mouthful. PID for short. It is not usual for us to find such complex labels in our model engineering. However, behind the name lies an easy to use precision controller, **photo 1**, which is definitely smart and highly intelligent, ideal for use with my bench oven design featured recently in MEW 267, May 2018.

Most of us know the Simmerstat controller. Invented in 1932, it still is an important controller. All kinds of heating devices are kept in check with it, from the church coffee urn to griddles, grills, and heaters. It is however a "dumb" device. Being dumb, it is just a proportional timer which varies the power by turning the device on and off in a fixed cycle. The control knob position on the Simmerstat determines what proportion of time is spent turned on. By knowing where to set the dial you can get repeatable temperatures, but it has no feedback. It does not reference the temperature of the object or material you are heating. The person watching the urn starting to boil, provides the feedback.

My current project is re-fitting a precision casting workshop. Temperature control is an integral part of this process. I need to have full temperature control of mould burnout cycles in my kiln. By combining a precision thermocouple with a PID microcontroller, one can automatically vary the heat input to achieve a pre-set temperature. It senses the temperature you are aiming for, and it will learn the nature of the heating environment you are using.

Fig.1



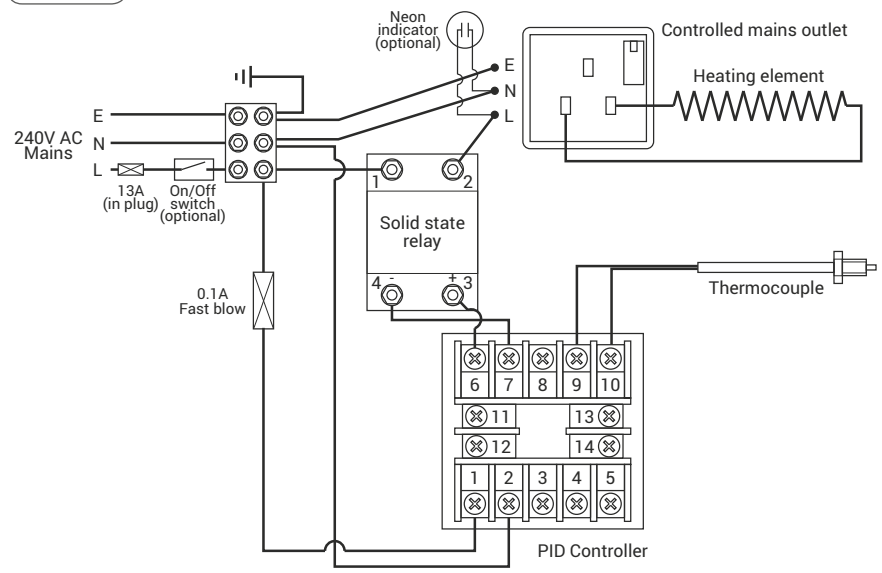
It will then keep your furnace at exactly the right temperature, pulsing the energy as needed.

About PID

A rough analogy goes: Aiming for 30 mph in a car: When you step on the accelerator in your car, the car goes proportionally faster the harder you press. Your brain provides feedback and you take your foot off the pedal. You then maintain the speed limit by stepping on the accelerator, up and down, as you judge visual cues from the speedometer and surrounding visual scene.

PID Theory is mathematically intensive stuff and is a specific branch of engineering and process control expertise. First a target value, in our case temperature, is set on the controller. This is SV or the Set Value. When you initiate heating, the controller heats way above SV. This is called overshoot. It then realizes the error, turns off, cools and tries again to arrive at SV. The controller measures how big the overshoot was, and how long it went on for. This is the Integral

Fig.2



2

Controller Components: Thermocouple and connector, controller, and Solid State Relay

bit. The next phase, Derivative has a predictive nature to it and can maintain the Set Value, having calculated the effect of energy into the system, as well as leakage out of the system as it cools.

Figure 1 shows the three conditions which can occur as the system hunts for the correct temperature. I will describe how precise arrival at the SV target temperature is achieved, later on.

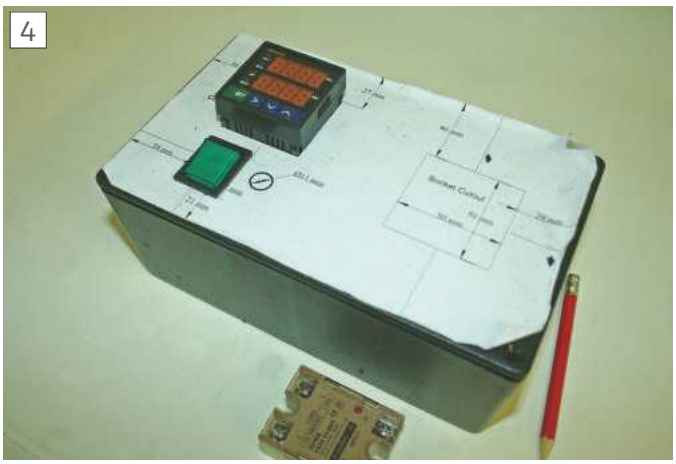
Temperature sensing: Data for the Controller

A thermocouple is used to sense the temperature and provide an input signal to the controller, **photo 2**. The controller will then turn on and off a Solid State Relay (SSR), which turns the heating element on or off.

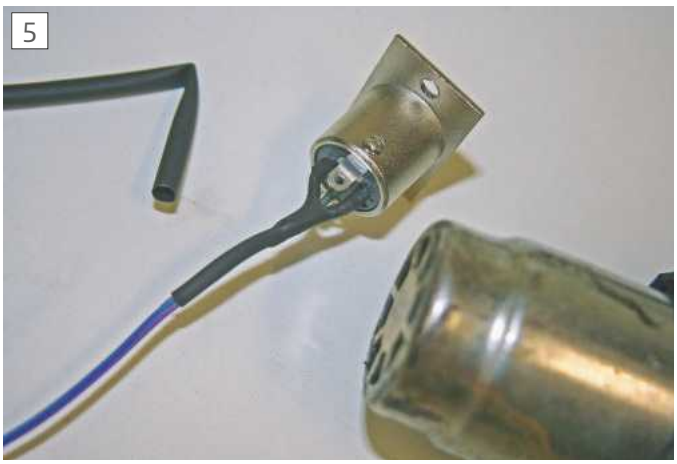
A thermocouple is essentially two wires of dissimilar metal, that have different electronegativity. When joined, a voltage is generated and that voltage increases or decreases proportionately according to heat. There are a variety of thermocouples with differing metal combinations. They do serve different temperature ranges. The most common ones which are

3

Medium and high temperature K type thermocouples



Component layout in progress



Soldered connection with heatshrink

internationally standardized are:
Type E (chromel–constantan), 200-16500 F or 95-9000C
Type J (iron–constantan), 200-14000F or 95-7600C
Type N (nicrosil–nisil), 200-23000F or 95-12600C
Type T (copper–constantan)32-6600F or 0-3500C
Type K (chromel–alumel) 200-23000F or 96-12600C
Types B, R, and S thermocouples use platinum or a platinum–rhodium junction.

Most of the controllers come with a K type thermocouple, **photo 3**.

Some K types come with fibreglass insulation and metal braid covering and are good up to about 4000C. High Temperature types come with ceramic beads on the wires and are good up to 12600C.

Note that if your controller indicates temperature decrease when you warm it with your hand, just swop the + and - thermocouple leads around on the controller.

A PID Controller: Affordable Precision

Many of my projects require heating to exact temperatures. This includes heat treating and tempering of tools, at the lower end of the temperature range up to controlling high temperature kilns and ovens used for burn-out of centrifugal casting moulds.

Searches for 'kiln controller', 'heat controller' or 'oven controller' produce two families of controller. One is a programme controller which lets you program a whole long cycle of heating patterns, and it is really designed for ceramics firing and glass annealing. They cost about £250. However, a precision PID temperature controller can be had for £10 or £12. Using this controller, only 3 basic parts are needed to switch a heating or cooling source on and off with great accuracy. They are (1) a thermocouple for sensing the temperature (2) the controller and (3) a relay to switch the current on and off. The controller is designed to control either a mechanical or solid-state relay. I elected to use a solid state electronic relay because of its simplicity and reliability. All three of these components are available through RS or Farnell electronic supplies, or online.

Purchasing advice; the controller I used was a "TET612". Search for 612 PID controller to find both domestic and foreign sellers. There is a version described as a REXc-100 or similar as well. The C-100 has a lower temperature range specification of from 0-4000C, so select a controller for your needs and check the specification. I found the best place to buy high temperature thermocouples for my kilns, was from Thermomart, (Canada). They have both controllers and the sensors for a vast range of applications and have been helpful when I had questions.

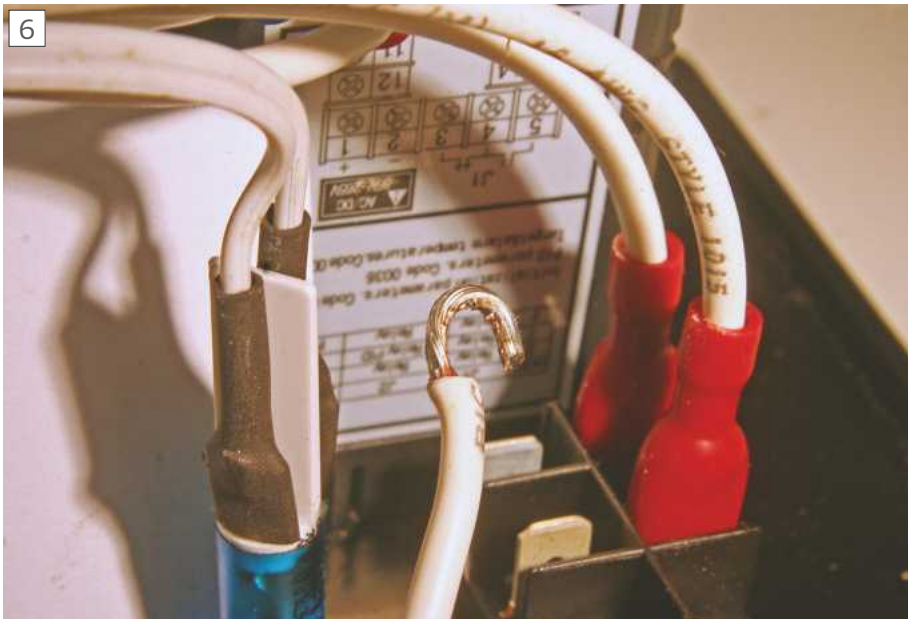
Construction

This unit plugs into the Mains. If you don't know what you are doing seek qualified help. Assembly is quite easy. The controller is made up of only 8 main components plus wiring. They are:

1. Controller: PID Temperature Controller for Furnace, Kiln or Oven , model 612 or other.
2. 25Amp Solid State Relay
3. Thermocouple K type Included with the controller or high temperature K type
4. DPST Illuminated Mains Switch: Maplin 16A Rocker GU49D. Fuse holder as needed.
5. Neon indicator: Maplin Blue neon, N92BN (used as a SSR output indicator)
6. 13 Amp switched domestic wall socket: Homebase or B&Q
7. 2 pin XLR Plug and Socket for thermocouple connection.
8. ABS Utility box

A pattern was made at 1:1 scale using Turbocad. Printing out on a desktop printer should give a pattern that is an exact fit. Most of the components are mounted on

> I elected to use a solid state electronic relay because of its simplicity and reliability.



Quality connections on all mains work

the lid with the Solid-State Relay and the XLR Socket being the only items mounted on the sides of the box.

The pattern was attached to the box lid using spray photo adhesive. This works well. It is repositionable and removable, **photo 4**. Once glued down, the openings are cut away using a scalpel to just cut through the paper pattern. You are then able to mill out the openings in short order. The corners of the rectangles were squared out with a file.

The schematic is straightforward as can be seen from fig. 1. A screw junction block will make easy work of laying out the connections. Note that it is important to maintain earth and ground continuity throughout the system, and fuses should be fitted as per the schematic.

Wiring: There are three good ways of creating sound safe connections. I really hate the odd rogue single strand of a cable that will always bend over and touch a terminal it should not touch. I almost always tin the ends of any stranded cable I'm using. My favourite is a soldered connection with heat shrink insulation over it, **photo 5**. Plain tinned wire under screw connectors is excellent as well, **photo 6**.

My least favourite are crimp connectors, as they need to be done carefully using the correct size for the cable and a good crimping tool. Most cables in this project are cut to about 200mm in length so you can work in the box easily, with the lid not held in too closely by the connecting wires. Rat's nests are minimized by using cable ties. Power carrying cable was swg 16. I used thin gauge stranded wire for the thermocouple connections with soldered connections. Ordinary bell wire was sufficient for the control signal from the controller to the relay, and to the neon indicator.

A locking XLR socket and plug enabled secure connections for the thermocouple.

The Solid-State Relay was mounted on the back wall of the box. I t has a large heatsink on its underside, which indicates it may get hot. If this proves to be a problem it will need to be mounted on an aluminium plate mounted on a hole in the back wall, supplying adequate heat sink ventilation. First indications are that even after 2 hours switching 1200 watts, it only gets slightly warm, well within the range of the plastic box.

.5 Litre water warming test

Trying it all out

I decided to test the controller in three temperature range environments. The first was done using an electric kettle to see how well the controller handled below-boiling temperatures, **photo 7**.

The second was with an electric hotplate with an inverted tin over it. This was to check mid-range temperatures, **photo 8**.

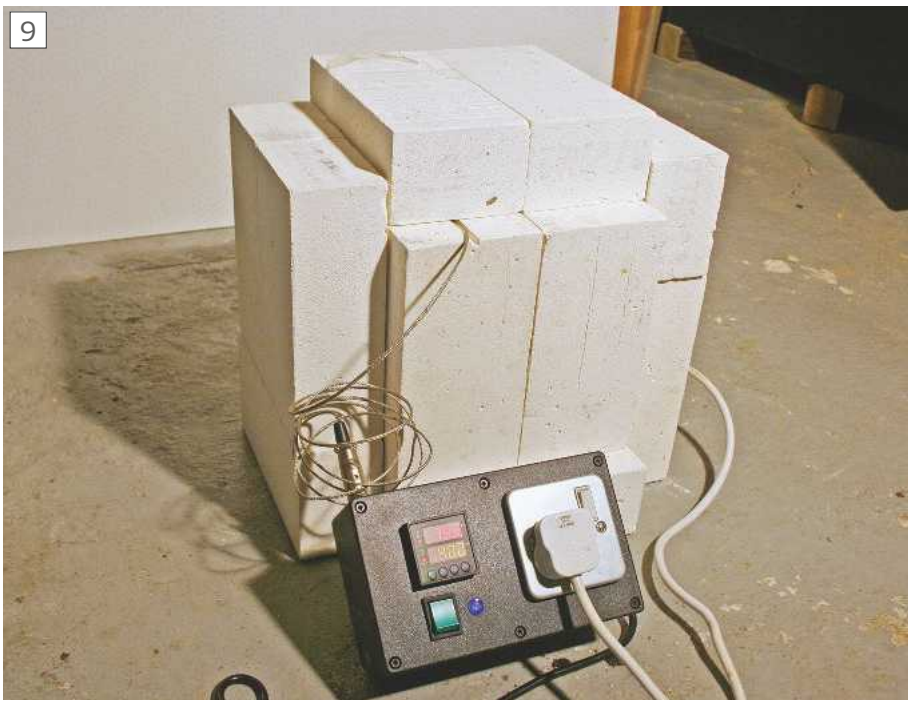
The third was to try it with the full kiln/furnace prototype, **photos 9** and **10**.

Having assembled everything, I checked that the default settings were all set as suggested in the manual. The manual is an on-line PDF document, but it can be found easily on the web if you lose the address. After you get used to the syntax, changing parameters is easy, pretty much like finding a setting on a smartphone. The only change to default settings was the type of thermocouple. I had to tell it to use a K type, as it comes set for a PT10 type.

I plugged the control box in and set SV (Set Value) to 400 C. I plugged in the family electric kettle to the controller and the controller to the wall outlet. Do remember to turn the kettle on. The controller pulse heated the water until it was about 10% over limit, cooled and re-heated to stay at exactly 40. It held this temperature with the occasional pulse of energy. Having watched the kettle heat and boil until my family was bored, I concluded that this was an excellent piece of kit. In this first instance the controller was shown to be excellent for work in the low to mid range.

Heated air space, medium range temperatures

> Having watched the kettle heat and boil until my family was bored, I concluded that this was an excellent piece of kit.



High temperature kiln test

Next, I tried the hotplate. The controller worked well switching the hotplate on and off and held the set temperature, showing that it worked well for a heated chamber, not just in liquid.

The next test was of a setup suitable for a muffle furnace, kiln, or a casting burn-out furnace which was the original goal of this project. Using refractory firebricks, I built an enclosed space with a standard electric hob element as a heating source. This was a new element, 1200 watt. The thermocouple was placed in the top with just the tip exposed to the heated cavity. The temperature was set to 4000 C. It took about 12 minutes to reach this. There was less of an overshoot, only about 8% this time but temperature stabilized at exactly 4000. I later replaced this with a ceramic bead thermocouple and control up to 9000C was perfect.

In each of these three tests the temperature overshot the target SV, cooled and oscillated until correctly settling on the target. While not important for something like the burnout kiln, this would not be acceptable for your fish aquarium or precision tempering or heat treating of new tooling.

Auto Tuning:

Built-in to the controller is a learning mode. The problem of over and undershooting is solved by enabling the "artificial intelligence" or Auto Tuning mode to do all the data gathering and calculations for you. This then modifies the program within the controller. It is possible to set all the mathematical parameters manually so that the controller arrives at the Set Temperature values precisely on target. This is however only achievable with a great deal of understanding of process control, and PID theory.

Initiating Auto Tuning:

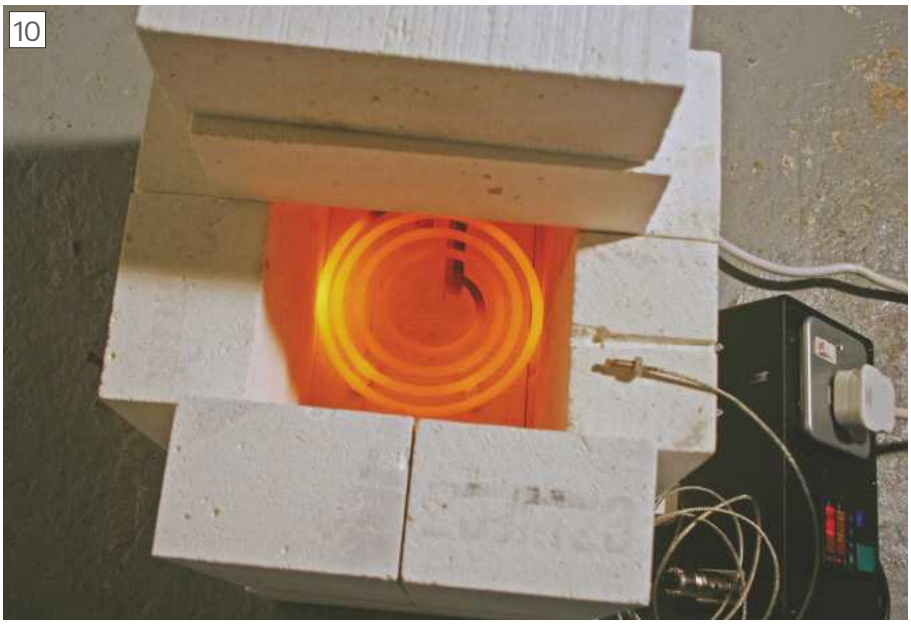
Auto tuning is the best attribute of these controllers. And is easily implemented. Heating a kettle with a litre of water in it to 400C differs wildly to heating a 5-litre kiln to 12000C. The thermal masses are different. So, for the kettle, after setting the set value of 400C on the controller, the "SET" button is momentarily pressed and held until the "AT" light goes on. This puts the controller in learning mode. It has started to "auto-tune". It sets all of its own PID parameters which control the over and undershoot. It supplies pulses of power and records how much power creates how much temperature change over time as it aims towards SV. The result is precisely targeted heating. After it completes the learning cycle the controller uses this pattern every time you use it, until you Auto Tune for a different application. This is an excellent feature of this controller and makes it easy to use for quite varied and sensitive applications.

The problem of over and undershooting is solved by enabling the "artificial intelligence" or Auto Tuning mode to do all the data gathering and calculations for you.

Once all the parts have been collected, this is a project which should easily be completed in a day. I have been surprised at the variety of tasks this precise controller has enabled. All the way from curing adhesives to controlling 8000C kiln cycles. This controller has proven to be a versatile piece of equipment with a variety of applications. ■

Suppliers

Thermomart **www.thermomart.com**
Farnell and RS can supply items domestically.
Hardware items are available from Maplin and Rapid Electronics **www.rapidonline.com**



High temperature kiln test

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Boring accurate internal recesses

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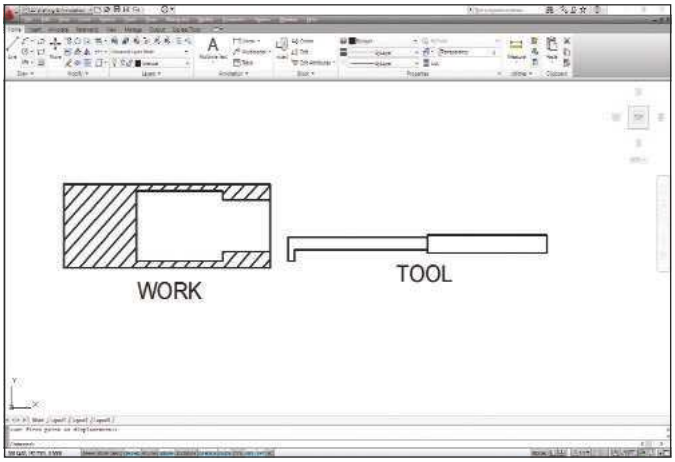


Glyn Davies wins this month's Chester Vouchers with a tip for internal boring.

I needed to machine an internal recess in a piece of 1" bar similar to that shown in the drawing. I made a suitable boring tool but wanted a means of arranging saddle stops to limit both the leftward and rightward movement of the lathe saddle. It is often necessary to limit the leftward movement of the saddle towards the chuck and I long ago made a simple stop that clamps to the lathe bed, **photo 1**.

I wound out the toolpost so that I could determine where the left and right stops should be, **photo 2**.

Here's the tip - with the tool at its right-most position, I placed a piece of rectangular bar (actually a ground parallel, but any suitable piece of bar will do) in contact with the right-hand side of the saddle. I then moved the tailstock so that it was touching the bar and clamped it up, **photo 3**.

To bore the recess, I removed the rectangular bar, got the tool inside the work and then replaced the bar up against the tailstock. I could then happily moved the saddle back and forth between the two stops until the cross slide dial told me that I'd achieved the required depth of cut.

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

Please note that the first prize of Chester Vouchers is only available to UK readers. You can make multiple entries, but we reserve the right not to award repeat prizes to the same person in order to encourage new entrants. All prizes are at the discretion of the Editor.

Modification to Optical Centre Punch

Trevor Winter improves an aid to accurate marking out.

I am a septuagenarian with eyesight not as sharp as it once was, and I find it increasingly difficult to accurately pickup the intersection of two scribed lines with a centre punch. On seeing an optical centre punch advertised at a reasonable price I decided to buy one, **photo 1**. It is quite a simple device consisting of an Aluminium base with a hole drilled in it, into which a polished Perspex rod with cross hairs engraved on the bottom is fitted. The cross hairs are lined up with the lines on the work piece. Then without moving it the Perspex rod is replaced with the centre punch which is struck with a hammer. It seemed well made but in use was rather a disappointment as I could not see the hair lines very clearly. Following some experiments, I found that by closing one eye


1

The optical punch


2

The loupe

and holding a watchmakers loupe, **photo 2**, just above the centre punch and a little away from my other eye gave an improved result but left me rather short of hands.

Modification 1. Permanently mounting the loupe

What was required was a device to permanently hold the loupe at correct distance from the optical centre punch. **Photograph 3** shows the assembly and the component parts. The base of the optical centre punch was drilled and tapped M5, the support rod was made from a piece of 1/4 inch dia. brass rod threaded both ends M5 The loupe support plate was


3

The loupe attachment

made from 1/4 inch MDF as no suitable Aluminium was available and it seems to be quite satisfactory. No sizes are shown as these depend upon the individual details of eyesight and loupe specification. A spring is used to hold the loupe holder firmly in position but allow it to be easily rotated away when replacing the Perspex rod with the punch. The result was a considerable improvement.

Modification 2 To use the Optical Centre Punch with small work pieces

As supplied it works well when marking out larger pieces metal but not smaller ones as it is difficult to balance it on them. To overcome this problem, it is necessary to firmly support the centre punch base above the workpiece but close to it to avoid parallax errors. **Photograph 4** shows how this was achieved. A small surface plate was used for a platform, although any piece of steel plate could be used. A hole was drilled and tapped M5 in one corner and a rod threaded M5 one end was fitted. A second rod was threaded M5 on one end and this was fitted into a M5 hole drilled and tapped into the side of the optical centre punch. Both rods had flats filed on the at the end to enable tightening with a spanner. The rods used were 8 mm dia. and 11 mm dia. because they were the only sizes available but 10 mm for both would be preferable. Joining these two rods is an Aluminium block with holes at right angles, slotted and with M5 Socket head clamp screws to secure the rods. An Allen key was cut down and Araldited into the socket to for a handle, **photo 5**.

It was found helpful to hold small items with a toolmakers clamp with the clamp resting on the base as this gave the workpiece firm support and made it easier to position the workpiece.

Additional light

The only light to reach the workpiece is through the Perspex rod when aligning the crosshairs to the mark to be spotted and visibility can be improved by adding a small light source directly adjacent to the Perspex rod. A suitable light, **photo 6**, was found online, with a flexible shaft which was shortened to 125 mm long and fitted by drilling a 5mm dia. bole in the rod with a 3mm tapped hole at right angles to it for a clamp screw, **photo 7**. In practice this was found to considerably improve visibility.

In use the Optical Centre Punch is slower than when using an ordinary centre punch, but I have found that the improved accuracy offsets the reduction in speed and overall probably is not much slower when checking the spotting with an eyeglass and having to tap over misplaced spots is taken into consideration. ■

Material suppliers

Optical Centre Punch
Axminster Power Tools
www.axminster.co.uk

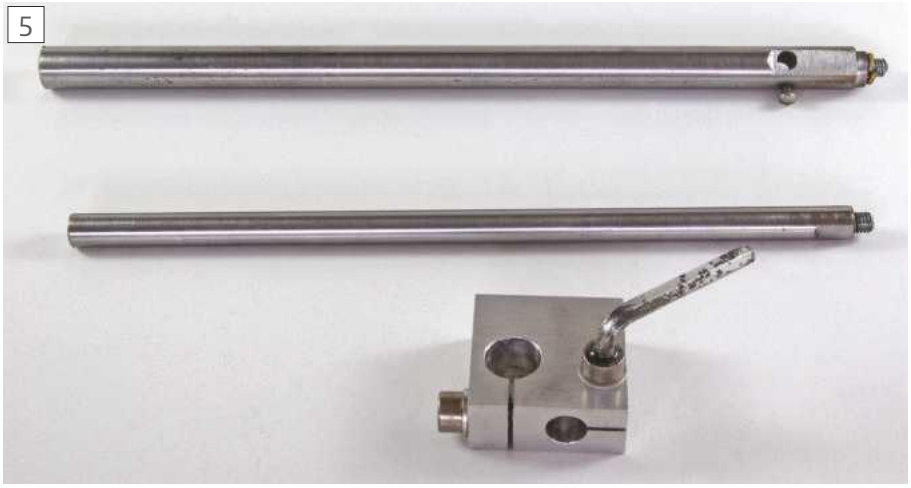
Loupe Quicktest **www.quicktest.co.uk**

Mountain Warehouse
Flexible torch/reading light
www. amazon.co.uk

4

The punch and loupe assembly fitted to the pillar and base

5

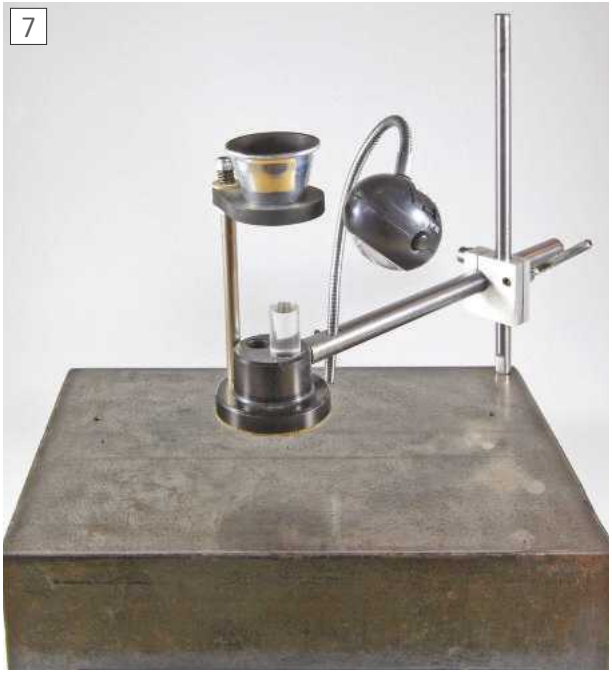


Rods and clamping arrangement

6

Worklight

7



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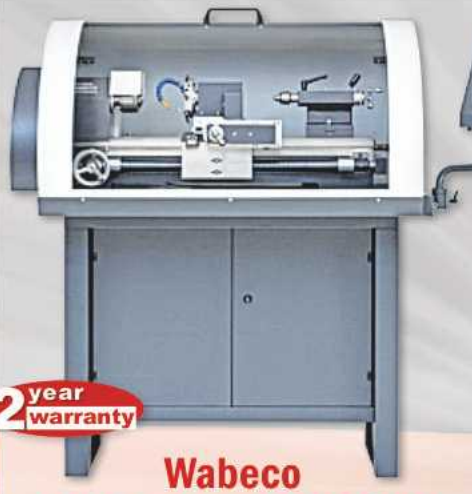

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Photographic Lighting for the Workshop

David Haythornthwaite describes some challenges and solutions for workshop photographers and describes a useful Ring Light for ideal for the workshop and photographing models.

The Author's Home-Made Ring Light

Having written a few articles for both ME and MEW over the years, also having my own website, www.Haythornthwaite.com, it has become apparent to me how important good clear illumination is for technical photographs. However, this has sometimes been a great challenge to me and some improvisation has been necessary.

This article lists some of the things that have proved to be important in my experience and illustrates my latest home-made gadget to help me to document my work. I hope that it will be of interest and help to others who wish to photograph their workshop activities.

My workshop is situated in my garage, sharing the space with my car. Whilst it has the advantage of sharing space with the heating boiler, thus keeping the machinery dry, it has the disadvantage that there is very little natural light, causing problems with both good illumination when working, and making it very difficult to take good photographs.

Work-light has, for some years, been created by fluorescent lights using daylight tubes, and I have had no problems associated with strobing, as I have seen reported elsewhere. Localised light has been provided using halogen machine lights on the lathe and milling machine. Recently however, I saw some small LED floodlights in a local bargain supermarket priced at under £10 and I purchased three of these for the workshop. The lights had a colour temperature of 6,400k and I was amazed at the quality of the light. Fastened above my machine benches, pointing straight down, they gave me the feeling that someone had inserted a picture window in the garage roof, and that the daylight was flooding in.

The Problems with Flash Photos

Most cameras have an on-board flash gun which is simple to use. However, a single small flash will give a very high contrast light, with hard shadows which is quite unsuitable for illustrating models or close-up photos of lathe and milling operations.

Placing a large, pale background card immediately behind the subject of the photo often helps as it will avoid showing those dark dirty areas behind the machine. Placing white reflecting sheets just offside of the photograph, at an angle to the camera axis will help to reflect the flash and give light from a different direction into the shadows.

Using Bounced Flash

As photography has always been an interest of mine, I bought an early digital DSLR camera back in 2004 and chose a Nikon D70 - quite an investment at the time, and as I take portrait photographs, I equipped it with three flashguns, all remotely controlled by the camera. A setup such as this is probably way above the requirements or budget of most model engineers, and indeed with the reduction

Using an Umbrella with a Remote Flash

in both size and price of modern camera equipment it is totally unnecessary.

Using multiple flash taught me a lot about balanced lighting and the advantage of plain backgrounds. I also I found that a white umbrella for bounced flash was a good way of filling in the shadows. First you should work out how to mount the umbrella and to trigger the flash.

Photograph 2 shows a setup where the flash is mounted on a tripod facing away from the model being photographed. This gives a nice soft light without much shadow and the small steam engine illustrated in **photo 3** was the result of this setup, using a single flashgun. A homemade adapter is being used to hold both the flash gun and the white umbrella. The umbrella has a ¼ inch shaft which fits into the umbrella adapter. The adapter is easy to make and is illustrated in **photo 4**.

Although some very large cameras have a different thread, almost all cameras have a tripod mounting which is a standard ¼ inch Whitworth thread. This makes it easy to make your own mounting adapters.

I have also made a bracket to fit the adapter, complete with flash and umbrella, to the side of the camera, utilising the tripod mounting hole on the bottom of the camera. In this manner, the camera and flash/umbrella can be used hand held. The flash would point away from the object being photographed and bounced onto the umbrella behind the photographer's head. As I used the setup, the flash was operated by the camera either wirelessly or on a long flash lead. Thus the (expensive) camera could control the flash strength and hence the exposure, via metering through the lens of the camera.

With today's preponderance compact cameras, these do not usually have the facility for control of remote flashguns. Often, they do not even have a flash trigger plug. Therefore, an alternative method of firing the flashgun would be required. This problem can be solved by using one of the light operated flash triggers, as shown in **photo 5**. This sits between the tripod and the flashgun. When the integral camera flash is triggered (i.e. when the photo is taken), the light of the camera flash is "seen" by the flash trigger, and a larger flashgun sat in the trigger "hot shoe" is automatically fired. The camera exposure must be controlled manually and the correct exposure is largely a matter of guesswork, but with digital cameras, any incorrect exposures may be easily deleted and the exposure settings changed on the camera for a second shot. The advantages of still life digital photography!

The flash trigger illustrated in the photo requires no battery, but is simply powered by the light (flash) that falls upon it. Multiple flash photography in the workshop is however, rather inconvenient. Trying to balance the light from various sources manually and mounting flashguns on tripods, is certainly challenging in my

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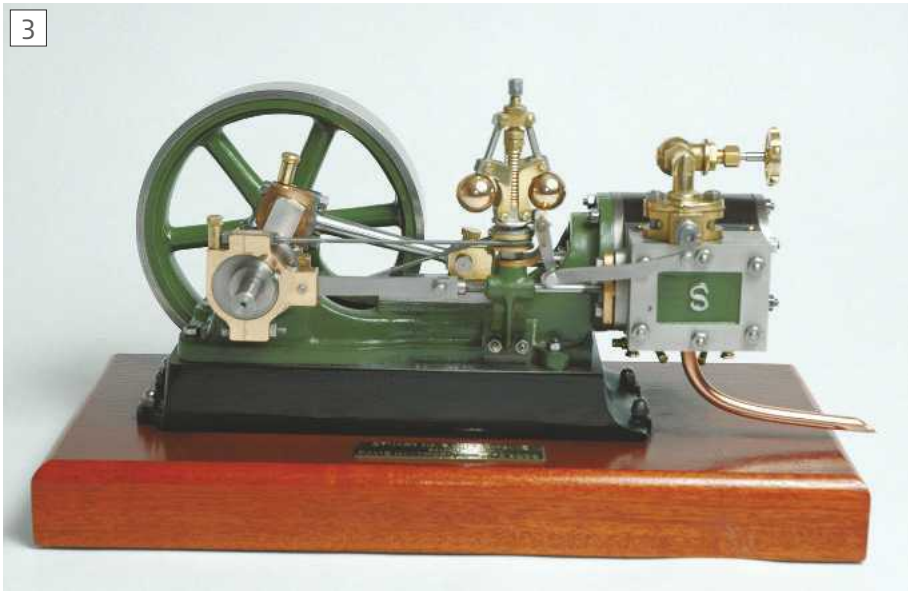

This Is the Result of the setup in Photo 2

4

An Adapter for Coupling a Flash to an Umbrella

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A Remote Flash Trigger

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Flash Photo of a Keats Angle Plate

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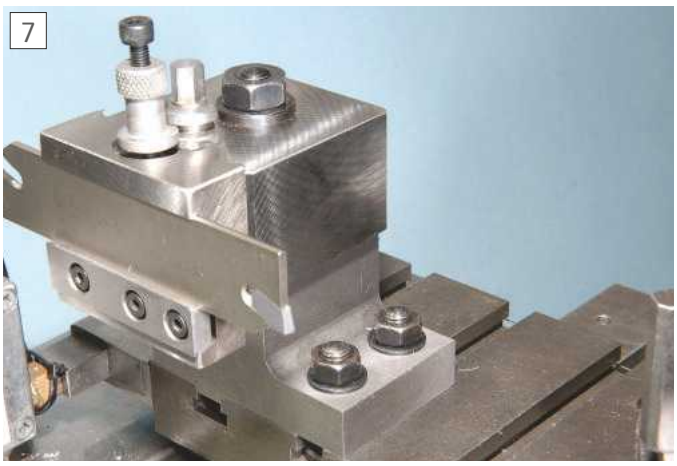
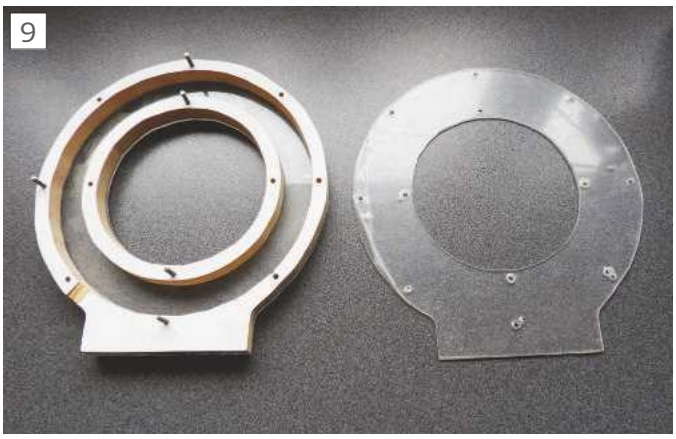


Flash Photo of a Rear Parting Tool

The Two Parts of the LED Array



Construction of the Four-Part Framework

small and cluttered workshop.

Photographs 6 and **7** illustrate what can be achieved using flash carefully. Both photos were taken in a fairly dark workshop using one flash on the camera and a balancing umbrella flash. The final effect is not entirely shadowless but gives a pleasant soft light with sufficient highlights to show the modelling of the subject. The backgrounds were both coloured art boards placed behind the lathe.

When taking photos on the milling machine, however, balanced lighting always proved difficult for me. On the one hand, it is more natural if the main light comes from above. On the other hand, this is almost impossible to achieve when working beneath a vertical milling machine head, with no available daylight.

Making a Ring Light

In 2016, I went to China for a special holiday, with my wife of 50 years and as the large camera with all its lenses and flash equipment is rather heavy, I bought a smaller DSLR camera for the holiday - a Nikon Coolpix B700. This is a superb, versatile little camera with a massive zoom, brilliant low light performance and you can fill the frame with a postage stamp. Ideal for my purposes, but unfortunately whilst

The Camera Mounting Bracket

it does have an integral flash, it has no external flash shoe and no connection for an external flash. Because of its low light performance, many photos are possible, however, under my LED workshop lighting.

Due to my difficulty with taking photos on the milling machine, I was about to make a ring of LED lights around the mill spindle, to improve illumination on the mill table. However, at the Doncaster model engineering exhibition a company called "The Craftlight Company" were exhibiting their range of craft lights and for a very reasonable price, they offered me a replacement LED array for one of their lights. The idea of the ring light was born.

The LED array shown in **Photo 8** consists of a ring of 21 LEDs on a circular printed circuit board together with a reflector ring that fits over the individual LEDs. The diameter of the LED and reflector array is 166mm and at first, I intended to fix this around the Milling Machine spindle, using neodymium magnets so that it would be easily removable. My Wabeco Mill head casing is however largely made of aluminium which made this problematical. Also, the diameter of the ring was rather large and I considered that it may get in the way when using the milling machine. I therefore decided to make a ring light to fit round my new camera lens and then perhaps make a bracket so that it could also be used as a work light on the milling machine itself. I have not shown any drawings here, as if the reader wishes to make this, their LED array may be different.

A look around the workshop produced some 2 mm clear acrylic sheet and some 12 mm lightweight fibre board, which proved to be ideal for the construction.

The Camera Mounted on the Ring Light

Construction

I started by making a sandwich of two sheets of acrylic and one sheet of fibre board 220mm x 200mm and drew out the shape illustrated in **photo 9**. You will possibly be able to see that the acrylic sheet came with a polythene film on each side to protect it during cutting.

The three layers were bolted together using some 5BA bolts. All twelve bolts (8 on the outer ring and 4 on the inner ring) were drilled 5BA clearance - 3.3 mm and the bolts were fitted to hold the three layers together. The outer shape was then cut out on the scroll saw giving me three identical layer shapes. The sandwich was then separated, and the annular ring was cut in the fibre board layer to be a close fit on the LED array parts. The array parts when assembled, are 12 mm thick in total, thus fitting snugly into the annulus in the sandwich.

My particular LED array runs off 5 volts DC and the polarity is clearly marked with

The Illuminated Light Ready for Use

The Soft Natural Light Created by the Ring Light

+ and - on the circuit board. 5-volt wall power packs are quite common, being available on the internet for around £5. I used one that I already had in a drawer. It needs to be 1A 5v DC and do check the polarity before soldering the leads to the circuit board. The circuit board was not exactly circular, as it had some mounting lugs on it which needed to be filed off.

Mounting the Camera

I was lucky in that I found a short piece of aluminium U channel in the workshop, and by cutting an angled piece, it formed a convenient camera mounting bracket as shown in **photo 10**. This worked admirably as the lens of the camera just clears the bottom of the hole in the ring light. On my camera, this means that I can pop up the inbuilt flash on the camera, if I wish, and the circular hole clears the flash. This is ideal for mixing both flash and the ring light as the colour temperature of the ring light is 6,400k and mixes flawlessly with the flash.

The camera is fixed to the bracket with the tripod screw shown in photo 10 and some rubber drawer lining was glued to the bracket to eliminate any tendency for the camera to swivel. The exact location of the camera, relative to the ring light, requires some thought as all cameras are different. My camera has an electronically controlled zoom, and there is no focus ring on the lens. I therefore mounted it a little way back from the ring light so that I could pick up the camera in the normal way, complete with the ring light attachment. If your camera has a zoom or focus ring on the lens, then that may dictate your camera position. The light runs completely cool.

The light may appear heavy and cumbersome in the pictures, but it only weighs 400g and the whole thing is very convenient in use. The fact that I used a U section for the camera mount means that the whole unit is easy to put down onto a flat surface, with the camera fully supported. Whilst readers' cameras will vary in type and the LED rings may not be of the same size, this idea should adapt to many camera set-ups, and I hope that it will inspire some workshop photography and perhaps some articles for the magazine. ■

A 'switch off' attachment for parting off safely

Jaques Maurel describes a device for avoiding some of the trauma associated with parting off. This article can be read in conjunction with his article *The Star System and More for Parting Off in MEW 265* - Part 2.

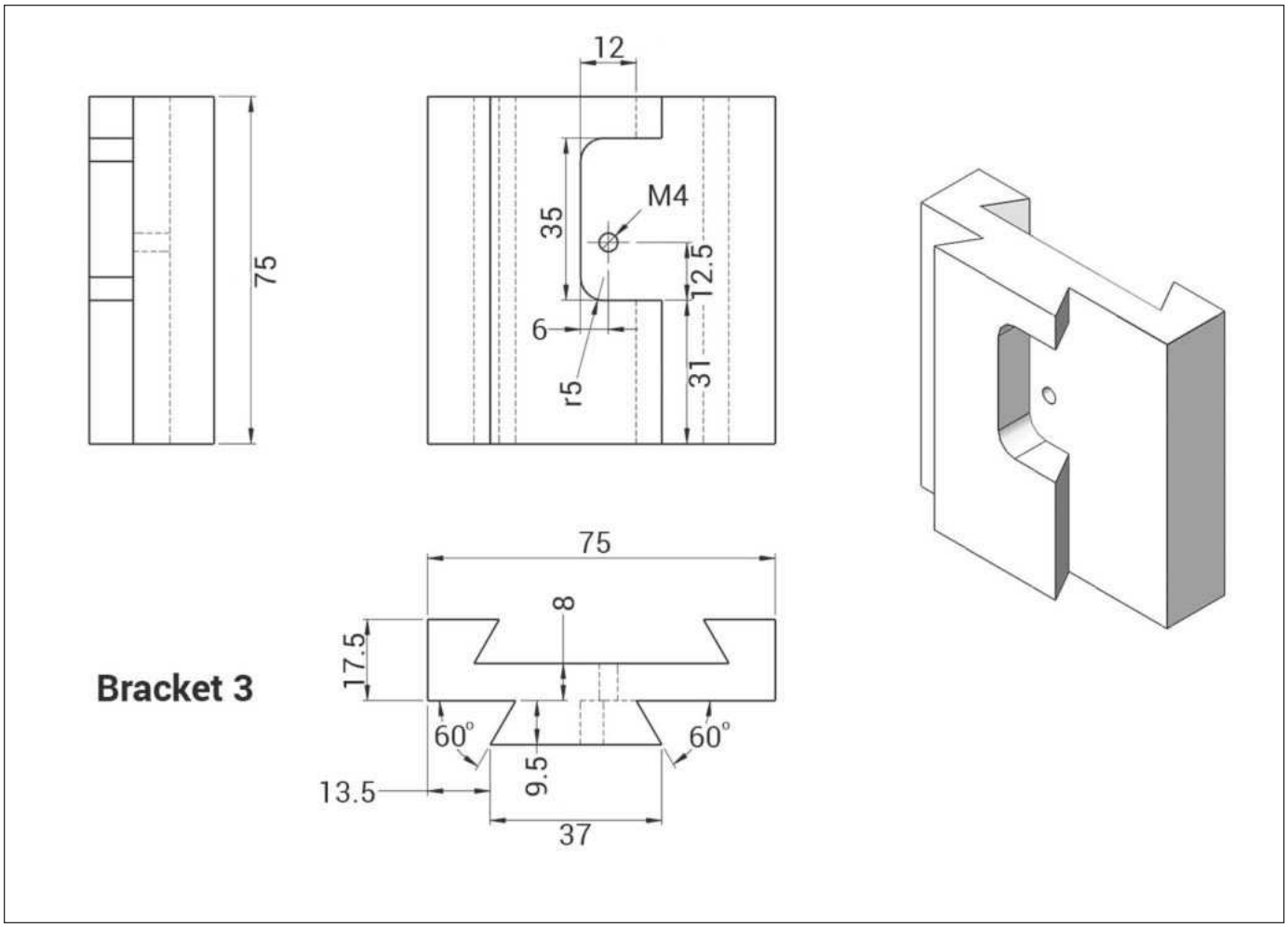
Assembly

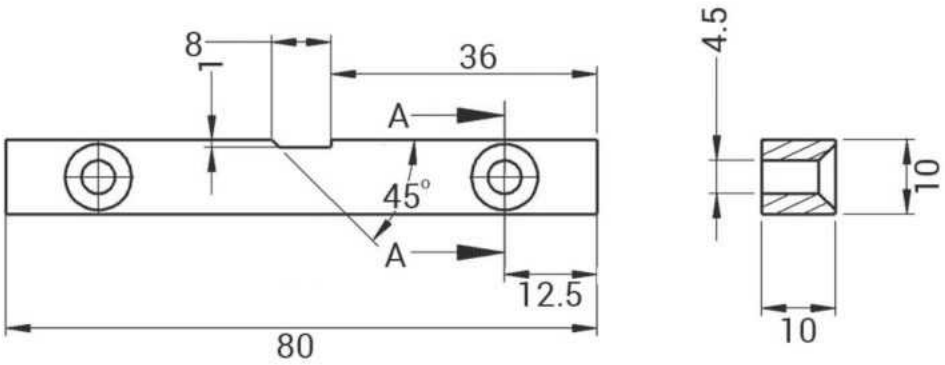
Fit part 4 on 3; tighten 14, now fit the dovetail slider (1, 2, 20, 21, 22, 19, 24, 23), grease and adjust the slide for no play.
Now attach to 1 parts 16, 15, 13, 25, 12, 9, 18. Put some grease on 15, between 4 and 16 and also between 1, 13, 12.
Fit 5 in contact with 15 and parallel with 1 by adjusting 17, set 6, 7, 8.
Finish with 11 and 10.

The Switch Off Attachment – no dovetail version

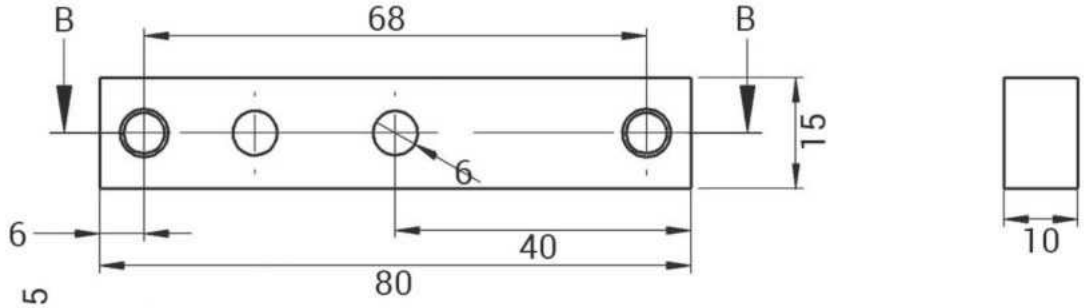
See **table 2** for the parts list.
For this version **figure 3** and **photo 6**, the flat contacts are between S2 and S1 and between S2 and S3, two cap screws S4 (locked by S19 and S20 after play adjustment) are used to keep the contact between S2 and S1 the 2 brass pads S20 have not the same length. Here the throw of part 2 is only 20mm. The play between S3 and the groove in part S2 must be kept to a minimum. All parts drawings are given only when different from the ones of the previous version.

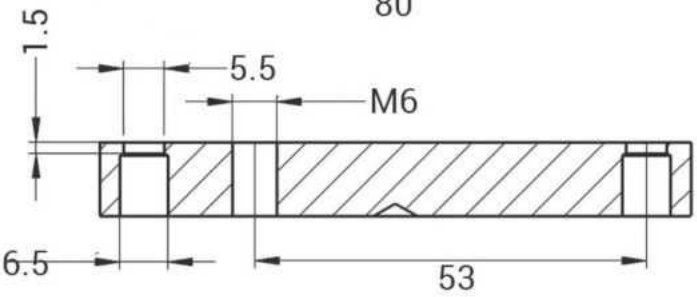
Note: the two M5 tapped holes named **"B"** on the slider drawing **(part S2)** are for fixing a carbide tipped blade holder as shown in **figure 4**.



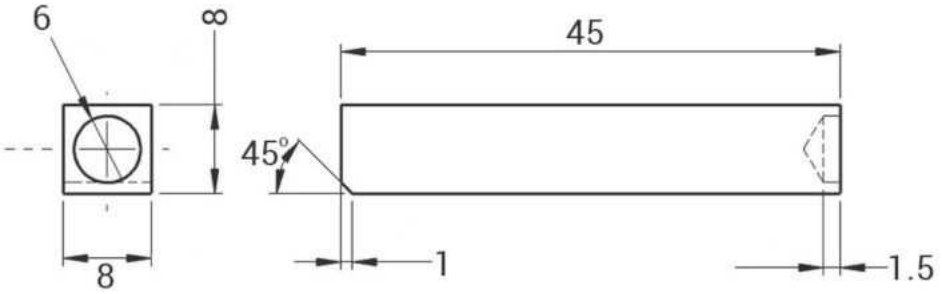


Part S3





Part S5



Part S16

Mike's WORKSHOP

A "Bolt" Flycutter

Mike Cox uses a bit of lateral thinking!

I was wandering around a local agricultural market and came across a stall selling, amongst other things, some large bolts with nuts. These were circa 125 mm long and about 20 mm diameter and I picked up two of them for £1. I did not really have any specific purpose in mind for them, but I thought they might come in handy for something.

When I got them home I measured them up and they were M20 x 135 mm bolts with a 2.5 mm thread pitch. As I was measuring them it occurred to me that I could make a useful fly cutter out of one of them.

The finished flycutter is shown in **photo 1**.

My mill takes tooling with an MT2 taper. The original bolt was 135 mm long, threaded section 45 mm long and the head was 12.5 mm thick, see **photo 2**.

Construction

The head of the bolt was 'painted' with marker pen. One of the nuts was screwed onto the end of the bolt and this was laid flat on a surface plate (i.e. a slab of polished granite). Using a height gauge, the across the flats measurement of the bolt was found. This height was divided by two and then a line was marked at this height using the height gauge.

The bolt was then mounted in an angle vice, **photo 3**, with the vice set at 14 degrees and with the marked line at right angles to the jaws. Using a 6 mm slot drill a 6 mm groove was milled across the head to one side of the scribed line to a depth of 5 mm at the shallowest end.

The bolt was then cut off 77 mm below the head on the bandsaw.

The bolt was returned to the lathe and the end of the bolt head lightly faced.

The top slide was set up for cutting the Morse taper. To do this on my mini-lathe a short piece of 8 mm round steel was chucked in the lathe, faced and then centre drilled. The tailstock chuck was removed and replaced with MT2 dead centre and another MT2 dead centre was then mounted with the point in the centre held lathe chuck and the blunt end supported with the tailstock centre. A DTI was mounted in the top slide with the tip at centre height and just touching the MT2 chuck. The angle of the top slide was then adjusted so that when the DTI was moved along the length of the taper there was only minimal movement of the DTI needle. The topslide was locked firmly in place on the cross slide and the DTI replaced by a sharp HSS knife tool.

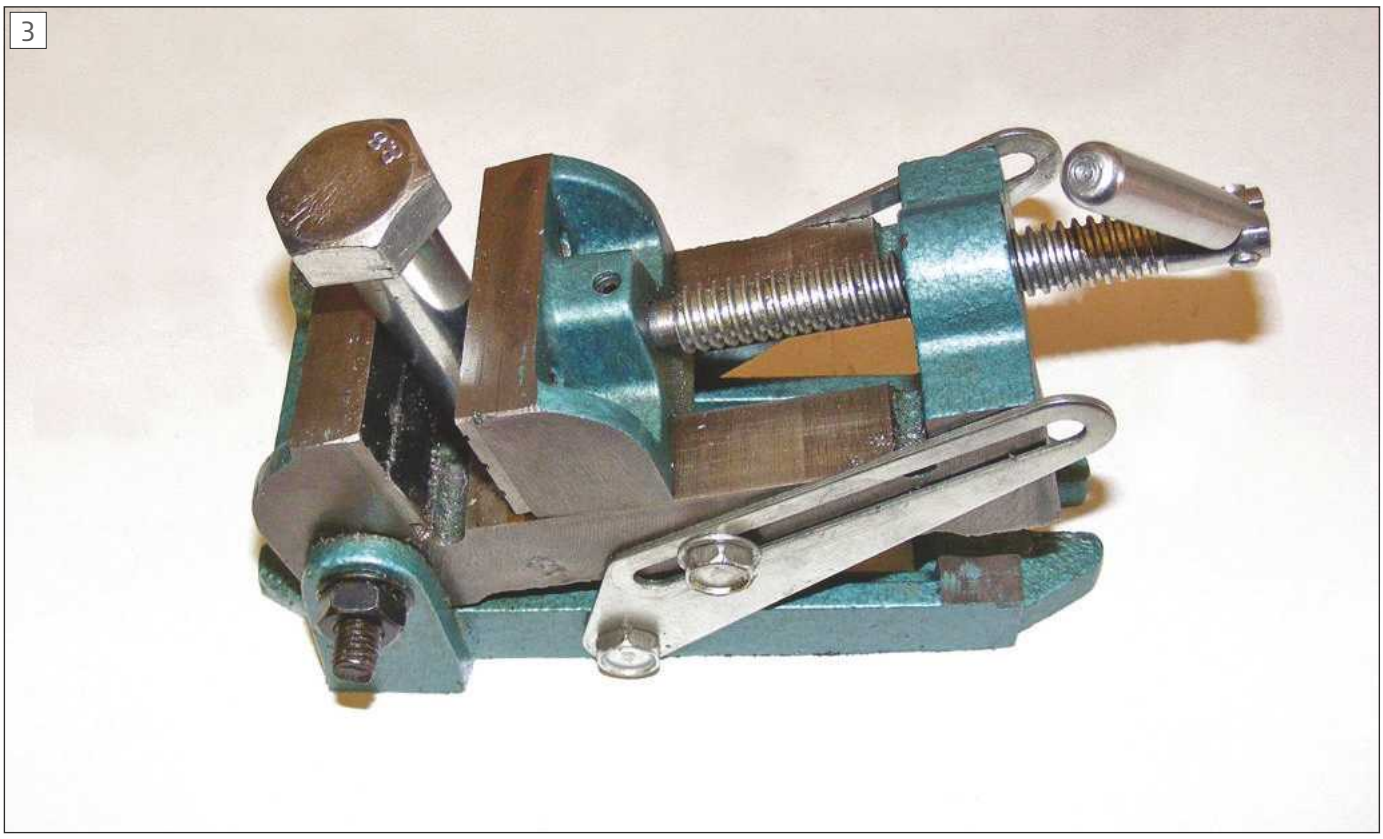
1

The finished flycutter

2

The bolt

The bolt was turned around so that the head end was gripped in the tips of the lathe chuck jaws and fixed steady was set up to support the round part of the bolt next to the chuck. The steady was then moved along the shaft of the bolt to be close to the threaded part. The lathe was rotated by hand to ensure that the bolt did not bind in the fixed steady. If necessary, loosen one of the fingers on the fixed steady to get free rotation and then lock it back into place. The end of the bolt was faced and centre drilled with a BS4 drill to full depth of the cone. The bolt was then drilled out with a 5 mm drill bit to a depth of 70 mm. The fixed steady



The bolt set up in the angle vice

was removed, and the end of the bolt supported with a live centre.

The Morse taper was then cut taking shallow cuts until the tapered section was 70 mm long. The tailstock was slid back, and the Morse taper checked. The work must not be removed from the headstock when checking the fit.

To check the fit, I always use an MT3-MT2 adaptor. I bought this originally to allow the use of MT2 tooling in the headstock of my mini-lathe. However, it has been used mostly to check home made MT2 tapers. The first thing to check is the length of engagement of the male MT2 taper into a female MT2 taper. I know from trying several commercial MT2 tapers in my MT3-MT2 adaptor that the finished taper should come to about 17.5 mm from end of the adaptor. It is important to ensure that both the male and female tapers are scrupulously clean when making such measurements. Not all MT3-MT2 adaptors will necessarily be the same it is necessary to establish the distance from the end of the taper and the end of the adaptor if a different MT3-MT2 is used.

Once the taper is 70 mm long then the adaptor was slid onto the taper and the gap between the taper and the end of the of the adaptor noted. The tail stock was slid back into place and a light cut of, say, 0.1 mm taken. Remove the tailstock and recheck the gap. Because of the shallow taper a light cut will make a big difference to the depth of engagement. This procedure was continued, taking light cuts until the engagement was correct.

Having achieved the correct engagement, the fit was checked by drawing a marker pen line along the taper. The adaptor was then pushed onto the taper and twisted about 60 degrees relative to the taper. The adaptor was pulled off and the line was examined. If the line was not smeared uniformly the tailstock was replaced and the lathe run at high speed and the high spots, i.e. those with the most smearing, were polished with fine silicon carbide paper with plenty of oil as a lubricant. The fit was then checked again and, if necessary, the procedure was repeated until the marked line was uniformly smeared along its length.

The flycutter showing the tool slot and clamp screws

Once a good fit was achieved then the tailstock was removed and the fixed steady replaced and slid over the end of the taper. The tailstock centre was then reapplied and the steady adjusted so that the fingers supported the tip of the taper. The tailstock was then moved away and the centre replaced with a drill chuck. Using an 8.5 mm drill the taper was drilled out to a depth of 70 mm. The drill was replaced with an M10 tap and the lathe rotated by hand to start the tap. The piece was then removed from the lathe and held in the bench vice whilst the hole was tapped.

The final operation was to drill two 3.3 mm holes in the bolt head flat parallel to the tool slot, **photo 4**. These were then tapped M4 and screws cut to length. These screws secure the HSS tool into the slot.

Usage

A piece of 6 mm square HSS steel is ground to produce a cutting edge and then clamped in the slot. The flycutter is then ready for use.

A useful tool for the cost of 50 pence and a couple of hours of workshop time. ■

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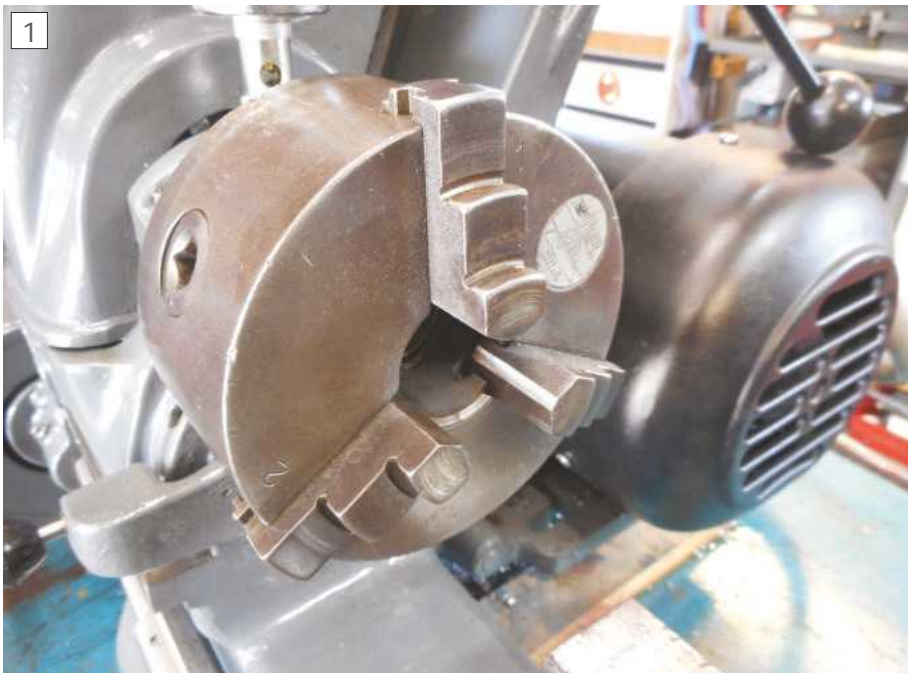
Beginner's guide to servicing your lathe chuck

Pete Barker outlines the basics of stripping, lubricating and reassembling the lathe's most-used accessory, the three-jaw chuck

Few parts of the lathe cop such a hiding as the humble three-jaw chuck, as can be seen on the well-scarred example in **photo 1**. For most of us, it's the go-to work-holding device, used day in, day out to grab jobs ranging from 1/16" diameter pins to six-inch flywheels and more. No matter the size of job, the chuck is always right there in the firing line of fresh swarf particles and cutting oil, which form a nice grinding paste on its moving parts. Then, if jobs slip under heavy cutting loads, we yank on the chuck key a bit harder, to "just nip it up". Life is not easy for the poor old chuck.

To ensure this unsung hero's long life and smooth action it needs more than just the regular cleaning and oiling of the visible jaws and the scroll plate that moves them, which should be part of your regular lathe maintenance routine. Let's take a look at stripping a chuck right down, giving it a thorough clean and relube and getting it all back together. It's something every chuck needs every few years.



The humble three-jaw chuck is the lathe's most used accessory yet seldom serviced.

Getting it apart

With the chuck on the bench, remove the jaws by turning the chuck key until they are free, **photo 2**. Visible in this picture too is the scroll, that rotating spiral ridge that engages with the teeth on the jaws and moves them. If the manufacturer has not done so, mark each jaw and its slot with either number stamps or centre punch marks so the same jaw will later go back in the same slot. Most chucks will be found to have the jaws numbered 1, 2 and 3. Some have the slots numbered by the factory too **photo 3**, others not.

Jaws removed, revealing the spiral scroll inside the body and the meshing teeth on the jaws.

Burnerd chuck comes with jaw and slot stamped as matching pairs, some others may not.

Three Allen-head screws retain the backplate. Three threaded jacking holes lie in between.

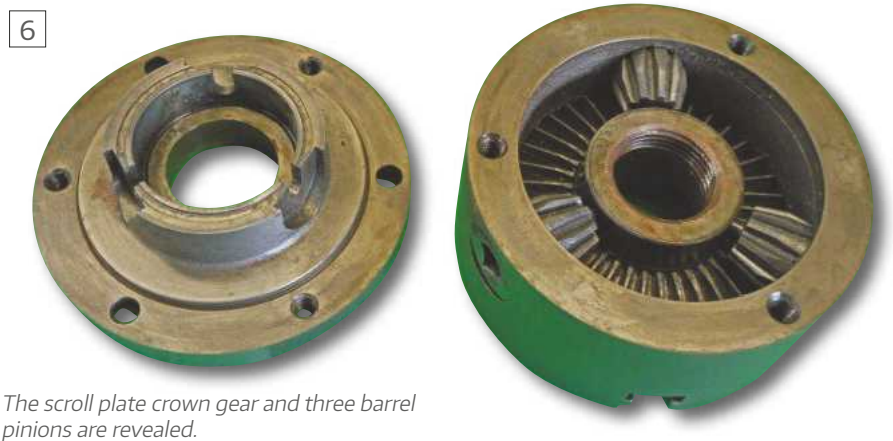
Gently ease the backplate off using the three jacking screws evenly.

The next step is to remove the chuck backing plate. Use a centre punch to mark the backing plate and the chuck body so they can be reassembled in the same position. This is particularly important where the backing plate screws on to the lathe spindle and the chuck fits on a stepped register on the backing plate. Reassembling those chucks in a different position on the backing plate can result in excess chuck runout.

On our example chuck, a Burnerd from a Myford ML7, the backing plate is held on by three Allen-head screws, **photo 4**. Remove these screws. In most cases, three threaded holes will be seen in the backing plate. Screw the Allen-head screws gently into these holes and gradually and evenly use them to jack the backing plate off the chuck body, **photo 5**. There is usually a step on the plate that push fits into the chuck body, so some minor resistance will be felt. If major resistance is felt, check carefully there are no further screws hidden in the assembly that need removing. If not, a few sensible raps from a soft hammer around the perimeter should free things up.

Once the backing plate is removed, the bevel gear teeth can be seen on the scroll plate and the three chuck keyhole barrels, **photo 6**. The three notches seen on the inner backing plate in the picture retain the barrels in operation. On our Burnerd example, these three barrels simply slide right out once the backing plate with its included retainer ring is removed, **photo 7**. On other chucks, there may be a ring, sometimes plastic on low-cost chucks, with three retainer brackets moulded into it, which has to be lifted out. Other chucks again, including older British Crown brand units used on Drummond lathes, may have three further screws passing through the chuck body and registering in grooves on the keyhole barrels. These are unscrewed to release the barrels.

Barrels pull straight out on the Burnerd. Others may have retaining screws or pins to be removed.



The scroll plate crown gear and three barrel pinions are revealed.

Yet other chucks have no backing plate as such. Instead, the whole rear half of the chuck body is removable, with the join line running through the middle of the three barrel holes. Again, use jacking screws in the provided threaded holes to separate the two parts. Do not be tempted to stick the chuck key in one of the barrels and whale on it with a hammer. It is quite possible to burst the side out of the barrel this way and good luck finding replacement barrels for older chucks. If your chuck has no threaded holes for jacking screws, judicious use of a small screwdriver to pry the sections apart evenly will have to suffice. Then drill and tap three jacking holes in the backplate for future use.

With the three barrels removed, the scroll plate can now be removed. This is usually best done by turning the chuck body over and banging it on the wooden bench top until the scroll plate wheel drops out, **photo 8**. If it is sticky, a few gentle taps with a brass drift and hammer will help.

That's it. That's all there is to stripping down a three-jaw chuck.

Cleaning and polishing

The chuck's interior will usually be covered with a mixture of grease and fine swarf grit that has found its way in so it's best to put all parts in the parts washer for a good scrub down. If you don't have the luxury of a washer, suitable degreaser or solvent in a sink or tin pan will do the job. I find an old toothbrush is ideal for cleaning gunge off gear teeth and out of the jaw slots.

Once cleaned, all parts are dried with clean rag and laid out on a clean surface for inspection, **photo 9**. Any burrs etc should be filed or stoned down and the part re-cleaned. Also, if you are doing a cosmetic restoration, now is the time to polish up the chuck's exterior. Wire buffing wheels seem to get some of the gunge off but make no difference to ingrained staining and rust of many years. Spinning the backing plate and body mounted on the lathe spindle at high speed and applying some 400 grit wet rub paper along with WD40 will give a pleasant

finish without looking overdone. Cover the lathe ways and carriage with damp rags to catch any abrasive grit flung about. Our example's jaws were similarly cleaned up with emery paper to match. Be careful to only polish and not remove metal from the parts of the jaws that fit into the chuck slots. We don't want to create more wear than exists already. Parts are washed and dried again after polishing.

Lubrication

There are two main areas of the chuck, which require two different forms of lubrication. The interior of the chuck is lubricated with grease, so it does not centrifuge out through the barrel holes in use and to properly lubricate the gear teeth on the back of the scroll plate and the barrel pinions.

The exterior parts of the chuck, the scroll, the jaws and their slots, are lubricated with machine oil so that less swarf sticks to them than if grease were used.

The ideal grease to use inside a chuck is a specialist high-tack, high-adhesion, high-pressure molybdenum disulfide grease such as Molyslip MTG (Machine Tool Grease). It will stick to the gears and chuck innards without so much flinging off under centrifugal force and the molybdenum will leave a lubricating residue on the gear teeth even if the grease moves away or eventually dries up.

Be warned though, the more common and less sticky automotive moly bearing grease will make one heck of a black mess on start up as it flings off the chuck all over the workshop. I speak here from experience. I have since found a much better substitute is synthetic grease sold for use on boats and their trailer wheel bearings. It is designed to be water resistant by dint of increased adhesion in part and works on chucks perfectly adequately if the specialist machine tool grease is not available to you, as is the case here in rural Australia.

Assembly

Re-assembly, as the workshop manuals too often say, is the reverse of disassembly, only this time with fresh grease added. It is good to apply a smear of your chosen grease over the interior cavity of the chuck, but not on the bottom surface where the scroll will rub. Add a little grease to the holes the barrels fit into, both in the outer body and the smaller holes in the centre where the protruding pinion shafts sit, **photo 10**.

Then load the gear teeth on the back of the scroll plate with grease and drop it down into position, scroll downwards, gear teeth upwards. Add some grease to the gear teeth and locating grooves on the barrels and slide them back into the same hole each came out of, as marked, until they mesh with the crown gear on the scroll plate. Avoid the temptation to pack the cavity full of grease. It serves no great purpose other than to increase the chance of a mess being flung all over the workshop on start-up. Add a couple of

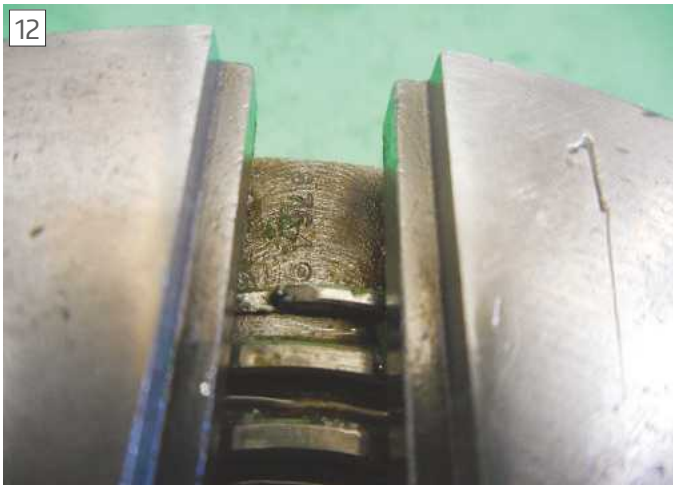
Scroll may be gently tapped out of body.

Cleaned chuck parts laid out for reassembly.

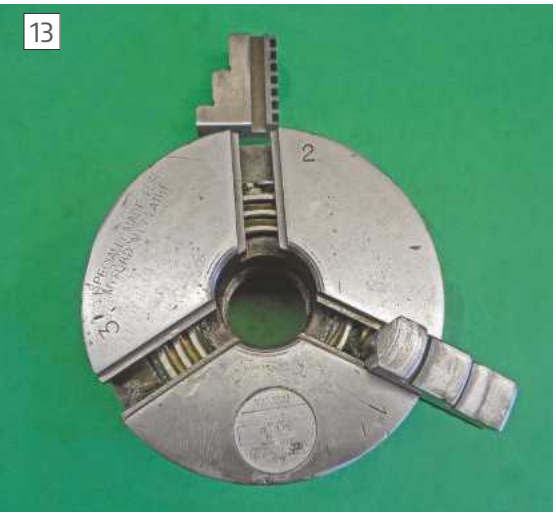
Grease interior of chuck body and the small holes for the pinion shafts.

›

Pack gear teeth with grease but no need to fill the whole cavity.



The start of the scroll in the centre of No.1 slot.



Start of the scroll in No.2 slot.

dabs for good luck if you must, but what's on the components already will do the job, **photo 11**.

Lightly grease the backing plate and place it in position, noting our marks to ensure original alignment. Make sure the barrel retainers are correctly located in the grooves in the barrels and jiggle the barrels until the plate slides home, or nearly home. Then apply some anti-seize to the three Allen-head screws and tighten them down evenly so the backing plate is drawn down into position. Nip them up tight but not too tight then flip the chuck over ready for the final step.

Installing the jaws

Lubrication on the jaws and scroll is by machine oil only, as mentioned. Whatever oil you use on the ways of your lathe will do fine here.

Getting the jaws back into their slots in the right order and position so they all meet in the middle when the chuck key is turned has baffled more than one beginner before today, so I outline the process here.

First, observe the manufacturers markings and determine which is No.1 jaw, No.2 and No.3. Then find No.1 slot on the chuck, either from the manufacturer's mark or the one you made before disassembly.

Next, using the chuck key, rotate the scroll until the outer end can be seen in the No.1 slot, **photo 12**. This is the start of the flat "thread" that winds the jaws in and out. Move the beginning of the scroll slightly to the right of the slot in the chuck. Insert the No.1 jaw into the slot as far as it will go. Rotate the chuck key as if tightening the chuck and rotate the beginning of the scroll around to No.2 slot. Repeat the process to install No.2 jaw and engage the scroll with the teeth machined on it. Repeat the process with No.3 jaw in the final slot. All three jaws are now engaged in the correct order with the scroll. Wind the chuck handle until the jaws meet in the middle and check you have not skipped a tooth on installation, which results in one jaw being out of sync with the other two. As the teeth on each jaw are machined in a slightly different position, they must be assembled in the correct order like this to match up.

Testing

The final step is to wipe off any excess oil and grease and then mount the chuck on the lathe and spin it at highest speed. You might want to stand to one side as invariably excess lubricant lurking in the outer chuck body will be flung off.

Stop the lathe once grease and oil cease flinging off. Try gripping pieces of round bar of varying diameter and make sure no binding or notchiness can be felt in the chuck-key action. The action should now be smooth throughout the range, providing the chuck's components are not worn out or damaged.

Conclusion: Get a grip

That's all there is to servicing your three-jaw chuck. It is a simple job that can be done in an hour but well worth the time. Done every few years it should ensure a long and pleasant life for this most-used accessory, **photo 14**.

The most important thing to remember is not to use excessive force on disassembly or reassembly as this can distort components. Use the jacking screw holes provided to gently ease the chuck apart.

Lubricate with the correct grease inside the chuck and oil on the outside components and reassemble with equal care.

In use, remove and clean the jaws periodically and clean the scroll and slots with clean rag and then re-oil them. The scroll is easily cleaned by rotating it with the chuck key while sticking a small screwdriver wrapped in rag in through one of the jaw slots until it rides in the groove. Resist the temptation to use compressed air to blow swarf off the scroll because small particles can be forced inside the chuck this way and cause premature wear.

Follow these simple guidelines and your chuck should give you many years of faithful service in return. ■

Finished chuck ready for many more years of faithful service.

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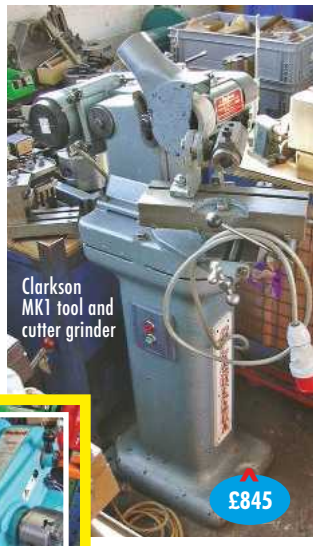

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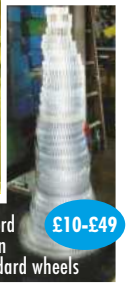

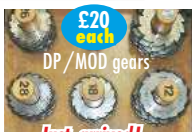

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