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MODEL ENGINEERS' WORKSHOP

Published by MyTimeMedia Ltd.
Suite 25, Eden House, Enterprise Way,
Edenbridge, Kent TN8 6HF
+44 (0)1689 869840
www.model-engineer.co.uk

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Model Engineers' Workshop, ISSN 0959-6909, is published monthly with an additional issue in August by MYTIMEMEDIA Ltd, Enterprise House, Enterprise Way, Edenbridge, Kent TN8 6HF, UK. The US annual subscription price is £2.95GBP (equivalent to approximately \$8USD). Airfreight and mailing in the USA by agent named Air Business Ltd, c/o Worldnet Shipping Inc., 156-15, 146th Avenue, 2nd Floor, Jamaica, NY 11434, USA. Periodicals postage paid at Jamaica NY 11431. US Postmaster: Send address changes to Model Engineers' Workshop, Worldnet Shipping Inc., 156-15, 146th Avenue, 2nd Floor, Jamaica, NY 11434, USA. Subscription records are maintained at dsb.net 3 Queensbridge, The Lakes, Northampton, NN4 7BF. Air Business Ltd is acting as our mailing agent.



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On the Editor's Bench

On My Bench

Well it seems that just about everything is on my bench at the moment, although there seem to be several projects hidden under the debris. I'm making progress with my telescope, but the focuser has proven frustrating. First, I managed to over-tighten my four-jaw chuck, marring the body where I had been hoping merely to skim the as-supplied surface to a good finish. I was able to fill the resulting dents with an aluminium welding stick and disguise them. Then disaster struck near the final hurdle. Unknown to me, the brass bracket I used to hold the read head for my z-axis DRO came loose, with the result that I skimmed an extra millimetre or so off the top surface. It may not sound much, but I needed as much 'meat' as possible for various adjustment screws, so the part became a scrapper anyway! At least I now have it as a pattern for a second try, and I have made the new blank a bit longer to avoid four-jaw problems.

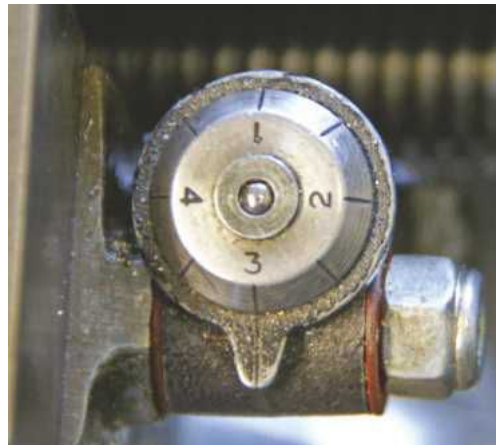
I have never made such a large and complex project out of aluminium stock before and I have found the 6082 aluminium very pleasant to machine. Uncoated carbide endmills (as recommended by Jason Ballamy in his article this month) work really well, as do uncoated CCGT lathe inserts. Recently one forum user, based in Poland, bemoaned that he could only easily source 1000 series alloys, which are near pure aluminium which is much softer and very 'sticky' making them weaker difficult to machine.

John Stevenson Trophy

The judges have been through the nominations for the trophy and selected a shortlist. By the time you read this we hope to have details of the entries on the forum at www.model-engineer.co.uk together with a link to the (anonymous) voting system. Congratulations to everyone shortlisted and good luck!

Thread Dial Indicators

For technical reasons, I was unable to bring you Trevor Hills' article on using thread dial indicators in this issue. I will be doing my best to make sure it is in issue 268.



Airbrush Valet

I know many readers use airbrushes for painting their models, and also (in larger sizes) for getting a good finish to painted tools. The Airbrush Company Ltd have been in touch about their Valet Service for your airbrush. They ask: "How many of you have an airbrush in a drawer that needs cleaning and servicing? Don't let that stop you. Simply send your airbrush to us for a professional clean and service to get it ready for use like it is new again. Your airbrush will be returned to you with aftercare instructions, helping you to keep it clean and ready for action."

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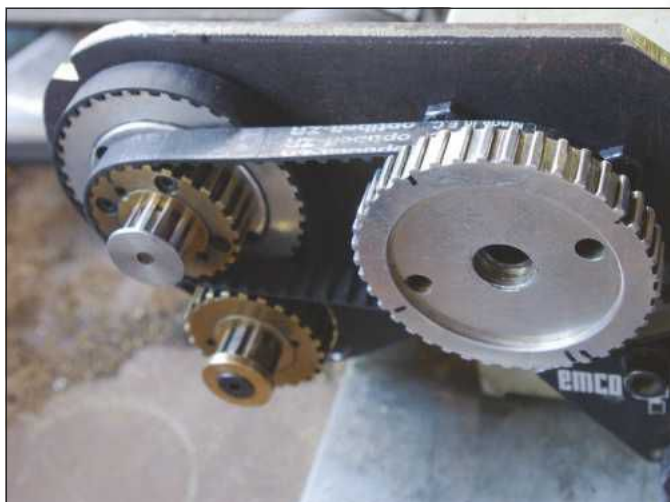
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Coming up in our next issue, MEW 268 another great read.



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THIS MONTH'S BONUS CONTENT

Log on to the website for extra content

Listen to the Earth! Hear Mark Noel's recording of the recent Welsh and Mexican earthquakes, as described in his article staring on page 13.

www.model-engineer.co.uk/quake



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?

Cup Wheels

Recommendations on the best abrasive wheels for a tool and cutter sharpener.

Unworkable Steel

Ever found some tool-proof steel? Explore the pros and cons of metal of unknown origin.

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CLASSIFIEDS EXTRA SUBSCRIBE ARCHIVE SUPPLIERS

A Unistand - a floor stand for a bench machine

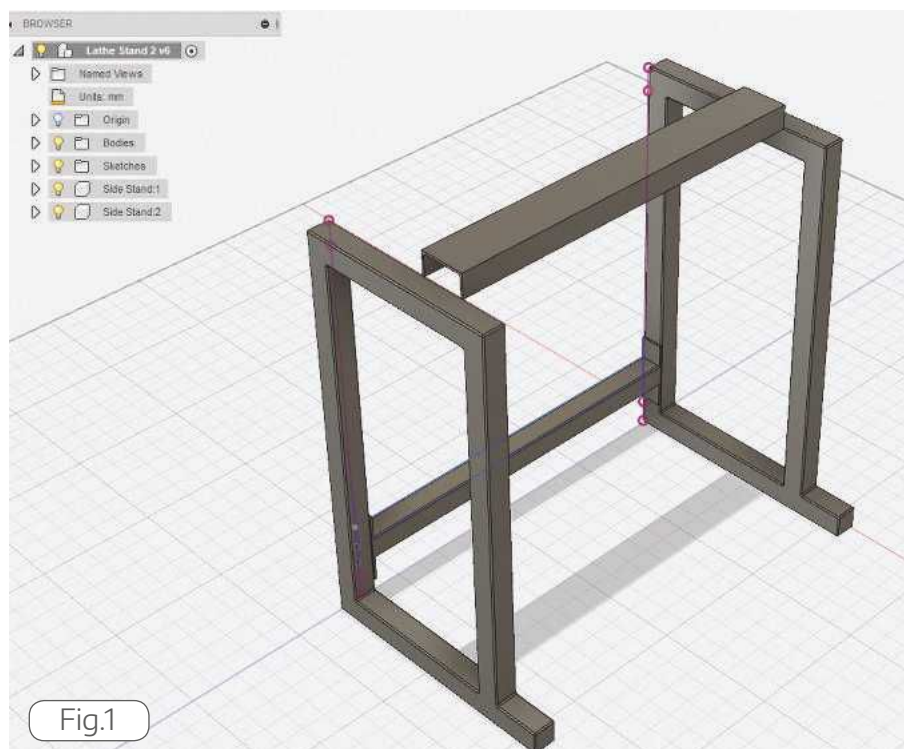


Sean Flood describes how he made a solid base for his lathe.

After starting my career in engineering and then spending 25+ years in IT and software development I am going back to my roots and returning to engineering. I am also member of the Institute of Engineering & Technology (IET). About 10 years ago I managed to pick up a Chester 920 lathe, initially it was put on a bench, it was not bolted down and it has been there ever since. The 920 is a Chinese lathe but with some careful setting up and updated accessories was a useful addition to the workshop. In the past few months I have been re-organising my workshop my space for a new machine (more on that another time) which has freed up some room for my lathe, which meant I needed a suitable stand. Initially I looked at ready-made stands but they didn't seem to offer the storage I needed, I did some research and



The finished bench fits around a roller cabinet



could not find a suitable design then I went to Google (Images) to get some ideas, so I decided to build my own, **photo 1**.

There were a couple of requirements I needed in the design, firstly I wanted the swarf/chip tray to be removable for easy cleaning, and secondly it needed to be sturdy. Finally, if I ever sold the lathe I wanted the stand to disassemble for shipping.

There are thousands of different designs out there but the one that caught my eye was a Beam design which often used in ships, I am not sure why ships are really any different to the rest of us. The lathe would be mounted on a strong horizontal beam and a tray went under the beam, making cleaning very easy. I also wanted a mobile drawer cabinet underneath the tray for the accessories and tooling, I already had a Clarke 7 drawer rollcab which I reduced the height of by replacing the casters with smaller ones.

I used Autodesk Fusion 360 to put together a design, **fig. 1**, I needed it to be relatively flexible because until the lathe was on top of it I wasn't sure how much room it needed at the back, so the final



Tubes marked up



Ordinary g-clamps used to hold tubes in place



Magnetic clamp to get a 90-degree angle

placement of the beam can be left to later in the build. Also to be considered in the design was the tooling I had available, I had quite a lot of 4 & 6 inch G clamps, a Workmate for securing the component parts during welding and finishing, I could drill holes up to 13 mm and my MIG welder could weld up to 6mm steel, at a push.

Preparing for the build, make sure metal is cut to length and has clean edges for welding. Invest time in marking the metal up and make sure you have all the items required, I used a marker pen to mark-up pieces (left & right, front & back, top & bottom), like a carpenter you are finding the best faces and edges, **photo 2**.

Next is drilling the metal, I had chosen M10 x 70mm bolts (from Screwfix) to assemble the stand, this worked well with the 50 x 50 square section steel. For the mounting cross beam I had 850mm of structural steel (100 x 50mm C section) which was broad enough to support the two base pads of the lathe. I also found some adjustable feet on an online auction site which had M12 threads, these were not any vibration but the weight of the stand and the lathe would be enough to sit it firmly on the workshop floor. Make sure you protect your eyes while drilling and cutting.

I did consider building a jig for the side frames, in the end I decided to manually assemble one side making sure it was as square & flat as possible, I clamped

metal to the structure steel beam to keep them flat, then tacked welded them and checked for square again before completing the welds. A short note about welding, it took me a number of years to get the hang of good welding, there are a number of variables such as power level and wire feed, when it sounds like

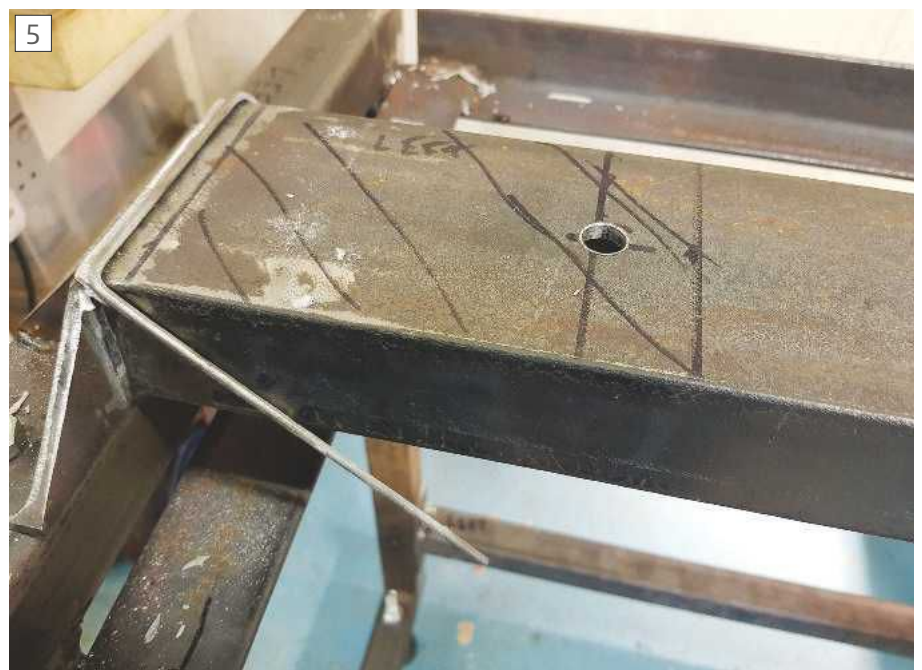
sizzling bacon you have the settings right, I have also found that the gap between the pieces is crucial then the weld will be good.

The second frame components were clamped or bolted with studding to the first frame, **photo 3**, the trick is to get both frames as identical as possible, the adjustable feet will cope with slight variation in the frame but a twist across the entire structure will be harder to adjust out.

As the frames got welded the combined weight is growing which brings a new set of issues, you need to make sure that the frame is securely mounted. If the frame is not secure and you have limited viewing through a welding mask then you can easily topple the frame, be careful it could be heavy & hot.

The rear lower cross brace is a simple 50mm box section with 2 end plates on each end, it is important to check the square-ness of the end plates, so they were tack welded and then adjusted before the full weld was done, **photo 4**.

The mounting beam is relatively easy compared to the other components, two small sections of 50 x 50 mm angle is welded to the mounting cross beam. At



Welding rod used to form spacer

this point the stand is assembled and the location of the mounting cross beam could be confirmed, it was then clamped and transfer punched, it was then drilled with 11 mm holes for the M10 nuts and bolts. The final addition to the mounting cross beam was a short section of welding rod across the 100 mm width and down the side, at both ends, **photo 5**, this was to prevent the coolant creeping along the length of the beam and the steer the coolant to the tray.

The coolant tray shelf was made up of two side sections of 50mm angle and a longer length angle section across the back to act as a back stop for the coolant tray. A flat bar was added to provide a front edge, it was placed so that the bolts for holding the Lathe to the beam could be accessed easily.



Coolant tray



Cross braces

I didn't try to fold the tray myself, I farmed this out to a fabricator mainly because I don't have the tools and secondly my standards are high and I didn't want to fail. The tray was aluminium and was 850mm x 400mm and about 50mm deep with welded corners, there is a drain pipe on the right hand front corner which drains through a hose to the coolant tank, **photo 6**. This enables the tray to be easily removed and the cutting swarf can be recycled.

In my original designs I included two diagonal bars across the back which keep the frame square and prevent the frameshifting left or right, **photo 7**. As the construction progress I became more confident that the frame would not need these diagonals, since the metal was cut they were included for completeness. An important factor in the design was the positioning of the joints, the top and bottom square section (Front to back)

sits on above and below the vertical square section so that the joints are under compression, the alternative would be the joints would be in shear and joints would have to have good welds.

Now that the frame is build is complete, then it should be disassembled and depending how go your welds are you may want grind them off and clean the metal. The frame was painted with a metal paint, of course the colour is a personal choice.

The newly painted frame can be assembled and placed in its final location, to level the frame start at the rear adjustable feet ensuring that the height is correct. I used a 1.2 Metre Builders spirit level across the top rear of the frame, if you are concerned about the accuracy then try reversing the level to confirm that the bubble is in the right position.



Lowering lathe into the stand

So this floor stand design can easily be adapted for any bench machine type, for a longer lathe just extend the beam and the rear cross member.

Next move to checking the front for adjustment on each side making sure that there is no rocking.

Finally, lifting the machine onto the new stand; lathes are notoriously difficult to lift as the heads are heavy and unbalance the lift also on bench machines the motor tends to hang out the rear of the machine which has a tendency tip the machine backwards. I used a hydraulic engine crane to lift the machine, **photo 8**, it is worth investing in new lifting straps (they are relatively low cost from an online auction site) and invest time getting the machine as balanced as possible. A final safety tip, take your time, you make mistakes by rushing through the lift & placement of the machine, remember fingers and toes are delicate.

In retrospect the 50x50 square is



Completed stand in place

probably overkill, I didn't do any load calculations I just used "Gut" feel, it could have been reduced to 40x40, this type of decision is based on your metal availability. I may upgrade the lathe in the future and I would hope that the stand can be modified to suit.

So this floor stand design can easily be adapted for any bench machine type, for a longer Lathe just extend the beam and the rear cross member. For a bench milling machine 2 top beams can be used to

support the corners of the milling, machine base. The vertical sections of the frames can be reduced or increased to adjust the height. So a very flexible design, welcome to the Uni-stand, **photo 9**. ■

References

Autodesk Fusion 360: www.autodesk.com/products/fusion-360/overview
IET: www.theiet.org/

In our Next Issue

Coming up in issue 268

On Sale 18th May 2018

Content may be subject to change

This June issue, number 268, of Model Engineers' Workshop brings you another fascinating read:



Jacques Maurel describes his switch off system to make parting less fraught



John Olsen's plans for toothed-belt drive for a unimat



Glyn Davies and his Dore Westbury Mill

DON'T MISS THIS GREAT ISSUE - SEE PAGE 52 FOR OUR LATEST SUBSCRIPTION OFFER

The Earth moved!

Monitoring earthquakes with homemade equipment

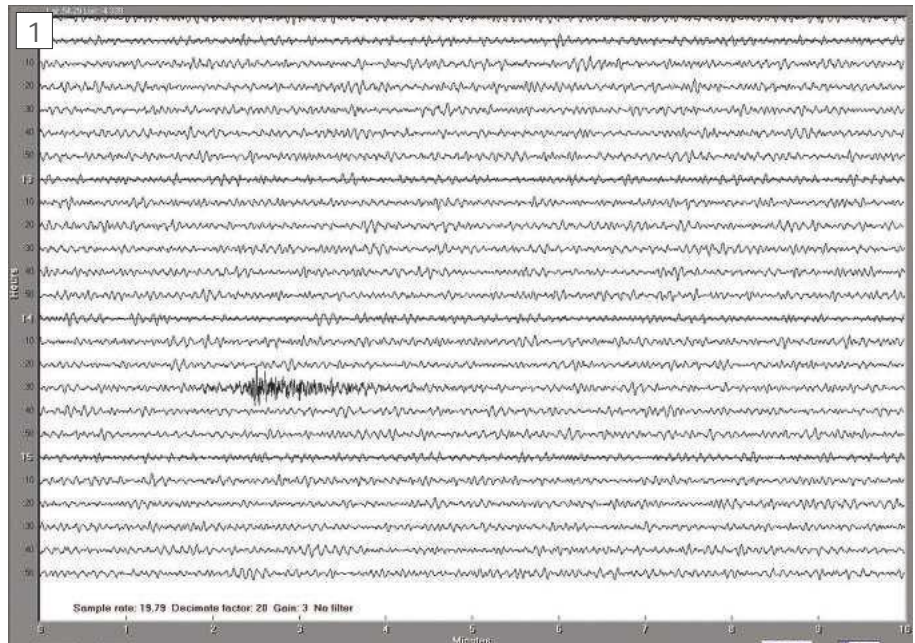


Mark Noel records global earthquakes with his own design of seismometer

At 14:31 GMT on 17th February this year a Magnitude 4.6 earthquake struck 7km beneath the village of Cwmllynfell in South Wales, UK and the vibrations were felt over much of Wales and southwest England. Although many people were alarmed by the shaking, fortunately no one was injured nor was property damaged. Nevertheless earth scientists were shaken since this was the largest 'quake on mainland Britain since the M5.2 event at Market Rasen in February 2008.

About 30 seconds after the Welsh geology cracked, my homemade seismometer 285km away on the Isle of Man picked up the ground vibrations which continued for around two minutes, **photo 1**. The day before a much stronger signal had been detected shortly before midnight, this time from the M7.2 earthquake that rumbled 37km beneath Pinotepa de Don Luis in Mexico, as the Pacific Plate nudged a little deeper beneath South America. This time the ground motion I recorded continued for about 90 minutes and had a completely different character to that seen for the earthquake in Wales, **photo 2**.

So how do these vibrations arise, and how can we detect them so far away from the underground source or 'hypocentre', to use the right terminology? The majority of earthquakes occur because of sudden movement along a contact between rock bodies in response to



Seismic Helicorder record of the earthquake in Wales on 17th February 2018. Each trace is 10 minutes wide, with time progressing left to right, then down to the next line. Note the constant wiggles of microseismic noise. The first wave to arrive has travelled down then up through the Earth's mantle.

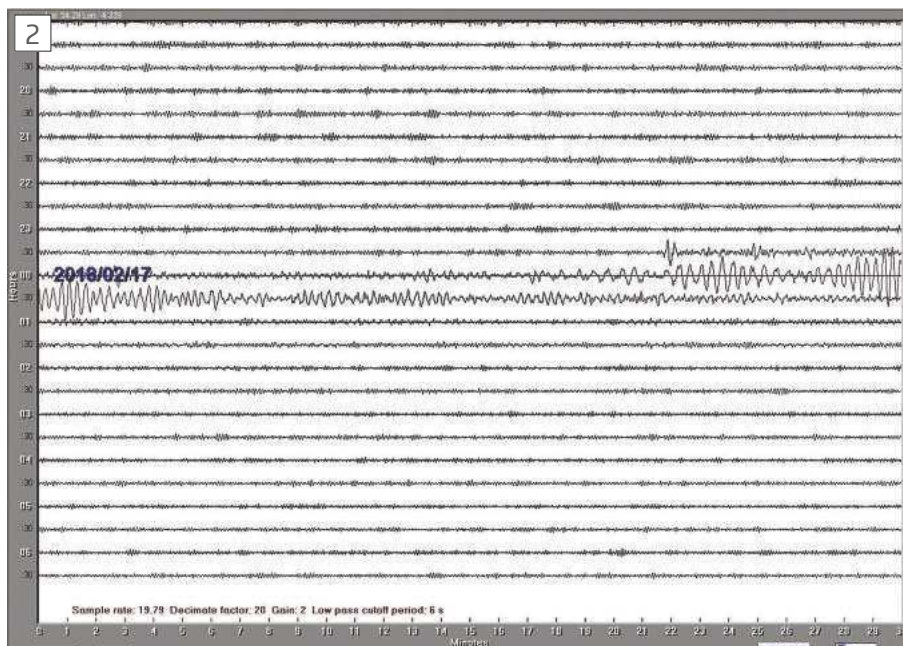
strong tectonic forces. This stick-slip frictional motion is similar to that we sense as a lathe carriage moves along the machine's bed, particularly when the surface is dry! Other processes that lead to earthquakes include volcanic explosions, magma flow, rockfalls and (rarely) meteorite impacts. Even turbulent winds passing over mountain peaks can generate significant vibration. Man-made events such as quarry blasts, underground nuclear explosions and the filling of reservoirs will also produce seismic signals, although the energy released by these events is usually negligible compared to most of the natural phenomena mentioned previously.

Most people will be unaware that the ground beneath their feet is continuously 'rolling', rather like an ocean wave, with a period of around 6 seconds. Now you have the perfect excuse for that wobbly walk home on a Friday night from the pub! The real cause has nothing to do with alcohol but is due to weather systems drifting over the ocean and rippling the sea floor, generating waves in the Earth's

crust that travel far into the continents. However, the exact mechanism remains poorly understood and therefore is a topic of particular interest to me, especially since these 'microseisms' are a constant hum that reflects changing weather in the Atlantic very distant from the Isle of Man.

Designing a seismometer with a useful performance brings a number of challenges. Although the peak motion from big events around the 'Pacific Rim of Fire' can reach several millimetres at my station, most global 'quakes have magnitudes below M7.0, producing movements here at the micron scale or less (<0.001mm). When Atlantic weather is benign, microseismic noise falls well below the micron level and greater sensitivity becomes beneficial to detect weaker events. Hence, it is useful to aim for a detector with nanometre sensitivity, if possible. However, this ambition creates the associated need for mechanical stability to a corresponding degree. Also, for optimum performance the instrument must be securely connected to the Earth:

Other processes that lead to earthquakes include volcanic explosions, magma flow, rockfalls and (rarely) meteorite impacts.



Seismic Helicorder record of the Mexico earthquake on 16th February 2018. In this case each trace is 30 minutes wide and a filter has been applied to suppress the microseismic noise. The long-period large oscillations are surface waves that have travelled round the Earth, often several times. Before that the waves arriving include some that have travelled down to, then back up from, the Earth's core.

ideally on a concrete base cast on hard ground, most definitely not on the 5th floor of a swaying block of flats! Over the years amateur seismologists have built instruments around electromagnetic, optical, LVDT, strain gauge, fibre optic and capacitance sensors, with the coil-magnet type of sensor proving the most popular since it is easiest to construct. For my VS1 seismometer, **photo 3**, I spent a year developing a sensor based on the

variable capacitance principle, or what I call a Digital Symmetrical Differential Capacitance Sensor. It certainly needs a snappy acronym - suggestions on a postcard please! This sensor can detect motion down to 3nm or 0.000003mm, in the bandwidth of several Hz to periods of almost a minute. For hours after a big earthquake the planet can bulge-wobble like a water-filled balloon and on quiet days my instrument can just manage to

detect these peculiar oscillations.

To delve deeper into the mechanics and electronics involved in designing a home seismometer would take more space than is permitted in this short article, which was written as a response to the recent seismic events close to home. There are plenty of resources on the Internet for those who want to investigate further, and it is possible that I may produce another article one day aimed at guiding the homebuilder in this fascinating hobby.

In connection with this article I have deposited a sound file on the MEW forum based on the 48 hours of data recorded between 00:00GMT on 16th February and 00:00GMT on 18th February. You can listen to this in Windows Media Player or similar software. The Mexican 'quake is heard halfway through the file, and the Welsh event a few seconds later. There is a major difference in how they sound reflecting their relative distance from my station and the various wave paths through our planet. Why not listen to this geomusic while jogging - how cool is that? ■

For hours after a big earthquake the planet can bulge-wobble like a water-filled balloon...



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TOOLS & MACHINERY

A Benchtop Curing and Tempering Oven

Chris Gabel describes an accurate electric oven with several workshop applications



Front view of the Benchtop Curing and Tempering Oven

The purpose of this project is to develop a compact heating oven suitable for low to medium heats, **photo 1**. It can be used for heat curing of adhesives and coatings as well as heat treatment and tempering, **fig. 1**. I wanted to explore a different door system, coupled with efficient insulation. A fully enclosed ceramic electric element would provide the power. This was all to be contained in a compact unit suitable for benchtop use, **photo 2**. In this instance I wanted to design a compact unit, but I also saw it as a prototype which could be scaled upwards in both size and power.

If one searches the web for 'heat treatment' and 'knife making' and 'forging

furnace' many examples of home-developed furnaces are available. Most all are based on using natural gas or propane, and almost all are much more powerful than I had in mind. As precise control was an aim, I liked the idea of an electric heat source, which could be controlled with a digital controller.

As a starting point I looked at the small sized forges. The knife making fraternity have many plans on the web, and many consist of a horizontal insulated cylinder, open at both ends. There is a tangential hole drilled in the side for the nozzle of the torch or dedicated burner to go through. From this I decided to use a horizontal cylinder, insulated with aluminium oxide

If one searches the web for 'heat treatment' and 'knife-making' and 'forging furnace' many examples of home-developed furnaces are available.



Oven rear view

Fig.1

Oven max. 750°C	2000°F 1093°C	Bright yellow	Forging
	1900°F 1038°C	Dark yellow	
	1800°F 982°C	Orange yellow	
	1700°F 927°C	Orange	
	1600°F 871°C	Orange red	
	1500°F 816°C	Bright red	
	1400°F 760°C	Red	Tempering
	1300°F 704°C	Medium red	
	1200°F 649°C	Dull red	
	1100°F 593°C	Slight red	
	1000°F 538°C	Very slight greyish red	
	800°F 427°C	Dark grey	
	575°F 302°C	Blue	
	540°F 282°C	Dark purple	
	520°F 271°C	Purple	
	500°F 260°C	Brown purple	
	480°F 249°C	Brown	
465°F 241°C	Dark straw		
445°F 229°C	Light straw		
300°F 199°C	Very light straw		

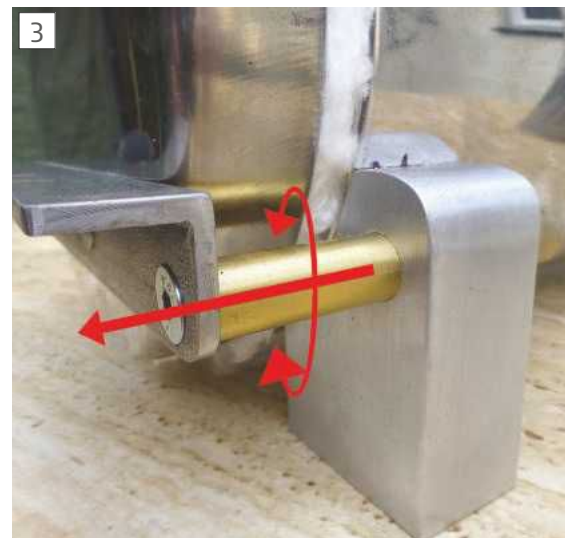
The operating temperature range and associated colours

wool, closed at one end, with a 'slide and rotate' front door opposite, **photo 4.**

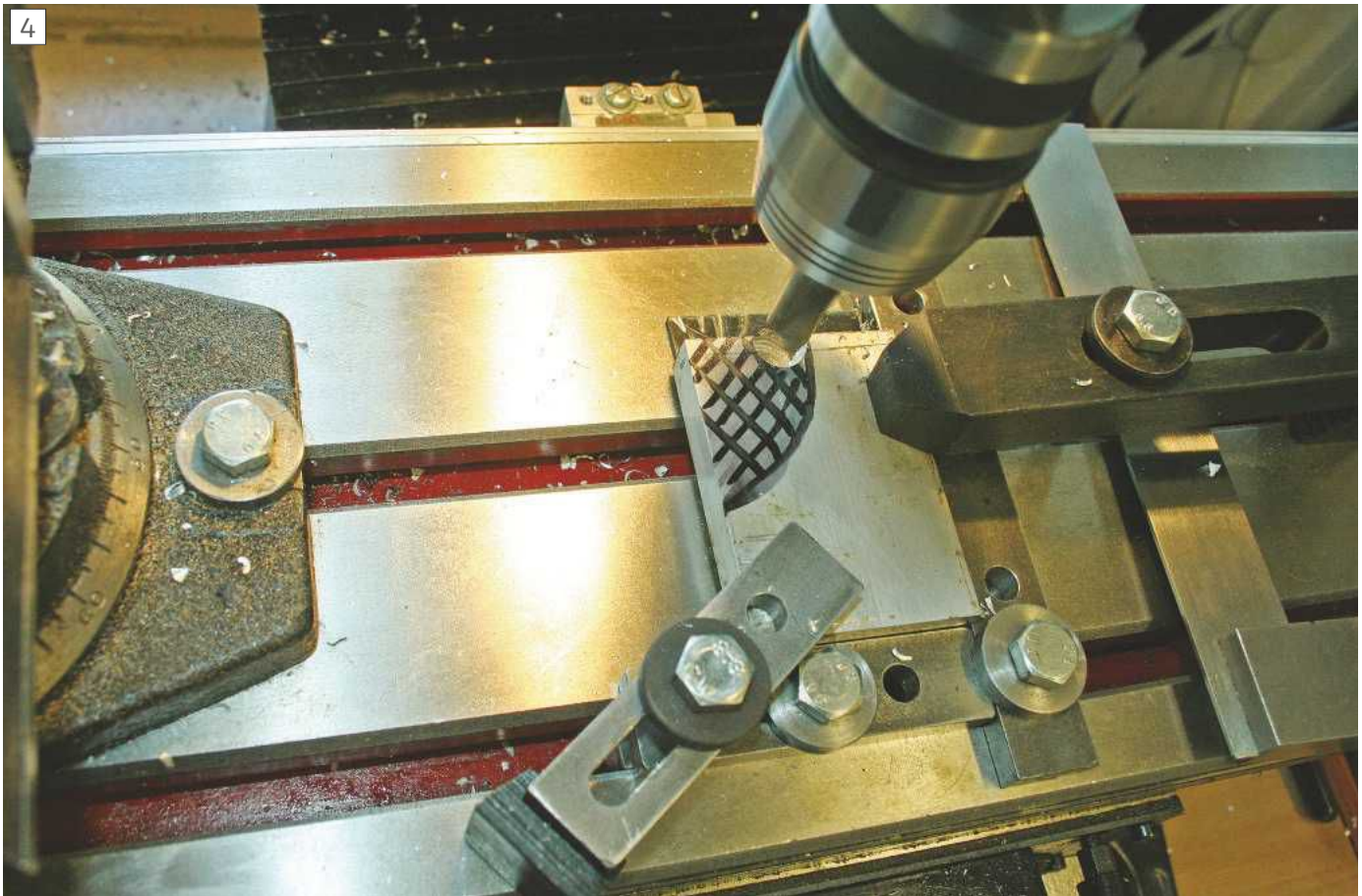
All told there are three main components: (1) The stainless steel body and legs, (2) The heating element and (3) The insulation. The oven works best with a digital temperature controller, but I will describe this at another time.

The Body and legs

If you are a purist, cylinders are easily made with a Warco, Machine Mart or similar Universal Sheet Metal Machine with their integral slip rolls. However, the world is full of metal cylinders, already pre-made. The most suitable can be selected from lubricant containers, fuel cylinders or steel drums or dustbins. I decided to use



The 'slide and rotate' hinge



Cutting the arcs on the mill



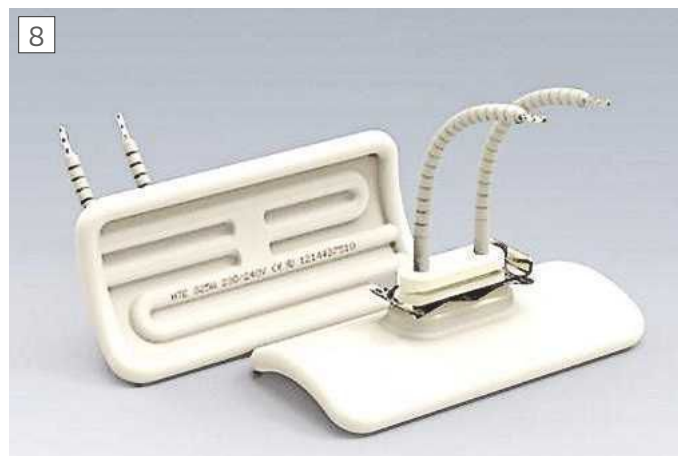
M5 Transfer points



Locating hole positions on the cylinder



Legs are fastened with M5 x 8mm long screws



The Ceramicx trough heater

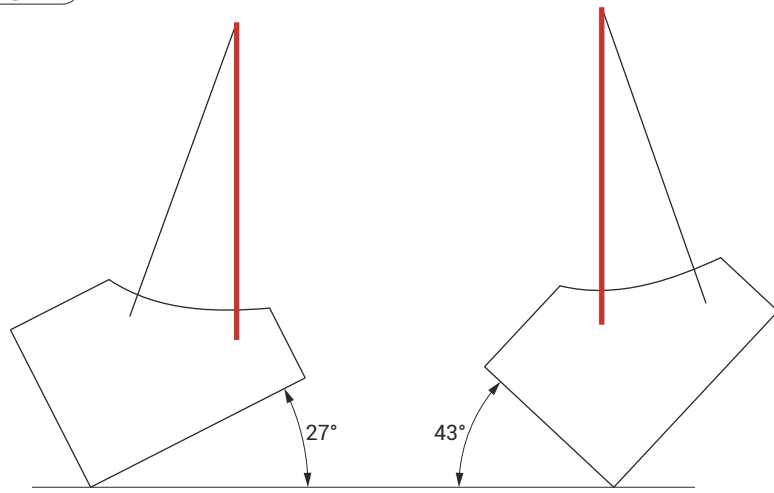
a cylinder found in the form of a mini bin. They are perfectly proportioned for this use and made in stainless. These come in a variety of graduated sizes as well. I chose items with a flat lid although domes were also available. Aesthetically and practically a dome lid did not seem as appropriate. The body was a straight cylinder, not tapered. As these were inexpensive, I purchased two which allowed me to have the same pan shaped closure at both ends.

Three legs were formed out of 1/2 inch / 12.7mm aluminium plate. The front right leg, which also functions as a part of the door hinge was the same shape, but 30mm thick. The manufacture of the legs was done on the mill. It was good practice in learning to cut precise arcs, as the arcs need to be spot on if they are to fit the curvature of the body. I used a DRO arc function on my mill, photo 4, but these could be made by hand methods as well.

The legs are held on by M5 pan head screws. The tapped holes in the legs need to be drilled perpendicular to the body of the oven. Mounting them on an angle block for drilling makes this easy. The correct drilling angles are shown in **fig. 2**, while **fig. 3** shows other details of the construction.

Location points for the legs on the body were marked by making M5 x 10 long 'transfer pins', **photo 5**, with sharp points

Fig.2



Drilling angles for the leg attachment holes

turned at one end. It was easy to use these to mark the position of the leg screw holes, **photo 6**. The legs are shown in **photo 7**.

The heating element is a ready-made unit. As a type, they go by the name of 'infrared emitters' and are made by several manufacturers. They come in a variety of shapes, sizes and wattages. They are

generally used in (sometimes vast) arrays for process heating such as plastic sheet heating in vacuum forming. The heater chosen here was only 200 watts in power, but as the heated volume of the oven is less than 1000cc it is more than ample. A high-power heater would be uncontrollable and cause vast swings of temperature as it cycled on and off. The upper temperature of these heaters is limited by the melting point of the ceramic glaze which encases the element. This heater has an upper temperature use of 750° C/1,382° F. I chose a trough shaped element which would fit the curvature of the oven, **photo 8**. The manufacturer of this element is Ceramicx, County Cork Ireland. The web address is Ceramicx.com. Their technical department

9



The modified heater retaining clips

10



The ceramic connection block and ground connection



Insulation for the front door.



Using a nibbler to cut the top hole.



Body Clips are pressed in a simple jig.

kind of tool is quite remarkable, and I was able to shape holes much better than by using a grinding point or Dremel style burr.

The back endplate is quite simple to attach. I formed simple clips which would fit over the rolled edges of both the body and end plate, **photo 13**. M5 screws held the clips in place. As there is no stress on the back plate, three clips were sufficient, **photo 14**. Do attach the rear plate before lining the oven with insulation. It is almost impossible to do with the blanket in place.

The thermocouple is a high temperature K type, purchased from Thermomart. It comes with its own ceramic holder and can be bolted straight on to the end plate. The mounting hole must be large enough so that the two conductors of the thermocouple do not short out on the oven back plate.

The front handle is formed from 20 x 25mm angle. This is attached to the front panel with two M5 x 10 CSK screws. Originally, I was going to add a wood section for grasping, but I have found it does not get hot and an insulator is not necessary. The handle and door assembly is attached to the brass sliding bearing with one M6 x 12 CSK screw.

I have not included a microswitch to turn

was very helpful in selecting the correct heater for this application. They also supply appropriate junction blocks, wiring and clips as well.

The element comes with mounting clips. I modified them so the standoff from the inside surface of the cylinder was 25mm, the same as the blanket thickness, **photo 9**. The tails from the element pass through the cylinder wall and are held in place by an insulation board spacer. The beaded tails are then connected to a ceramic connection block, **photo 10**. The element itself has no provision for grounding. However, the ground connection of the oven cylinder is connected to the ground wire of the main electrical connection.

The insulation I used is a Ceramic Fibre Insulation Blanket, often used in kilns or ovens, **photo 11**. It is useful up to 1260°C. Ceramic fibre is a man-made mineral fibre consisting mainly of alumina and silica. The actual blanket is firm and somewhat rigid. It can be cut with scissors. Breathing the fibre dust is probably not good for you. Pottery, Kiln and Ceramic materials suppliers often stock this by the roll or sheet. This material I used was 25mm thick.

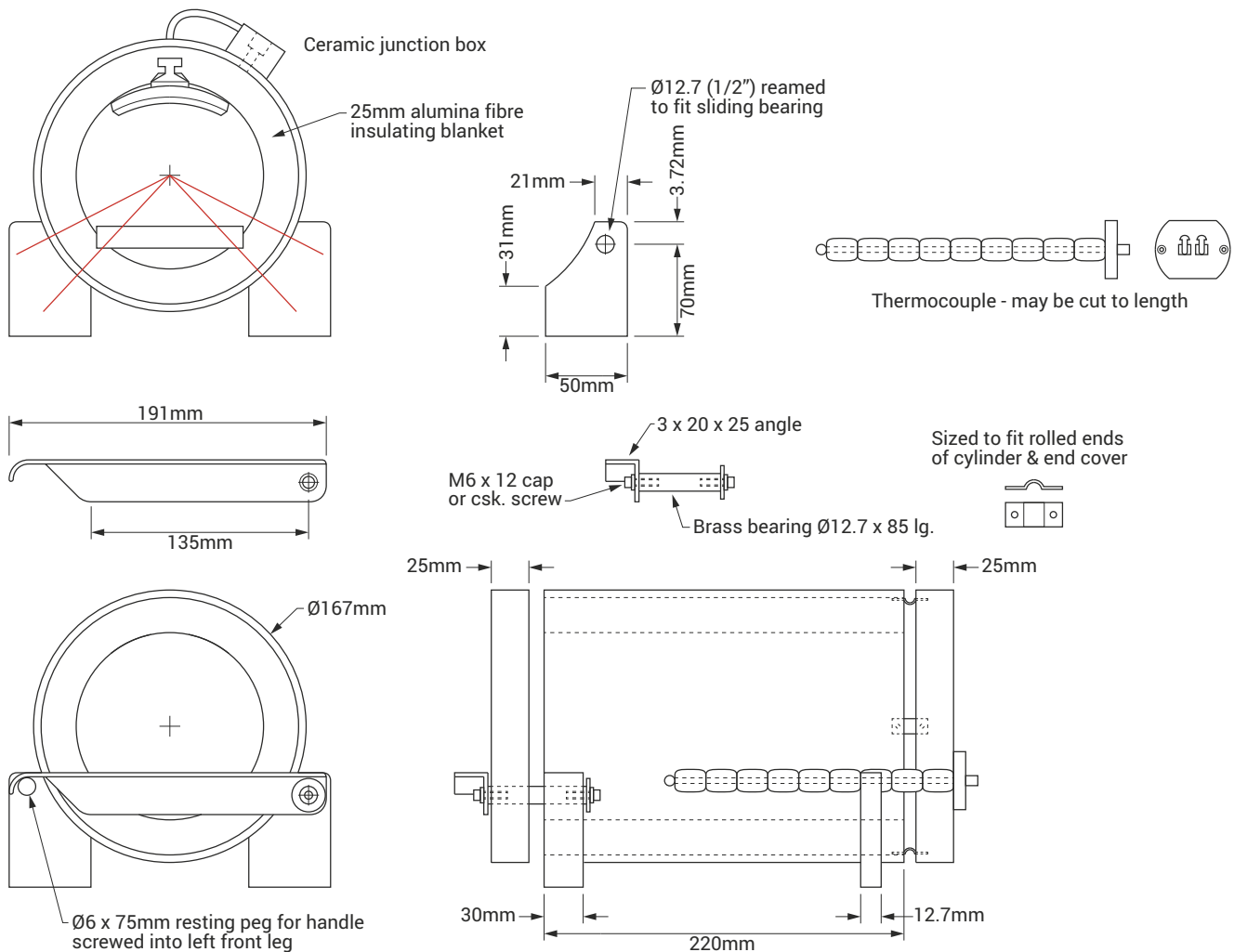
Secondary parts and processes:

Cutting stainless steel holes is difficult. The metal is thin and tough. Filing holes to shape does not work very well. The clearance slot for the heating element was made using a sheet metal nibbler, **photo 12**. The amount of control possible with this



Clips are held in place with screws or self-tappers.

Fig.3



off the power when the door is opened, as the element is completely enclosed. However, if you wish to add one, it could best be fitted at the left end of the door handle, and would cut the power when the handle is lifted. A microswitch only needs to handle the 200 watts in this small sized oven.

At times a long piece of work may need to be inserted in the oven. A 10mm hole in the back panel will enable this. When checking lower operating temperatures, a spirit thermometer can be inserted at this point as well.

I have found this to be a surprisingly useful workshop appliance. Curing adhesives and coatings particularly in the winter time is now more efficient even when the shop can be quite cold. A digital temperature controller ensures that no damage or weakness is caused by overheating, **photo 15**. Precise tempering of small parts is now an easy operation. If you use the oven with such a controller, gentle curing of adhesives and coatings and perfect tempering is an easy task. ■



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Making Holes on a Pitch Circle



For those who don't have a dividing head or rotary table, Peter Worden describes an alternative jig-based approach.



The pulleys before lightening

Whilst building my latest project I had the need to lighten a couple of pulleys, **photos 1** and **2**. The technique that I used is one I came across at the place I worked when I first left school, many years ago. The idea is to bore a number of holes equally spaced on a PCD (Pitch Circle Diameter) on a lathe.

The first thing that is needed is a fixture to hold the component in the correct position to bore each hole in turn, **figs 1** and **2**. The diameter of the fixture is unimportant but must be big enough to accommodate the fixing and locating points. The fixture is held in a chuck on the lathe.

Point 'A' is the pin that the centre of the component locates on. Any system of location can be used providing the component can be rotated. Point 'B' is on the lathe spindle axis and is where each hole is bored in turn and is the same diameter as the holes to be bored. When



After lightening



each hole is bored the component is rotated on Point 'A' so that a peg, which is the same diameter as the hole to be bored, can be inserted to line it up with the same diameter recess at point 'C'. The sequence of operations is as follows:

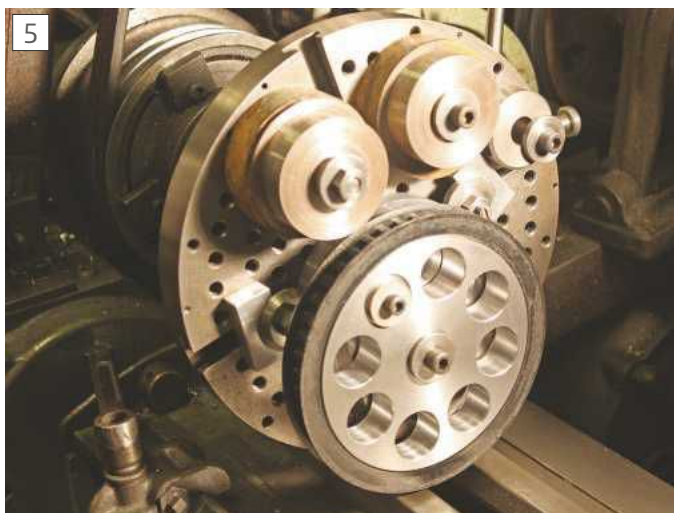
- Load the component to the fixture and tighten the nut, **step 1**.
- Bore the first hole using the locating peg as a gauge, **step 2**.
- Loosen the nut and rotate the component until the peg locates in the recess at point 'C'. Tighten the nut, **step 3**.



The fixture



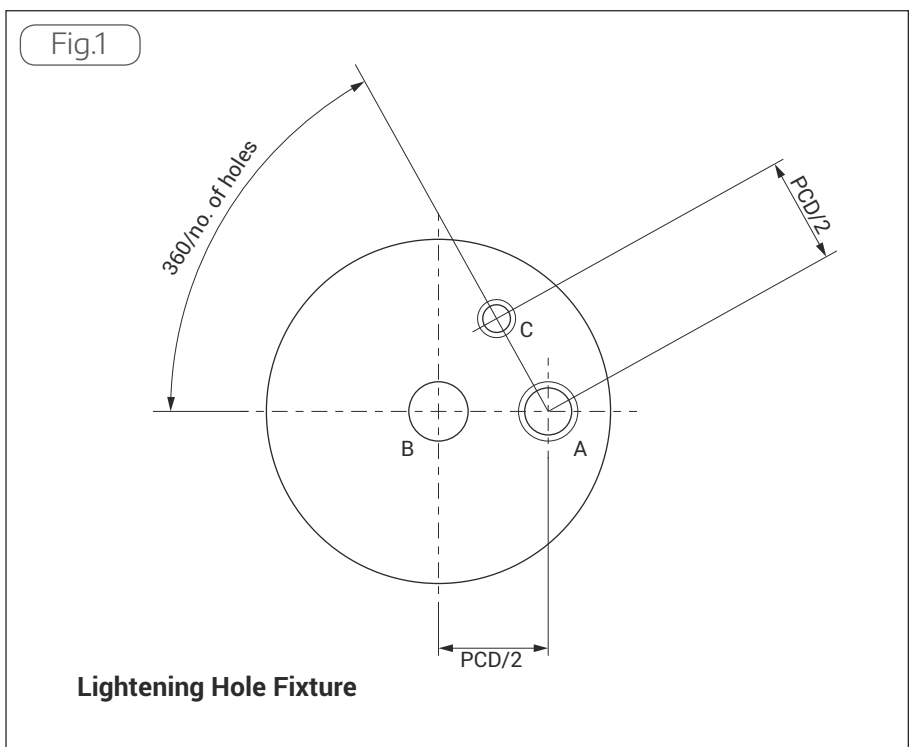
The fixture fixed to the faceplate with balance weights



With the pulley attached

- Bore the second hole and rotate and locate as before **steps 4 and 5**.
- Repeat until all the holes have been bored **steps 6 and 7**.

The fixture I made for my purpose was designed to accommodate both pulleys **photo 3**. The smaller pulley had holes of $\frac{3}{4}$ " diameter, and the larger one had $\frac{7}{8}$ " diameter holes. The two corresponding locating pegs can be seen in front of the fixture. The fixture was clamped to a faceplate on the lathe photo 12. The two round objects in **photo 4** were brass blanks found in the scrap box and were necessary as counterbalance weights as the fixture plus a pulley were considerably off centre, as can be seen in **photo 5**. It was still advisable to run the lathe at a slower than maximum speed to avoid it walking around the workshop. ■



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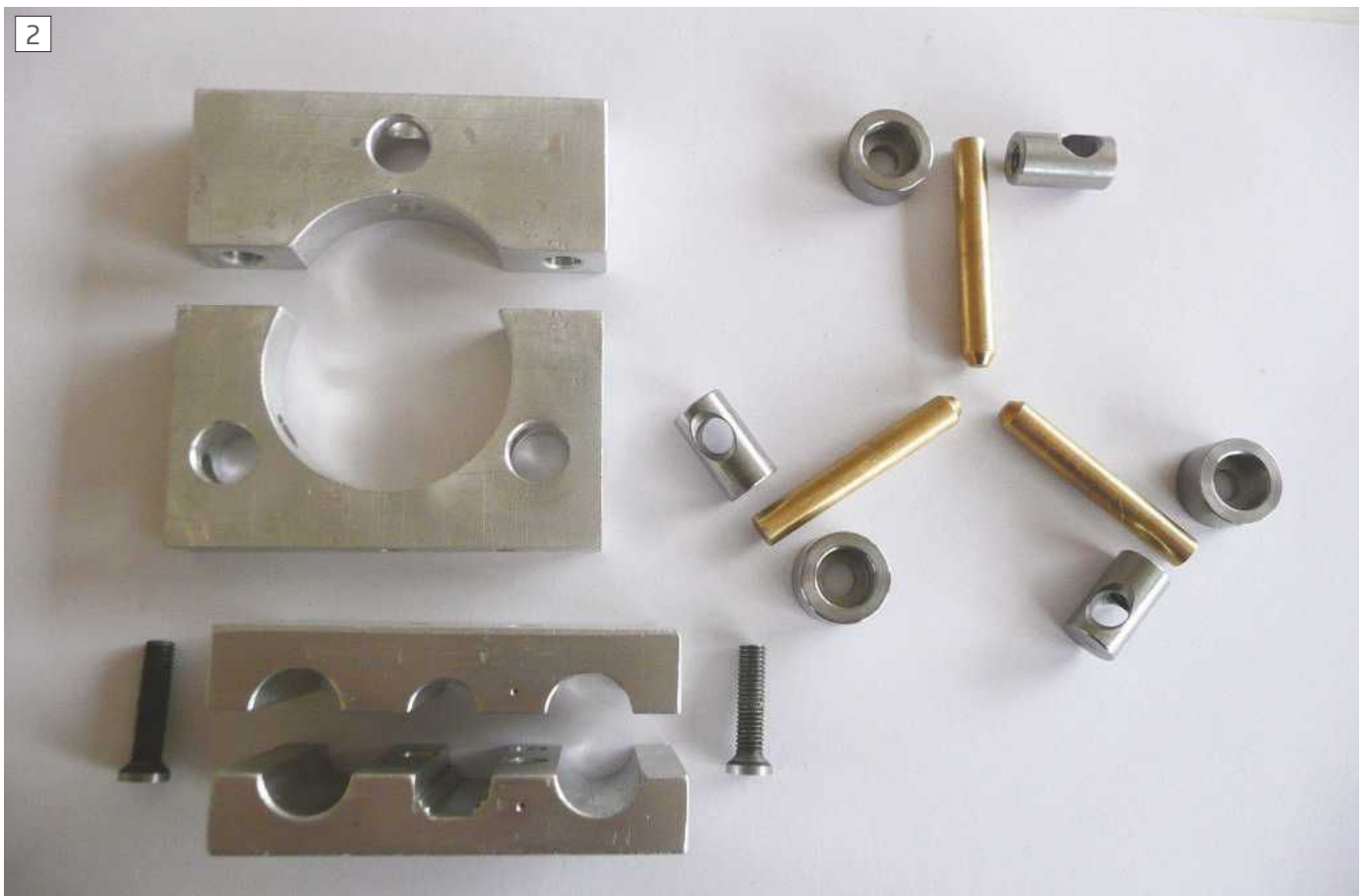


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Components of the steady

Marking Out and Drilling Jaw Holes

With the datum centre point spot drilled, as described in the previous issue, the location of all 10mm Dia. and $\frac{1}{4}$ " Dia. holes and all centre lines are set out from this datum point all as **fig. 5**. At this stage the datum point was drilled to 6mm Dia. only, the 40mm Dia. hole was bored on the Myford lathe later.

Accuracy is needed when aligning the centre lines of the 6mm and 10mm Dia. holes as viewed from the front elevation of the bracket in **fig. 5**. Any inaccuracy will prevent the jaws (5) finding their holes in the jaw holders (6). Accuracy in aligning

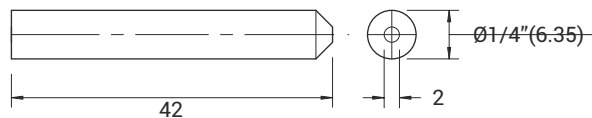
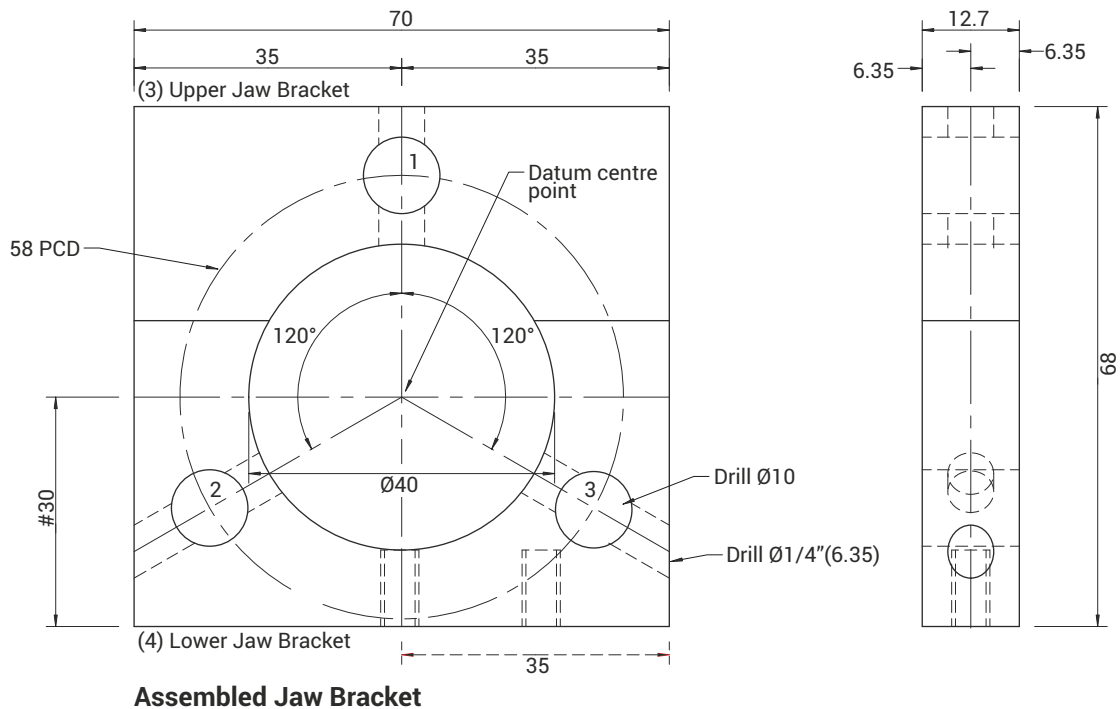
the centre lines as viewed from the end elevation is not so critical and would only result in the jaw holders not protruding from the bracket as intended – only large in-accuracy would prevent locking of jaw and holder by the retainer (7) and retaining screw (8) when finally assembled as **fig. 8**. To ensure this accuracy when drilling, the assembled jaw bracket was attached to a swivelling cross-slide assembly which positioned the datum centre point at Myford spindle level and enabled the $\frac{1}{4}$ " and 10mm holes to be drilled at common centre lines

The cross-slide assembly used for mounting and drilling the prototype rest

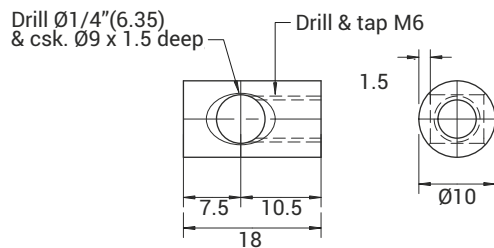
was an improvised assembly of old cast iron angle plate and scrap box bits and pieces – not to be repeated!

Figure 6 shows the elements of a simplified assembly for this article. The angle plate (10) is imagined as a plain commercially available angle plate and showing only those holes and tapping's necessary for the cross-slide assembly, shown at (A) and (B), to perform as intended. The 6mm Dia. hole for the locating bolt can be drilled in the angle plate (10), but the corresponding holes in the base plate (9), indicated in **fig. 6**, will be carried out later. The #41mm height shown for the M6 pivot bolt tapping in

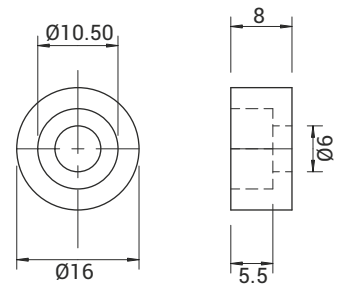
Fig.5



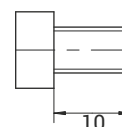
(5) Jaws
Mat'l: Brass, 3 off



(6) Jaw Holder
Mat'l: Brass, 3 off



(7) Jaw Retainer
Mat'l: BMS, 3 off



(8) Retaining Screw
Mat'l: M6 socket screw, 3 off

Fixed Steady - Jaw Locations

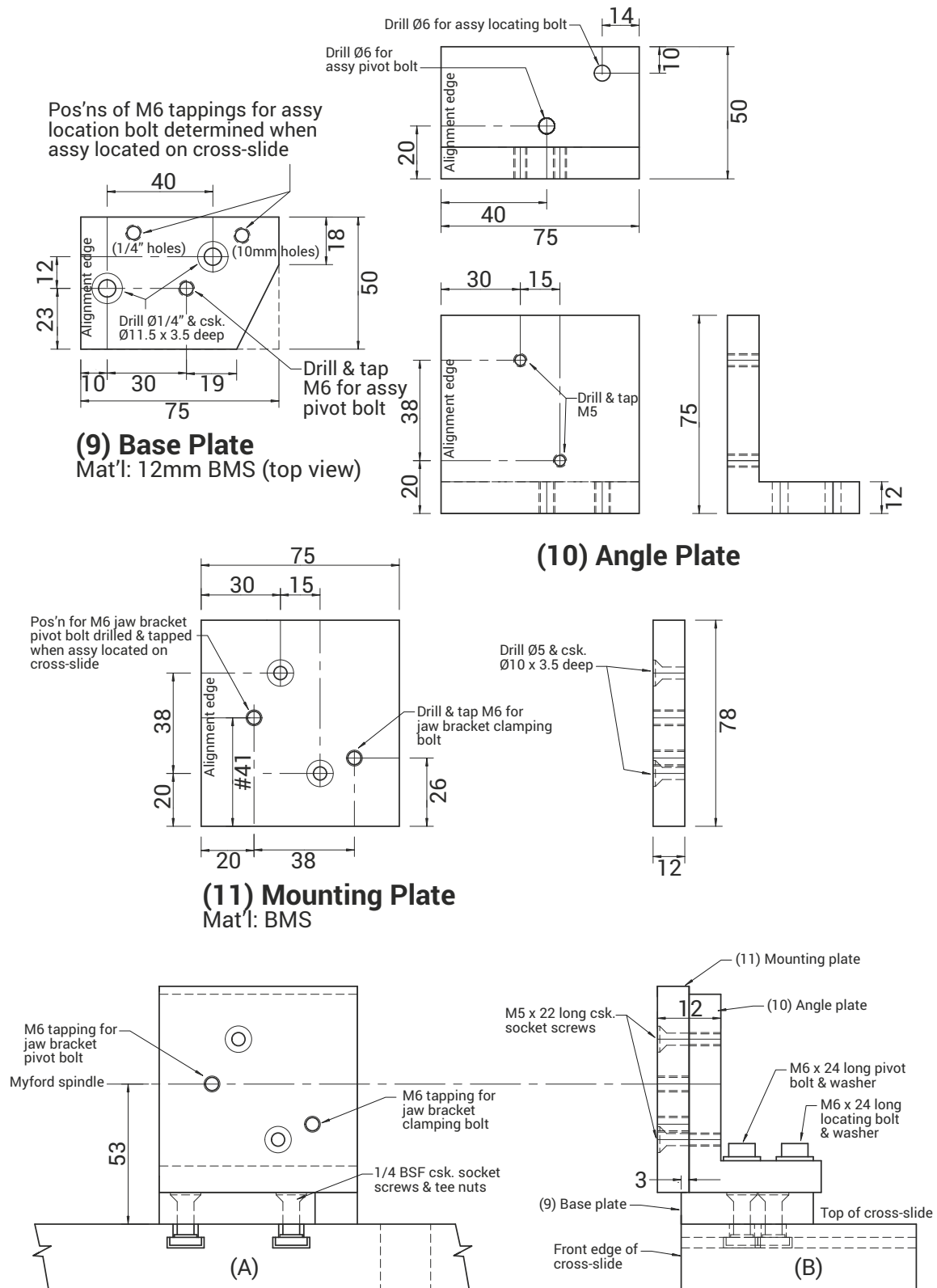
the mounting plate (11) is indicative only and the drilling and tapping for this bolt should be carried out later as below. Base, angle and mounting plates were now assembled as follows. The base plate was clamped to the cross slide with countersunk screws and tee nuts with one side flush with headstock side of the cross-slide as indicated at (B) in fig. 6 and (D) in **fig. 7**. The Myford tee nuts were

used with some 1/4" BSF countersunk screws from the scrap box. The angle plate was next located over and clamped to the base plate, with the pivot bolt and large washer, with the angled edge of the plate parallel to, but inset 3mm from the base plate, again as (B) in fig. 6 and (D) in fig. 7. The vertical face of the angle plate should now be perpendicular to the lathe spindle axis and the indicated alignment

faces of all three components should be flush and parallel to the spindle axis as indicated at (D). If able to vertically drill above the cross-slide now is the time to spot drill through the locating bolt hole in the angle plate to locate corresponding hole in the base plate, as noted in (D) for drilling 10mm Dia. holes.

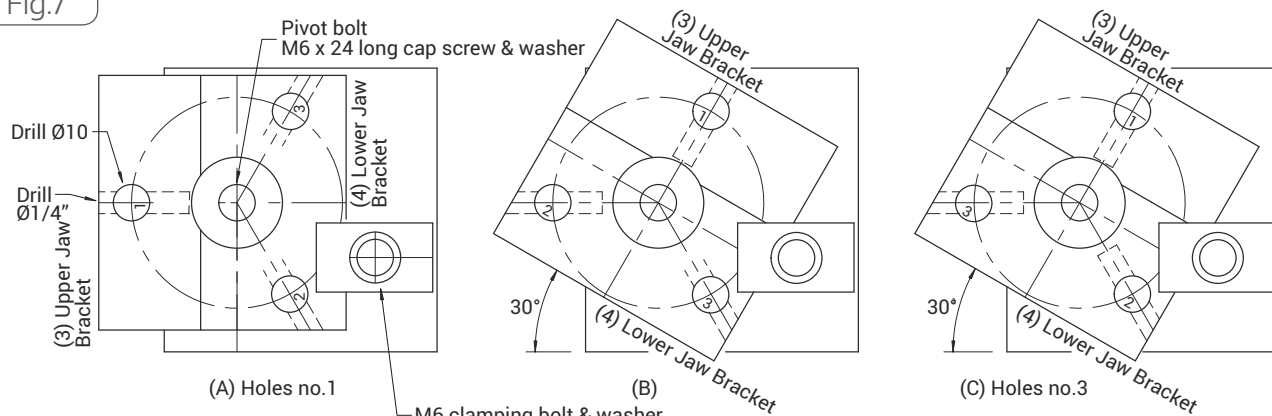
With the pivot bolt loosened, the angle plate rotated 90 degrees anti-clockwise

Fig.6

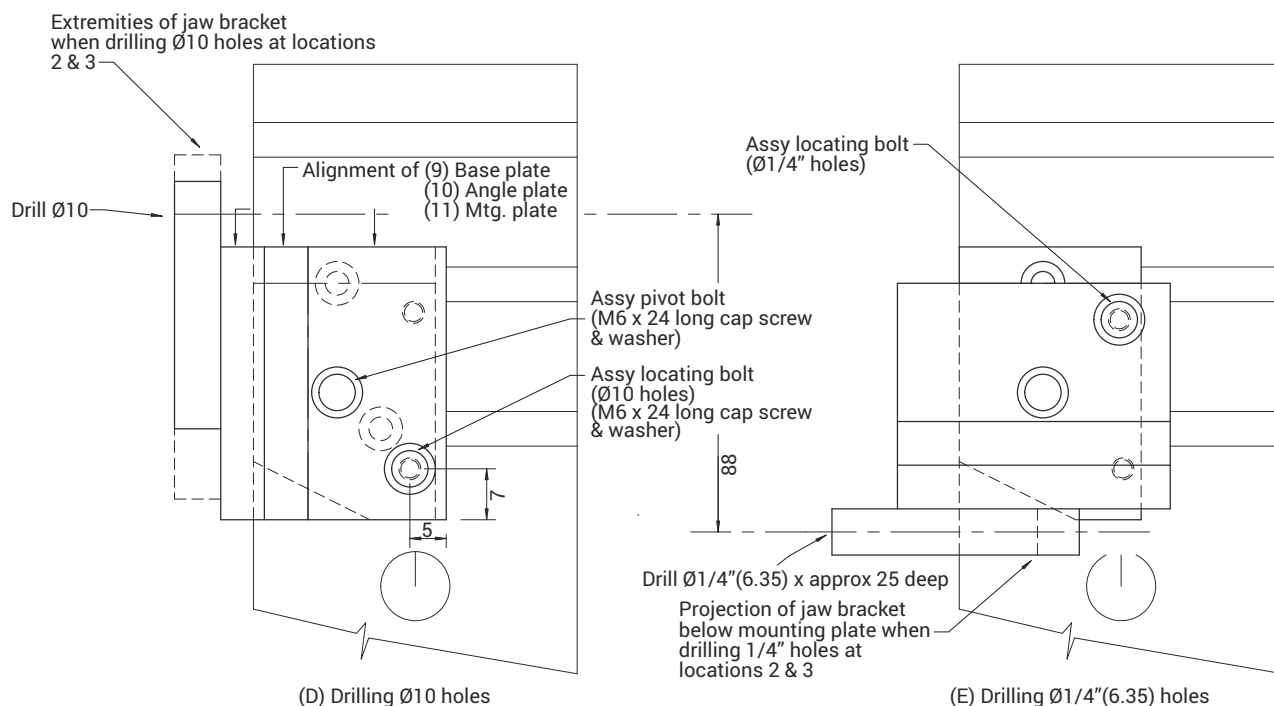


Cross-slide Assembly Fro Drilling Jaw Holes

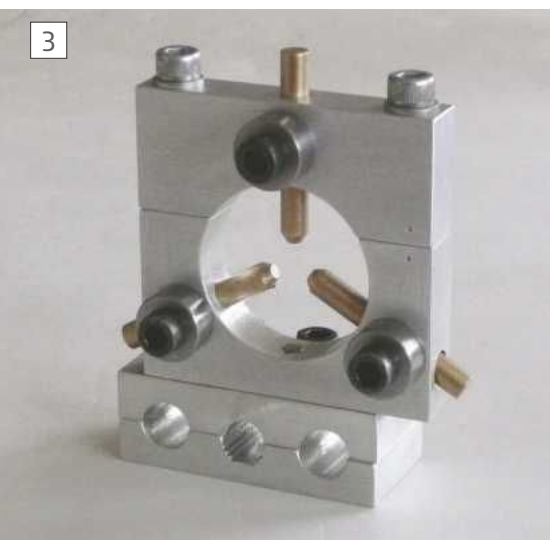
Fig.7



Locations Of Assembled Jaw Bracket On Mounting Plate



Rotation Of Assembly For Drilling Jaw Holes



Rear view of the assembled steady

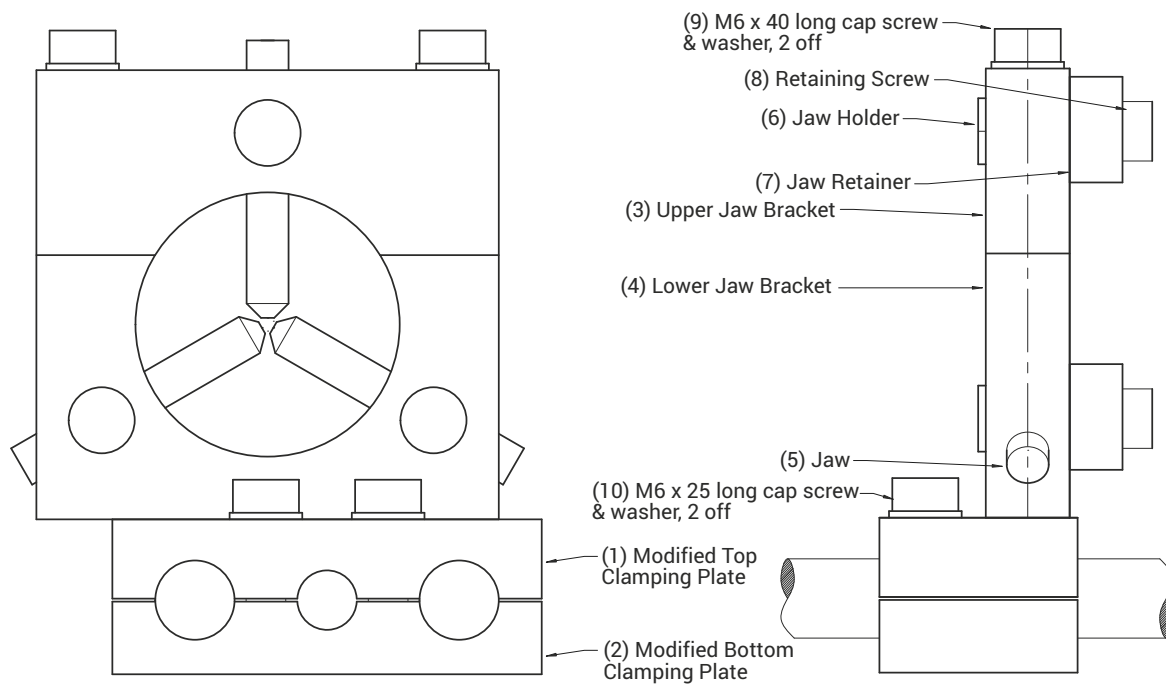
(By set square and faceplate) and bolt re-tightened, the second locating bolt position, as noted in E for drilling $\frac{1}{4}$ " Dia. holes, can be spot drilled in the base plate. Using a separate drill press for the prototype meant moving from lathe to press between each alignment. The base plate should then be removed and both locating bolt holes drilled and tapped M6. With base and angle plates re-assembled as (D) in fig. 7, the pivot and location bolts tightened, the mounting plate (11) is then bolted to the angle plate as (A) and (B) in fig. 6. Using the cross-slide to align the vertical centre line of the mounting plate pivot bolt, this hole can now be drilled and tapped.

The jaw bracket is next bolted and clamped to the mounting plate for drilling at each of the three pairs of hole locations as shown at (A), (B) and (C) in

fig. 7. The jaw bracket is turned front to rear when mounted for drilling holes at No. 3 position, as the hole numbering sequence will indicate. If after drilling at No. 2 position the bracket is simply rotated to No. 3 position (as originally intended) the bottom of the jaw bracket will obscure the tapping in the mounting plate for the clamping bolt! A suitable type and size of clamp will be self-evident, its main purpose being to prevent rotation of the jaw bracket around the tightened pivot bolt when drilling.

For each jaw bracket mounting in turn, as (A), (B) and (C) in fig. 7, the angle bracket is first rotated as (D), both pivot and location bolts tightened, and the cross-slide wound to align the 10mm Dia. hole centre line with the spindle and the hole drilled. For drilling the $\frac{1}{4}$ " Dia. holes, the angle bracket is next rotated as (E), both

Fig.8



Fixed Steady Final Assembly

bolts tightened, the cross-slide wound as necessary to align the spindle and hole centrelines and hole drilled to the depth shown. With the base plate clamping bolts and tee nuts located as shown in the first and second cross-slide tee slots to the rear of the top-slide spigot hole, as shown in fig. 7, the cross-slide travel necessary between (D) and (E) positions is within the 5" (125mm) or so maximum travel possible with the Myford ML7 standard cross-slide.

With all holes drilled, the assembled jaw bracket was centred in a four jaw chuck, around the previously drilled 6mm Dia. hole at datum centre and the hole drilled and bored to 40mm Dia. as **fig. 9**. Finally, the jaws (5), jaw holders (6), jaw retainers (7) and retaining screws (8) were fabricated as fig. 5 and all components assembled as **fig. 8**. **Photograph 2** shows the separate components and **photo 3** a rear view of the assembled steady..

The jaw holders in both fig. 8 and Photo 3 are shown inserted from the tailstock face of the rest but all can be inserted from the headstock face and **photo 4** shows the steady set up on the Unimat for facing and turning the end of a long component, with the lower jaw holder reversed to the headstock face to give additional clearance for the toolpost and cutting tool if needed. In this position, however, the jaw holder and retainers obstruct key access to the rest clamping cap screw nearest the operator (perhaps I should change it to a

hexagon headed bolt?).

For this example, the rest was initially clamped close to the chuck and the upper and furthestmost jaws clamped in contact with the mounted workpiece. The rest was then finally re-clamped near the furthestmost end of the workpiece, the remaining jaw brought into contact and clamped, at the same time rotating the workpiece by hand to ensure all jaws are simultaneously remaining in contact. Not potentially as accurate as setting all jaws

at the same time but adequate for my purposes. Also visible in photos 2 and 3 is the end milling needed for leadscrew clearance in the bottom plate, not foreseen when originally machining these clamping plates.

The tailstock raising block can be used if needing the fixed steady with raised headstock. In the unlikely event of needing both tailstock and rest at high level, another raising block will be needed! ■



The assembled steady fitted to the lathe

On the Wire **NEWS** from the World of Hobby Engineering

“Best Polly” prize awarded at SMEE AGM



Mike Chrisp (left) awards Stephen Hall the Polly trophy at the SMEE AGM in March 2018. (Photo courtesy of Richard Dedman)

Stephen Hall was awarded his prize for the best Polly model at SMEE's recent AGM. The winner was decided by course participants at SMEE's Christmas social.

The Polly course “Building a simple steam engine” takes beginners through construction of a simple oscillating steam engine and boiler to the design of T.D. Walshaw, “Tubal Cain”. The 2018 course restarts on 12th May.

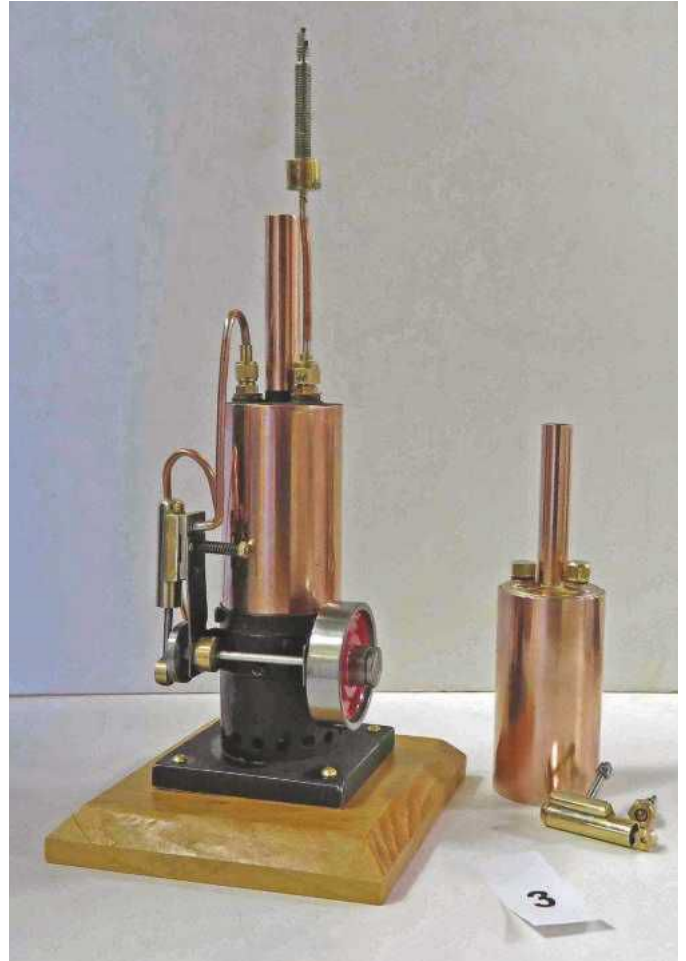
Now in its 13th year over 120 budding engineers have enjoyed the course. Most have gone on to build larger and more complex engines and gained valuable engineering skills.

Stephen is a semi retired chemical engineer who worked in the oil industry.

He said “I wanted to start making things and the Polly course seemed a good practical start. Although it was challenging to do new things it was all interesting”. He is now building a Gauge 1 steam locomotive.

Stephen praised the quality of teaching on the course. “The volunteer teachers are excellent demonstrators” he says. “They show a variety of metal working techniques including making small boilers using silver brazing, sheet metal work using soft soldering, safe use of hand tools to cut metal, turning parts using a lathe, drilling and shaping parts using a milling machine”.

Students then make parts in their own workshops in time for the next session. They enjoy the support of an active online community to help members solve any problems that may emerge



Stephen Hall's winning Polly model with spare boiler. (Photo courtesy of Mike Chrisp)

in their model engineering.

The Polly course is open to all. SMEE also runs courses on milling and grinding (the latter for members only).

Organiser Allen Berman is a keen model engineer who recently restored the late Ian Bradley's workshop engine shown on the SMEE stand at the London Model Engineering Exhibition. He says SMEE courses demonstrate basic metal work techniques now rarely taught in schools or evening classes.

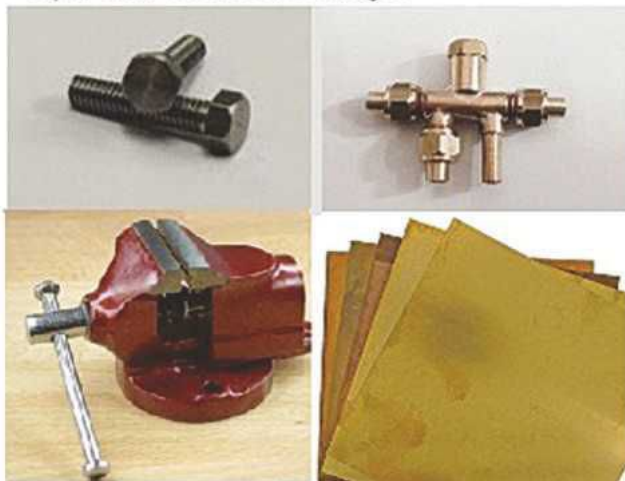
Further information on the SMEE website www.sm-ee.co.uk or write to SMEE Courses organiser courses@sm-ee.co.uk



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Mike's WORKSHOP



A bandsaw blade lubricator

This month Mike describes a simple coolant system that could be adapted for lathe use.

My bandsaw is a fairly standard Asian 6 x 4 version that was supplied by Axminster several years ago. It gets used frequently - mostly to cut mild steel and aluminium. Some users have built continuous flow flood coolant systems for these bandsaws but the down side to this is that there must inevitably be some run off and mess with coolant. Flood cooling is only really necessary when heat can build up rapidly at the cutting tool tip, such as when taking a heavy cut with a lathe tool or milling cutter. In a bandsaw most of the blade is not cutting at any given time so it has plenty of opportunity to cool down. Flood cooling does have some benefits in flushing cutting debris away, especially in milling processes, but in bandsawing most of the debris is carried along in the teeth and can only be released once the blade emerges from the cut. However, lubrication of the blade and the work is important and in the past, I have used a brush to supply mineral oil when cutting mild steel and kerosene when cutting aluminium.

Lubrication increases the cutting rate, reduces the load on the motor, lengthens the life of the blade, improves the finish of the cut surfaces and in the case of aluminium prevents the blade jamming. This latter problem with aluminium is not severe for most aluminium bar stock but when sawing aluminium castings it can be a real nuisance. Once the blade jams then almost inevitably the blade will come off the drive pulley.

Using a brush to supply oil/kerosene to the blade is a little tedious because it must be applied little and often to be effective. I came across this simple modification, by Mike Levy, to the bandsaw at youtu.be/N-ZkI8EqhzE, to provide a continuous small flow of oil to the blade and I decided that this might provide a better solution. The device consisted of a small bottle containing lubricant with a small valve to



The first experimental lubricator block.

control the flow. The lubricant flowed down a flexible rubber tube with a slit in the end that straddled the bandsaw blade.

First experiments

In order to test the idea, I made a very

simple arrangement consisting of a 250ml plastic water bottle and a length of rubber tube. The cap of the bottle was drilled out 6mm and a brass connector made to allow the rubber tube to connect with the bottle. I did not like the idea of a slit in the tube to apply the oil to the blade and a made a small steel block, **photo 1**, with a slit in one end which was 1mm wide and 10mm deep. The other end of the block was drilled out 5mm to connect with the slit and then tapped M6. A length of M6 studding was turned down to 5mm diameter for 20mm and then cut off to give a total length of 30mm. The 10mm threaded portion was screwed into the block with some PTFE around the threads to make a seal. The block was attached to the rubber tube and the block slipped over the bandsaw blade and attached to the blade guide using a 12mm diameter 3mm thick neodymium magnet. The magnet is visible in photo 1. The bottle was filled with 20w50 motor oil and the first tests were made with the bottle hand held over the saw while cutting some 10 x 20mm hot rolled stock. This test worked very well, and a thin film of oil coated the bandsaw blade when the machine was running. I went on to make a crude support for the bottle from a length of 3 x 12 hot rolled strip, **photo 2**. The bottle



was attached to the strip using two rubber O-rings. The strip was also bent, as shown in the photograph, so that when the band saw arm was in the upright position then the oil could not flow out of the bottle.

This system was very easy to make, and it works very well when cutting steel. It does have some draw backs though. Firstly, if the bandsaw arm was inadvertently left in the down position then the oil would slowly leak from the bottle creating an oily mess under the block. A second problem was if the saw was used for a long period of time the flow of oil would eventually stop since there was no way for air to enter the bottle to replace the oil flowing out. This can be cured fairly easily by lifting the saw to the vertical position so that air enters the bottle and then when returned to the horizontal position the flow re-starts. The final problem was that attempts to use the system with low viscosity fluids such as kerosene resulted in too much flow.

What was really needed was a system to control the flow better.

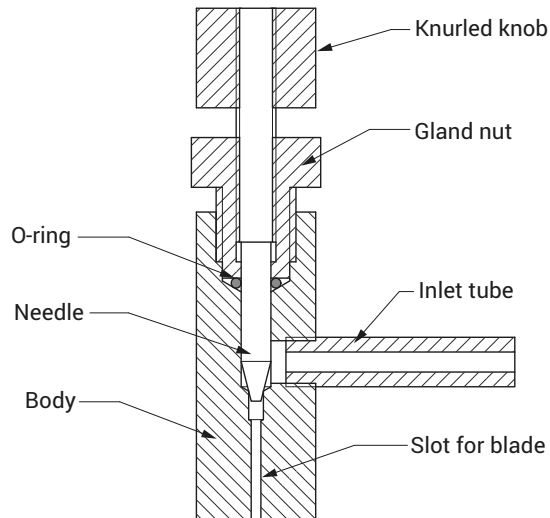
The second version.

The first option was to obtain a small valve to control the flow. Mike Levy had used a small valve intended for aquarium use in his version in the youtube video. I toured several aquaria supplies shops and could find nothing suitable. However, on ebay there were plenty of suppliers of air control valves for aquarium use including some that looked robustly made in metal. These were quarter turn stopcocks that would provide a coarse flow adjustment. These were very cheap, and I ordered two from China at a cost of about £1. However, the delivery time was quite long.

Whilst waiting for these valves to arrive I started thinking about actually incorporating a valve into the metal block that fitted over the saw blade. The advantage of doing this is that using a needle valve type of construction then the flow can be accurately controlled. The quarter turn valve from China could then be used as a simple on/off valve.

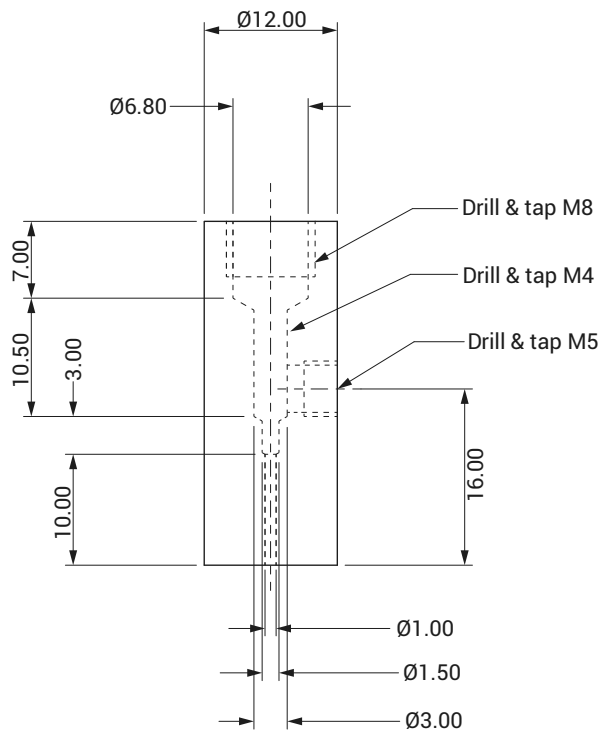
A cross sectional drawing of the lubricator block incorporating a valve is shown in **fig. 1**. It consists of four components: the body, the gland nut, an

Fig.1



Cross Section Through The Valve

Fig.2



Body

O-ring and the needle.

The body, **fig. 2**, was made from a piece of 12mm square steel. A 31mm length was cut off on the bandsaw and the centre of one end found use odd leg callipers. The centre of the end was marked accurately using a centre punch. The piece was then set up in the four-jaw chuck on the lathe with the centre on axis, centre drilled and drilled out 1.5mm for a length of 21mm. It

was then drilled out 3mm for a depth of 17.5mm followed by 6.8mm for a depth of 7mm. With an M8 tap in the tailstock the chuck was rotated by hand until it had started to cut a thread. The end was then faced off. The piece was inverted in the chuck and the other end faced off. The final length should be 30.5mm.

Using odd leg callipers one side of the body was marked out 16mm up from the

This system was very easy to make, and it works very well when cutting steel. It does have some drawbacks though.

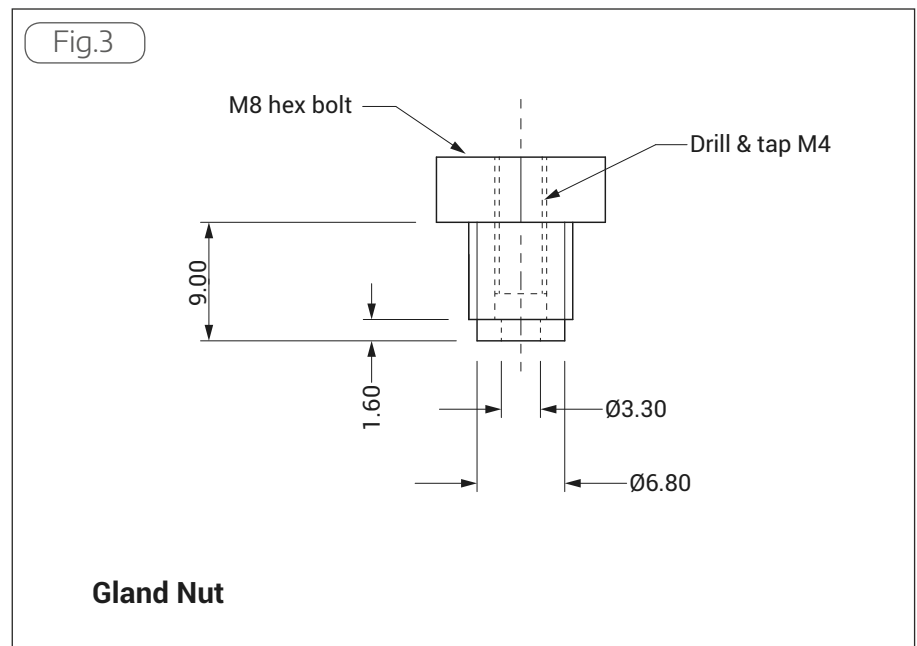
un-drilled face and 6mm from both edges. The position was marked with a centre punch dot.

The body was mounted on parallels in the milling vice with the centre punch mark on the top. The mill was set up with a 63mm diameter x 1mm slitting saw mounted on an arbor. This was lowered until the saw just touched the top face and the z axis was zeroed. The piece was moved away from the saw and the saw lowered by a further 6.5mm. This centres the saw in the middle of the piece. A slot was then cut in the un-drilled end of the piece to a depth of 10mm. The final operation in the mill was drill and tap the hole for the inlet tube. The slitting saw was replaced with the drill chuck and with a fine centre drill the centre punch mark was located and centre drilled. The centre drill was replaced with a 4.3mm drill and drilled to a depth of 6mm. Finally, a M5 tap was mounted in the drill chuck and the chuck rotated by hand until the tap was started in the hole.

With the body mounted in the bench vice the two threaded holes were cut using taper, second and bottom taps.

The inlet tube was just a 24mm length of steel 5mm diameter that was drilled through with a 2.5mm drill in the lathe. The end of the tube was faced, chamfered and then threaded M5 for a length of 4mm. The inlet tube thread was wrapped in PTFE tape and screwed into the body.

The gland nut, **fig. 3**, was made from a M8 x 20 hex head screw. An M8 nut was screwed onto the end of the screw and the assembly was mounted in the three-jaw chuck with the screw head toward the tailstock. The screw was centre drilled and then drilled through with a 3.3mm drill to a depth of 16mm. The screw was



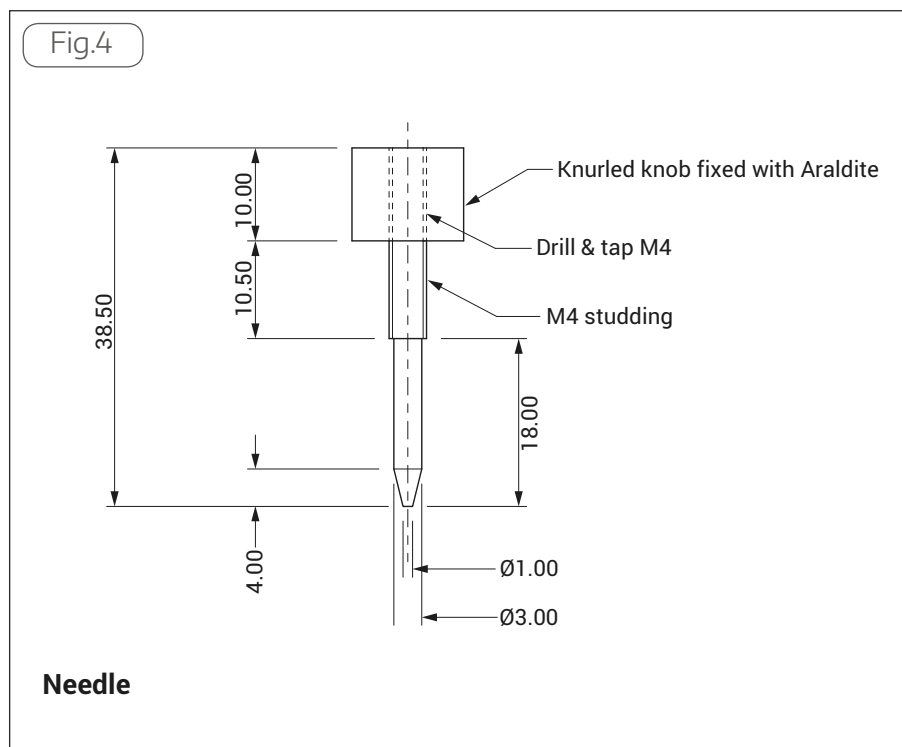
removed from the chuck and gripped at the threaded end in the chuck. The head end was supported with a rotating centre. Using a knife tool, the threads were removed from a section 7.4mm from the head to 11mm from the head. A groove was then cut with a parting tool starting at 9mm from the head. The groove was cut to a depth of 1mm. The screw was removed from the lathe and cut using a junior hacksaw at the groove position. The screw was not parted off on the lathe because parting off with one end supported in a centre can lead to jamming as the two parts separate. The screw was then returned to the lathe, with the head towards the chuck, whilst supported on a 3.3mm drill, running through the centre,

held in the tailstock chuck. The lathe chuck was then tightened onto the hex head. The 3.3mm drill was replaced by a small centre drill and any rough sawn edges were removed to leave a small conical lead-in to the hole. The screw was removed from the lathe, held in the bench vice, and tapped M4 from the head side. The tapping should be done using taper, second and bottom taps until the pointed tip of each tap just protrudes from the bottom of the screw.

The needle, **fig. 4**, was made from a short length of M4 studding. The studding was chucked in the lathe with 7mm protruding from the chuck. The cross slide was set over at 20 degrees from parallel with the lathe axis. Using a sharp tool, the tip of the studding was turned to produce a blunt point about 1mm across. The studding was extended from the chuck to 19mm and the tip supported in a rotating centre. Using a sharp tool and light cuts the stud was turned down to produce a parallel section, without threads, 3mm in diameter. The exact diameter is not critical as long as it is less than 3.3mm.

The knob for the needle was made separately from a 12mm round bar. This was faced at one end, knurled for a distance of 13mm, and drilled out 3.3mm for a distance of 12mm. A M5 tap held in the tailstock chuck was started in the hole, the end was chamfered and the knurled end parted off 10mm from the end. The parted off piece was held in the bench vice and tapped right through M4.

The knob was screwed on to the needle by passing the parted off face of the knob over the point of the needle and then turning the needle until there was 10.5mm of thread exposed. The studding was then cut off flush with the parted off face of the knob using a junior hacksaw. The knob was unscrewed from the needle and the cut end of the needle cleaned up





with a file. Both were degreased in lighter fluid before smearing the hole in the knob and the cut tip of the needle with a little Araldite adhesive. The knob was screwed onto the end of the needle with the parted off face outwards. Excess adhesive was removed using a cotton bud soaked in acetone. The assembly was left to set overnight. The following day the threaded end of the assembly was wrapped in two turns of paper and lightly gripped in the lathe chuck. The out faced was lightly faced and then chamfered.

The lubricator block was assembled by screwing the needle into the gland nut until the blunt point has fully emerged. A 3mm ID x 1.5mm O-ring was placed over the needle and the gland nut screwed into the body and tightened down. The needle was then screwed in until it bottomed. The valve may be tested at this stage by

attempting to blow through the inlet tube whilst dripping diluted washing up liquid all over the body. Any foaming indicates a leak. If it passes this test, then open the valve a little and check for airflow through the slot. Once this test has been carried out then the lubricator should be dismantled and all surfaces washed, dried and oiled before reassembly. The assembled lubricator block is shown in **photo 3**.

A new reservoir for the lubricant was made. This was again made from a 250 ml water bottle, but the lubricant outlet was made at the bottom of the bottle rather than in the cap. The base of the bottle has an uneven thickness and it has a thick area in the centre, **photo 4**. This raised thick area tends to make the drill wander so an initial hole of 3mm diameter was drilled through the centre of the base. This was enlarged to 6mm using a drill and then enlarged to

8mm using a needle file to correct any off centre. A 25mm M8 bolt was drilled through 2.5mm and the outside turned down to 5mm diameter for 15mm. This, with a fibre washer under the head, was guided into the hole in the bottle from the inside using a socket spanner and a fibre washer and an M8 nut screwed onto the thread outside the bottle.

The new block and reservoir were connected using rubber tube and the arrangement was tested using both 20w50 motor oil and using kerosene. When the saw was in the down position to cap on the bottle could be loosened to allow air into the top of the bottle. This arrangement was tested extensively during a variety of sawing operations and it gave good control of the flow of lubricant under all conditions. The downside to this arrangement was that it was necessary to turn the valve off to stop the flow of lubricant and also close the bottle cap before moving the saw to the vertical position. Before using the saw again, it was necessary to put it in the horizontal position open the cap and reset the flow which is all a bit of a hassle.

The final version.

The aquarium stopcocks eventually arrived from China. These had an M6 fine thread on one end. An M8 x 13mm bolt was drilled out 3.5mm and at the head end this was enlarged to 5.2mm for a distance of 8mm and then tapped M6 fine. This bolt was fitted through the hole in the plastic bottle from the outside together with fibre washer and a fibre washer and nut then fitted on the inside of the bottle. The aquarium stopcock was then screwed into M5 fine recess using a little PTFE tape to make a good seal. **Photograph 5** shows the bottle outlet arrangement. This modification allows the flow to be interrupted without having to adjust the needle valve.

The bottle cap was modified to allow air



to enter. An M6 x 12 brass hex screw was drilled through 2.5mm in the lathe. A piece of 10mm brass hex bar was drilled out 2.5mm for a depth of 20mm and then out to 5mm for a depth of 8mm. This was then tapped M6. The piece was parted off at 18mm from the end. It was turned around in the chuck and the end reduced to 4.5mm diameter. A 6mm hole was drilled in the bottle cap. The bottle cap had radial ribs on the inside and to ensure a good seal a thick rubber washer (actually a 1/2 " tap washer) was screwed onto the hex screw. This was pushed through the hole in the bottom cap and the tube adaptor screwed on tight.

The final modifications were to tidy up the support for the bottle using a couple of brackets rather than the O-rings used on earlier versions, **photo 6**. The bottom of the bottle was connected to the lubricator block using nitrile rubber tubing, **photo 7**. The top of the bottle was also connected to a nitrile rubber tube that was bent around and passes through a hole in the support, **photo 8**. This bend prevents the oil escaping when the bandsaw arm is in the vertical position.

The nitrile rubber tubing was 3.5mm bore and it is highly resistant to oil. It is readily available and used for fuel lines in the automotive industry. It does not harden like PVC tube when exposed to oils.

The block is still held in position with the 12mm diameter x 3mm neodymium magnet. Initially I was apprehensive about using a magnet for this because I imagined the whole lubricator and the blade guide becoming covered in bits of steel cutting debris. In fact this does not happen.

This lubrication system works very well and is very convenient to use. The quarter turn tap is simply turned on and the band saw arm lowered into the material being cut. At the end of the cut the tap is turned off and the arm raised. I have found that using a 50/50 mix of motor oil and kerosene seems to work well for all common materials (i.e. steel, extruded aluminium, cast aluminium, and zinc diecasting alloys). ■



Scribe a line

YOUR CHANCE TO TALK TO US!

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

Model Engineering Courses

Dear Neil, Just saw Joe Venable's message in scribe a line, might I suggest he looks at Axminster tool company they do courses at two locations, I think its Axminster and Warrington ?

I know nothing of the courses but I have use Axminster for supplies of woodworking tools etc and find them very helpful as a company. Maybe other suppliers do courses? also the SMEE in London (see On the Wire in this issue – Neil).

John Fawcett, Brookhouse, near Lancaster



Strange Vice and Views on Content

Dear Neil, See the following link to the patent for the vice mentioned by Trevor L. Jones.

<https://tinyurl.com/y8p3g7uu> (link is to espace.net)

Can we have fewer tool sharpening articles and more general stuff? I will scream if there is another build for tool sharpening. The flute one was good, and I'd like more on old machine repair (and costs!). Steam engine workshop was very interesting. Bike engineering always interesting. In fact, I would change the magazine title and remove "model" from it!

What about an article on those granite chip techniques in building machine tools? They seem interesting.

Philip, by email

Thanks Philip, and also to Michael Gilligan who sent me a pdf of the patent, they have both been put in touch with Trevor – Neil.



Leather Washers



Dear Neil, I was interested in the article on leather washers in this issue as it took me back to my days working on a steam turbine at a power station in South Wales. The main turbo-generator rotor is raised in its bearings prior to rotating it on a pony motor by high pressure (jacking) oil.

This oil (as I recall over 1000 psi) is introduced into the bearing housing via a probe which was sealed in the housing with - you have guessed - leather washers.

I showed my grandson Jacob my published article, "MEW to the rescue" and he seems to really understand it (see photo taken by his father Jon Pitts who wonders if he is the youngest reader) which is more than can be said for me and I wrote it!

The gremlins seem to have struck photo 7 in the article as the main point of the photo had been cropped off: the stud bar is not shown.

Laurie Leonard, by email

Apologies for the mis-cropped photo, here's the full thing! - Neil



Richard Smith's Toolholders

Dear Neil, just an email to convey my thanks to Richard Smith for his recent clarification in Issue 263 page 45 regarding my questions on his tool holders.

I write articles for a similar publication as yours in New Zealand and often we take for granted that a reader cannot quite grasp the ideas being propagated as they are reading about either a new concept and they don't have access to a prototype in the flesh to hold, roll about in the hand and work out how it all goes together.

Many thanks to you Richard, a lovely system and I will draw up a unit for my Boxford over our winter and make them. (Unless of course a pre-manufactured kit comes out from your workshop and production plant in which case I would buy one).

Bryce Clifford, New Zealand

Mystery Tooling



Dear Neil, I have a small collection of milling cutters - a type of endmill but with a 1/2-inch thread through them and a groove across the bottom face, clearly designed to fit onto a drive dog of some kind. They have 6 cutting faces with spiral side cutting faces. I have them for 1 inch, 1-1/8 inch and 1-1/4 inch diameters.

I wondered if anyone knew of them and particularly of what arbour was used to drive them. All response will be gratefully received.

Geoff Garrett

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Milling for Beginners



PART 4 - CUTTING TOOLS

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This month Jason Ballamy takes a look at the various options for cutting metal with the mill.

Having previously looked at work holding and tool holding this month I will cover the actual cutting tools that are likely to be used in the average beginner's workshop.

Milling Cutters

If you look back through old articles in Model engineer or most of the books on the subject you will see two types of cutter tend to be mentioned 99% of the time which are slot drills and end mills. These two cutters were the mainstay of the model engineer and each was used for particular jobs but now there is a far greater choice of cutter available at reasonable cost that can do more things than the two.

Slot Drills (2-flute cutters)

These cutters have two cutting edges created by grooves known as 'flutes' and when you look at the cutting end one of these edges will be longer than the other and passes through the centre. This longer edge allows the slot drill to be plunged down into the work as the centre cutting edge will remove metal right to the middle. This feature can be used to advantage where a slot is needed that does not exit either end of the work piece or where an almost flat-bottomed hole is required then the cutter can be plunged straight in.



2-flute slot drills

The other main use of slot drills is for cutting accurate width slots where the full width of the cutter is used. When cutting a slot, the advancing edge that is doing the cutting can deflect the tool to one

side particularly if the cut is a bit heavy or a long slender cutter is being used. If this were a 4-flute cutter the next edge coming round would tend to cut a slight amount off the side of the slot due to this



4-flute end mills



FC-3 and larger 3-flute cutters



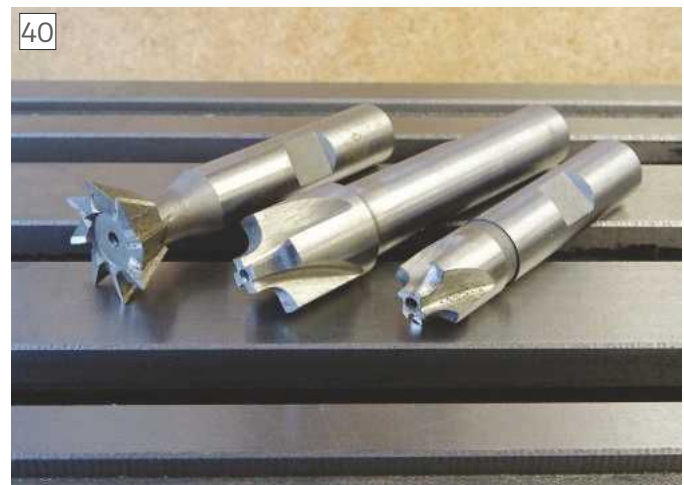
Roughing Cutters



Different helix angles to suit material



Ball nose cutters



Dovetail on left and corner rounding

deflection which results in an over width slot. However, as the next flute on the slot drill won't start cutting until the previous one has ended its cut and is therefore not deflecting the cutter you get a slot of the correct width.

They can also be useful when milling softer materials such as plastics and aluminium where large amounts of material can be removed in a short space of time, the 2-flute design giving greater clearance for this swarf to be removed from the cut as recutting chips is to be avoided, **photo 34**.

End Mills (4-flute cutters)

These cutters traditionally have four flutes and none of the cutting edges pass across the centre of the end of the tool which means they can't be plunged down into the work as the "pip" left in the middle stops them from doing so. Therefore, they can only start a cut from the end of the work which is an easy way to remember their name.

As mentioned above they are not really suitable for cutting slots due to a tendency to cut oversize, if you only have end mills and need a slot to be a specific width then use the next size down cutter to remove metal from the middle of the slot and then move the work evenly each way to enlarge the slots width.

One of their common uses is to flatten a surface which is best done in several passes across the width of the work piece using cuts that overlap approximately 2/3rds of the cutter's width. Another is if you need a rebate where a lot of the side of the cutter can be used and finally machining the side or end of a piece of metal where the whole depth can be cut in a series of passes.

These 4-flute cutters have a larger cross-sectional area than 2-flute ones so are best used where rigidity is needed such as when using long series cutters to reach down into a pocket or when using a large proportion of the cutters side.

More recently these cutters have become available in centre cutting form with either two edges meeting in the middle like a drill bit or with one longer cutting edge passing through the middle, **photo 35**.

FC-3 or Disposable Cutters & 3- Flute cutters

The FC-3 type cutters are generally available in sizes up to 6mm or 1/4" though they can be had as large as 10mm or 3/8". The disposable part of the name reflects the fact that they are not economic for industry to sharpen and to save throwing away more HSS than needed they tend to have fairly short flutes and proportionally

short shanks which are usually of the Weldon type. Having three flutes these are a good general purpose cutters as they fall somewhere between the slot drill and an end mill, larger 3-flute cutters are also available. They are quite an economic buy when you need cutters in the smaller sizes which seldom need long cutting flutes and this also makes for a rigid cutting tool, **photo 36**.

Roughing Cutters

These cutters are designed to remove larger amounts of metal in a given time without causing vibration on CNC machines, but they can also be used to good effect on our lighter bench top machines allowing a bigger cut to be taken for the same amount of power available. They can be recognised by the serrated looking edge, similar to that of a tap, which tends to produce small chips rather than long splinters of swarf. However, this same serrated edge does tend to leave a striations on the surface so a finish cut with a conventional mill is usually required where a good finish is needed. Not a cutter that the hobby machinist needs to keep a full set of but one or two in the 10 - 12mm size bracket can be useful to have when a lot of metal needs hogging out, **photo 37**.



Tee slot on left and Woodruff on right



Jobber drills and shorter stub drills

Material specific cutters

While industry has many different cutters aimed at getting the most cost-effective metal removal rates most of these cutters are beyond the needs of the home workshop. One exception are aluminium specific cutters which are designed to allow more metal to be removed and the swarf ejected from the cut faster, they do this by having a higher helix angle to the flutes. These cutters are also uncoated which allows for a sharper cutting edge than coated cutters so as well as being ideal for aluminium they work well on brass, bronze and other non-ferrous metals as well as plastics, photo 38.

Bull Nose Cutters

As well as the straight sided and square ended cutters mentioned above there are a number of shaped cutters available that all have their uses about the shop. Probably the most commonly used one of these is the ball nose or ball ended cutter which has a semi-circular end. These can be used where a fillet is desired on an internal corner to relieve stresses or if making a part that you want to look like the internal fillets found on a casting. They can also be useful where a hole needs to be started at an angle to the work surface, the ball nose cutter being

Shank Types

1. Threaded Shank. These were the traditional shank type found on almost all milling cutters and designed to fit into "Posiloc" type holders where the end of the collet is threaded. Should the cutter start to slip in the collet it will screw itself deeper into the collet rather than being drawn out and possibly marking the work.

2. Weldon Shank. These are named after the company that first introduced helical flutes on milling cutters - the very old ones having had straight flutes. They have a flat ground onto the shank for a grub screw to engage onto which will lock the cutter into a holder.

3. Plain or Parallel Shank. These just have a plain ground shank with no other means of locking them into the cutter.

All three types can be held in the commonly used ER collets as well as R8 and Morse Taper direct collets.

fed in first does not deflect like a drill would and is used to form a pocket for the subsequent drill to locate into, **photo 39.**

Corner radius Cutters

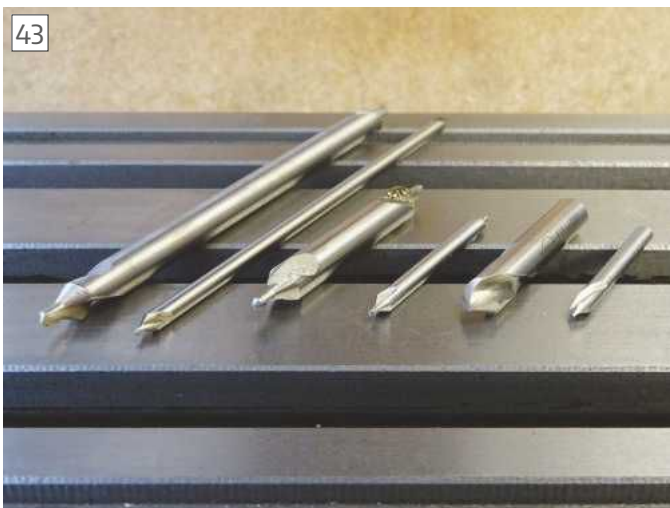
These look like conventional cutters, but the corners are shaped to a convex profile but to a radius less than that of the cutter. Like the ball nose cutter these are used where an internal fillet is needed but they are able to remove metal faster than the ball nose which can be a bit slow as the cutting edge at the centre is moving very slowly.

Corner rounding or round over cutters

These are similar, quite short, cutters not needing to cut on their sides but have a concave profile to the corners of the flutes and are used to round over external corners, **photo 40.**

Dovetail cutters

Another one for the tool makers amongst our readers, these cutters have angled sides that are used to cut the mating faces on dovetailed slides and are available in 45, 55 and 60-degree angles.



Long series and standard centre drills and spotting drills



Counter Bore and Countersink sets

45



Cone and step drills

46



Hand and machine Reamers

Chamfer Cutters

If you enjoy making workshop tools, then a chamfer cutter can be useful to take the hard edges off tools and make them less likely to throw up a burr if knocked.

Tee Slot and Woodruff Cutters

Another cutter that is likely to be used more by those that have an interest in making tools. These cutters have a short larger diameter cutting section on a smaller shank and are used to cut the tee shaped slots found on milling tables, lathe cross slides etc. A slot is first cut the width of the top of the tee slot and to the required depth which then gives clearance for the shank of the tee slot cutter which widens out the lower part of the Tee slot.

The Woodruff cutter looks quite similar to a tee slot one but the best way to tell them apart is that the woodruff has straight teeth and the tee has then set at alternate angles. Cutting curved bottom slots for woodruff keys in shafts is their main use, **photo 41.**

Other cutting tools - Drills

The mill makes a very accurate drilling machine, even more so if equipped with a DRO which can be used to position holes without the need for marking out. If you work in imperial, then a set of drills from 1/16" to 1/2" in 1/32nd steps would be a good starting set or if funds allow go for 1/64th increments. If you prefer metric, then 1-12mm in 0.5mm steps to start would do with the addition of some tapping size drills but if working in smaller sizes then a 1-5.9mm set in 0.1mm steps is very useful. These standard-length drills are often called 'jobber drills' and are a good all round length.

I quite like to use shorter drills known as stub length drills as they are more rigid and therefore less likely to wander. They also have the advantage of reducing how far you have to wind up the head or knee to fit them in as the size and corresponding length goes up. There will be occasions where the jobber drill bits are not long enough, in these cases long series or even extra long series bits are available but these are probably best

bought as and when needed or if you see them at a good price.

Ideally go for fully ground drill bits rather than rolled ones as they tend to be of a better quality and will hopefully give holes closer to their nominal size. Split point of 4-facet bits which have a second grinding angle to the end tend to cut better and can often be started without the need of a punch mark or location hole, **photo 42.**

Centre drills and Spot Drills

This brings us onto the fact that when you look at the end of a drill bit you will see a short straight bit between the two cutting edges, when this contacts the flat work piece the drill can skid about and not start exactly where you want it. To locate the drill a small recess can be formed in the work using either the end of a centre drill or more recently the use of spotting drills has become a lot more popular as they are not as fragile as a centre drill with its small diameter pilot. Also, if the recess is formed to the right size with the spotting drill that can save having to follow up with a countersink or having to deburr the edge of the hole. If marking out by hand then a punch mark can be located under the spindle to locate the end of the drill, **photo 43.**

Countersinks and Counter Bores

A countersink bit is used to form a conical recess around the end of a hole to take the head of a countersunk screw or if just used lightly will remove any burr thrown up by the preceding drill. If you are using socket head screws, then counter bores are used to cut a suitable hole to take the head. They have a pilot to locate in the clearance hole which some people find to be quite large, if you want a closer fit around the screw then a milling cutter can be used to counter bore the hole but do put a slight chamfer at the top of the clearance hole so that the radius between the screws head and shank does not make contact and prevent the load being spread under the screws head, **photo 44.**

Step and cone drills

If you are going to be doing much sheet metal work then a step drill or two can be very useful as they will cut a circular hole in thin materials where a standard jobber drill can have a tendency to form a tri lobed hole, they also seem to be less likely to snatch and jam. A cone drill can be used in a similar way to open up holes to any size, but they may need finishing with a file if you want straight sides, **photo 45.**

Reamers

The hole produced by a drill more often than not will not come out the exact nominal size of the bit so where a hole is needed to be an exact size such as one where a shaft will slide or rotate then it is best to drill a little undersize and then follow up with a reamer. There are two main types - the machine reamer which has a round ended shank so easily held in a collet and short parallel flutes which as the name suggests are ideal for use in the mill or lathe. The other type are hand reamers which have a squared off end to the shank so they can be turned with a tap wrench and long flutes which have a lead in taper on the end. Although meant to be turned by hand I find they work just as well held in a collet and run at a slow speed, **photo 46.** ■

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>

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Modifications to a SIEG CO 'Baby' Lathe.

Tony Bird describes how he got the best out of this little machine.



Boley Lathe.

For many years, the author had used and owned an 8mm Boley & Leinen "Reform" watchmakers lathe, **photo 1**. A fine lathe for what it was designed to do, but not very powerful. To get more use of this lathe's very accurate collets and chucks thoughts were given to buying a small lathe which could be adapted to use them. This was ten or more years ago, when the small Sieg CO lathe first came into this country, the author had had a lot to do with small lathes during his working life and had come to the conclusion that the smaller the lathe the more important it was that its proportions were good - hands don't get smaller as the lathes do. Having played with

the Sieg CO at a model show it appeared to be well proportioned for its size, so a lathe with all its available accessories was purchased for show price of £174.00, even without the discount it wasn't expensive.

The standard equipment that came with the lathe: 3 jaw chuck, dead centre and a tool kit. The lathe's accessories were as follows: fixed steady, auto-feed attachment, compound slide with tool post, live centre, wood turning rest, Jacob chuck and a face plate, **photo 2**. The head and tailstock mandrels were threaded 14mm, so a tap was also bought so that fittings could be made for them. The lathe came with an instruction manual which came

with an exploded parts diagram that turned out to be very useful. The paper work that also came with the lathe stated that it was only available factory assembled so would require cleaning, adjustment and lubrication as appropriate prior to use.

So, a start was made on cleaning and modifying a "Sieg CO Baby Lathe", as it was called by its suppliers. The lathe and its accessories were covered in an oily greasy mixture to protect it and everything that could be loose was. It wasn't an exaggeration that cleaning and adjustment would be necessary! So, the lathe was taken apart almost every nut and bolt being removed. The components were



C-O lathe and accessories.



Compound leadscrew.



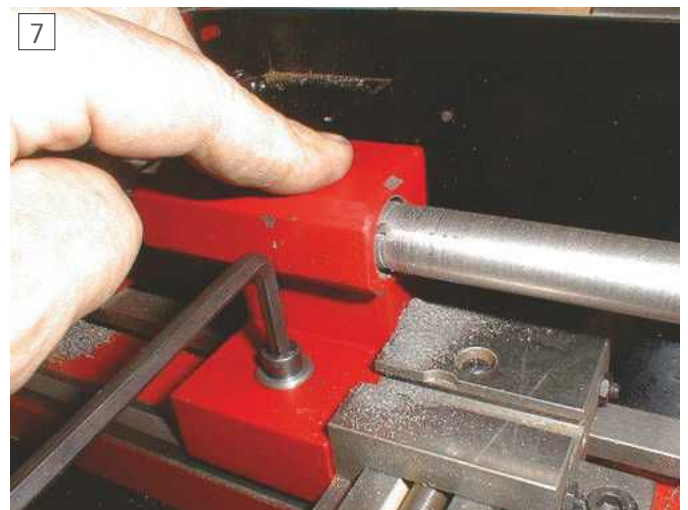
Bed & Base.



Access hole in base.



Boring set up.



Boring in progress.

cleaned, dried and assembly began. The slack in the compound lead screw bearing was adjusted to reduce backlash, **photo 3**, it was found that when the lathe bed was fitted to its base there was no access to the saddle adjustment plate screws, so a hole was cut in the base. As there were some of the lathe's electronics housed in the base a cover was fitted inside the lathe bed to

reduce the chances of swarf getting into the base through the access hole that had been cut, **photos 4 and 5**.

With the lathe, back in one piece, disaster! It was found that the tailstock centre didn't line up with a centre fitted in the headstock. It was a large misalignment, nearly 1mm! So, some time was spent thinking of how it could be corrected, the

first idea considered was the fitting of a new base to the tailstock, possible but a lot of work. Then the possibility of boring out and sheaving the tailstock was considered. After a great deal of thought an idea came about: a boring bar supported at the end of the bed by the fixed steady and the tailstock being pushed along the bed by the saddle in auto feed, **photo 6**. The tailstock



Boring the sleeve.



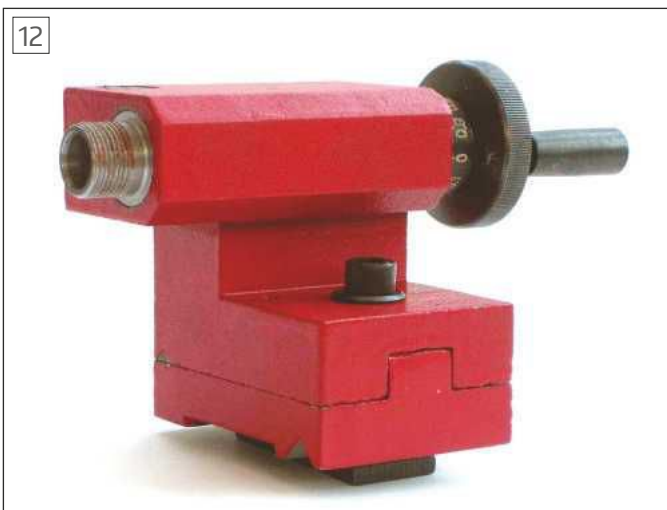
Sleeve mounted on shellac mandrel.



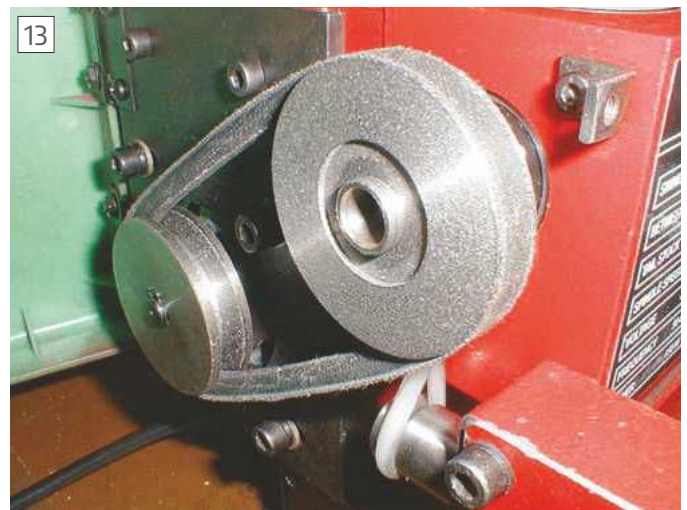
Tools used to make the sleeve.



Turning test bar.



Adjustable tailstock.



Recessed pulley.

is not intended to move along the bed smoothly, so the bed was well lubricated and the movement of the tailstock was controlled by easing its locking nut and pushing down on it, **photo 7**. With very light cuts it worked!

A larger lathe was used to bore a sleeve with a wall thickness of about 2mm, **photo 8**, when the tailstock mandrel was a slide

fit in the sleeve the sleeve was transferred to a shellac mandrel to machine its outside to fit in the tailstock, **photo 9**. With the sleeve glued into the tailstock a test bar was turned, **photo 10**. The boring bar and shellac mandrel used to bore and make a sleeve for the tailstock are shown in **photo 11**.

A lot of the first Sieg CO lathes that came into the country had these tailstock issues

which were later corrected by the use of an adjustable tailstock, **photo 12**.

The lathe was now usable, and a start was made on modifying it. From the outset, the idea was to use the collets and chucks from the Boley, but in the end, it also involved modifications to allow accessories from other sources to be used. The modifications described that follow aren't necessarily in



14 New pulley fitted.



15 Vacuum cleaner belt in use.



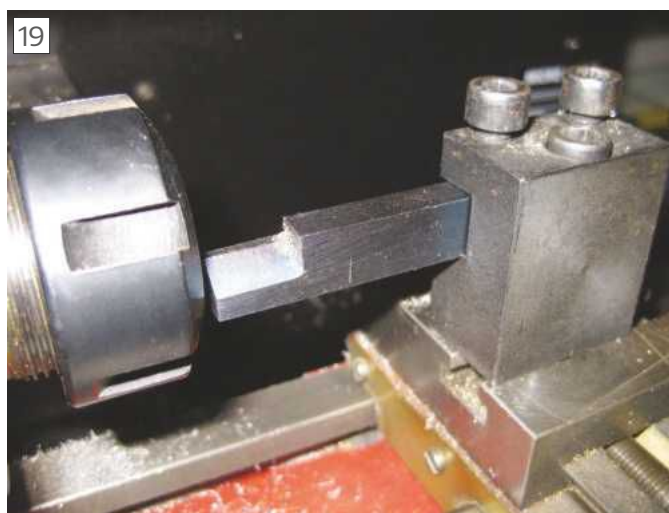
16 Turning a larger job.



17 New base for t-rest.



18 Turning a lace bobbin.



19 Hand turning rest.

the order in which they were done, it was a long time ago to remember which came first!

The modifications

The Sieg C0 has an impressive electronic speed range of 0-3800 rpm, unfortunately at the bottom end there isn't much power so turning a 50-mm rod wasn't on. The

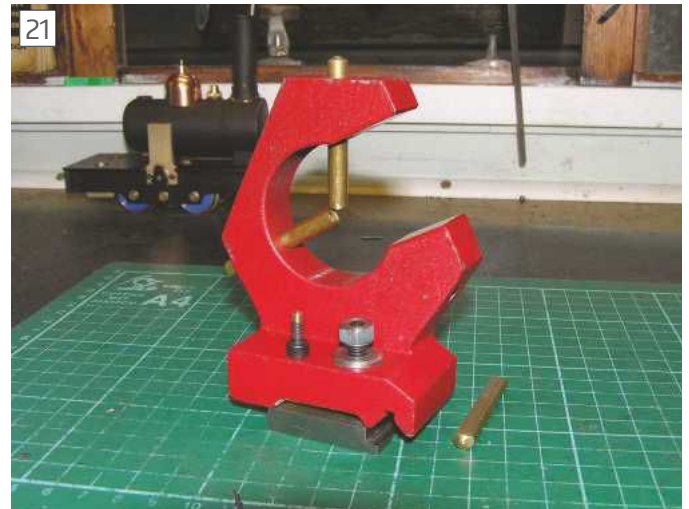
motor drove the head stock via 1:1 pulleys and a 'V' belt, **photo 13**, it was decided to lower the pulley ratio to about 2:1. To this end the pulley was turned around and another groove was cut in the shoulder that used to face the motor, to allow the reversed pulley to be fitted part of the motor support bracket had to be cut away, **photo 14**. A local hardware shop supplied

a vacuum cleaner belt of a suitable length, **photo 15**. A 50-mm steel rod being turned, a light cut but it just stalled before the modification, **photo 16**.

The author does some hand turning of metal. So, the wood turning rest supplied was modified, first the 'T' rest was shortened and then a new easier to fit locking plate was made, **photo 17**. The 'T'



Fixed steady and locking plates.



Altered fixed steady.

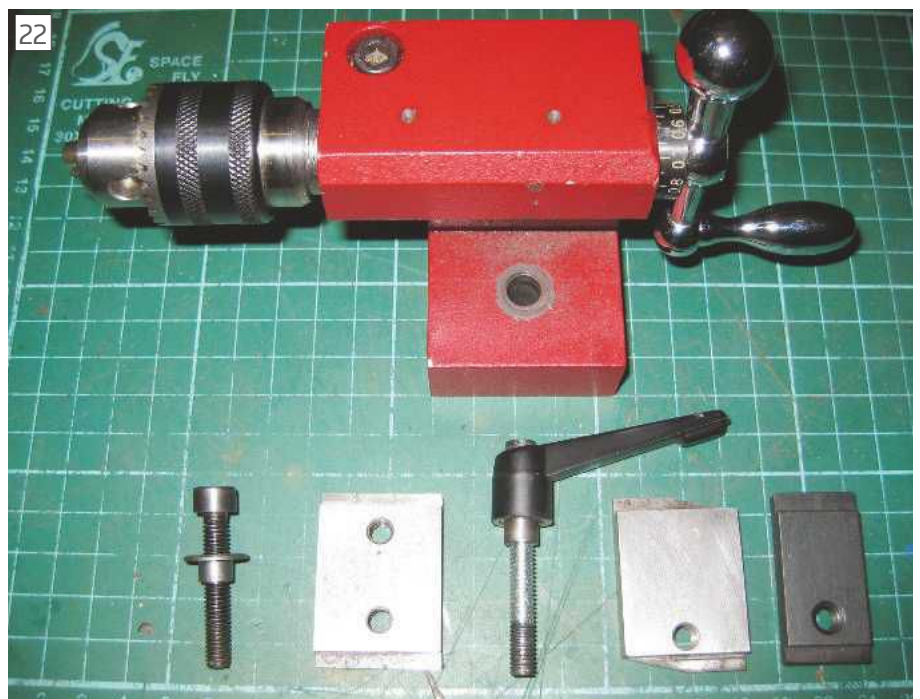
rest being used to turn a brass lace bobbin, **photo 18**. A hand turning rest that would fit in the tool rest was also made, **photo 19**.

A new locking plate was fitted to the fixed steady, **photo 20**, which also had a section removed so it was easier to fit the work piece, **photo 21**.

The tailstock as well as having a new locking plate, had an indexable locking handle fitted along with a ball handle to replace the rather small original one, both lead screws received similar treatment, **photo 22**.

At about this time in the lathes life another Jacob's chuck was bought so that both the head and tailstock could be fitted with one. Also, another compound slide and tool post was purchased, the tool post was converted into a vice, **photo 23**, so when mounted on an angle plate the compound slide became a vertical slide, **photo 24**.

● To be continued



Tailstock assembly.



Tool post converted to a vice.



Toolpost vice used as a vertical slide.

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Machine-DRO readout kit for Myford 7- series lathes

Crankpin reviews this recently released kit, in this first part he looks at fitting the kit.

Allendale (**machine-dro.co.uk**) advertise this kit as a 'bolt on' accessory for Myford 7 and Super 7 lathes, requiring no permanent modifications to the lathe. The comprehensive kit includes all the components necessary to provide 2-axis digital read out on a large display console which provides a range of options from mm/inch, radius or diameter display, tool offsets, taper measure and 200 SDM zero memory.

The prospect of a DRO on the S7 was attractive, since having previously installed a cheap 3-axis system on my mill, the benefits were evident even if its performance problematic. The price of the M-DRO kit was not inconsiderable so in the cramped confines of my workshop, **photo 1**, it would be important to assess both its quality and ease of installation.

The contents of the large container were very well packed and isolated in protected compartments. First task was lay out the numerous bags & boxes as in **photo 2**.

Next, consume coffee whilst reading



Initial arrangement of the Myford and other clutter.



Contents of the package.

through the 5 booklets! Anticipating the sort of assembly instructions one gets with flat-packs, it was gratifying to find an A4 booklet with clear colour illustrations and straightforward guidance for installation on a Myford, example as **photo 3**. The other (A5) booklets covered the functions of the "MDC700" display unit.

Somewhat surprisingly, I was expected to drill out a couple of M4 threaded holes and re-thread them M5 in the supplied bracket, in addition to enlarging a few other holes for clearance. Doing so later only took a few minutes but any purchaser will need a set of metric drills, metric hex keys as well as a M5 tap suitable for soft aluminium. (I've since been informed M-DRO will now do this drilling and tapping before dispatch).

After acquiring my new S7 twenty years ago, improving the saddle locking mechanism was the first priority. It was now apparent from the illustrations that the modification would no longer fit beneath the new cross slide magnetic strip holder. A return to the original hexagon bolt

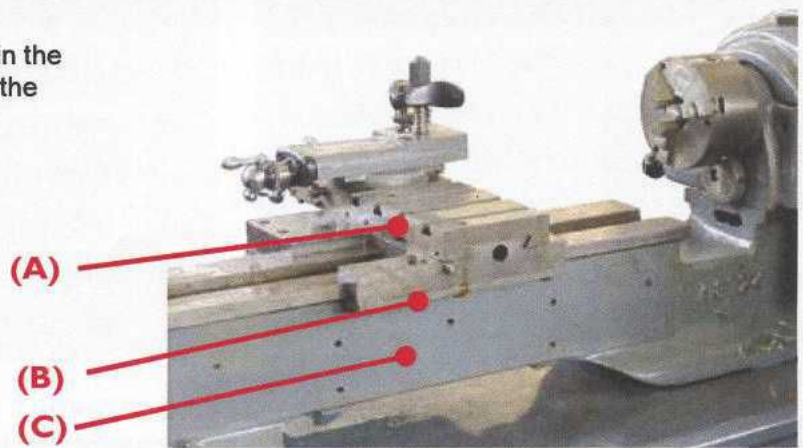
3 Step 1:

Please ensure the machine is cleaned down in the following areas prior to starting installation of the DRO kit:

The tail-stock side of the cross slide (A);

The saddle/rear saddle strip (B);

The taper turning area (C)



Example of a guidance note.

would be required! The new cross slide encoder requires 75mm extra clearance beyond the cross slide when fully wound in. Checking for this and the modified but now redundant saddle clamp can be seen in **photo 4**.

Like most model engineers with limited workshop space, my lathe and its bench are against a wall and accessing the back of the lathe entails reaching over. Therefore a few minutes spent removing the tailstock, chuck and top slide proved worthwhile for an ageing back. Following the advice to ensure key areas of the Myford were cleaned and degreased, I began with white spirits followed by a proprietary aqueous degreaser. After that a start was made on assembling the many parts which had to be mounted on existing holes at the back of the Myford. The numbered sequence of instructions referred me to the content of the requisite labelled plastic bag and progress was fast. Fitting the components to the rear of the Myford was the first step in assembly. One procedure to cause some delay was the need to ensure the long magnetic strip holder was mounted accurately below the bottom of the bed shear. The relevant picture showed this being achieved with a digital vernier in **photo 5** but it took quite a while to do in practice and three hands would have been advantageous! With hindsight, it would be time well spent to first make two identical pieces of say $\frac{1}{2}$ "D x $1\frac{7}{8}$ " long, steel rod to be balanced on each end of the bar. Then by simply pulling up and holding the bar tight against the bottom of the shear with one hand, the other hand could tighten the cap head screws.

The remaining items such as the bracket which required drilling out to 4.2mm and threading M5 were fitted to the rear of the lathe quickly and without any problems thanks to the unambiguous printed guidance, **photo 6**.

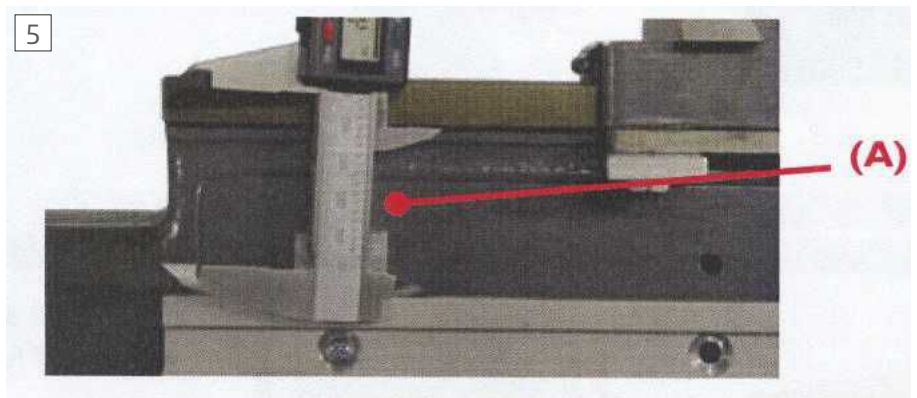
At this stage, about 2 hours into the job, it was clear that M-DRO had devoted effort into ensuring the kit had been well tested for fit on a Myford lathe and the components were of high quality. Other



Checking for clearance beyond cross slide.

than the issue with ensuring the long encoder strip was parallel, the only other uncertainty had been the recommendation to use "several sheets of paper or card measuring a thickness of 0.25–0.5mm". This is to ensure the gap between the reading head face and magnetic tape was constant along the length; paper or card

being non-abrasive against the stainless steel protective cover, **photo 7**. Folded paper seemed an imprecise feeler gauge and finding a piece of clean card of suitable thickness took a time. Keep that piece of card somewhere safe though because it will be needed again for the cross-slide encoder strip.



Suggested method for ensuring guide is parallel to bed.



Carriage encoder, strip and cover fitted.

Fitting components to the cross slide

M-DRO's introduction to this section states:- "The cross slide magnetic tape carrier simply locates against the cross slide and can easily be removed. The profile will overhang the rear on the cross slide. The Super 7 overhang is approximately 75mm, the standard ML7 has a shorter cross slide and the overhang is approximately 68mm to cover full range of travel. If the overhang is not convenient then it can be reduced by cutting the length of the support profile and magnetic tape. A loss of reading may occur when travelling the cross slide to it furthest outward position." As before, I had checked that there was sufficient clearance for a 75mm overhang (just!) and although it was not envisaged that any working with the cross slide would fully in would be done, it was decided to use the supplied carrier 'as is'. Assembly was straightforward and accomplished without incident, taking less than an hour, **photo 8**. No cover plate was supplied and exposure of the encoder head to swarf, cast iron dust etc suggests that one will



Shows the gap which has to be gauged with a piece of card between 0.25 & 0.5mm for both the carriage and cross slide.



Cross slide encoder and strip fitted.

have to be made, a simple enough job.

The completed cross slide is shown in **photo 9**.

Now was the time for a long-anticipated switch-on. The display unit was connected

up to the 2 encoder cables and the 240v supply cable, **photo 10**.

Traversing the carriage and turning the cross slide feed screw produced welcomed readings of X and Y axis movement.



Forgot to reinstall the original Myford saddle clamp before fitting the encoder unit, fortunately there was just sufficient room!



First switch on.



Rear of MDC700 display unit.

Mounting the display unit

A substantial mounting bracket and fitments are included with the kit and obviously its positioning will be governed by personal preferences and constraints. The rear of the unit, with leads is shown in **photo 11**.

The booklet MDC700 SET UP states that an earth connection should be made from the unit to the machine. This is not supplied. I ran an insulated copper wire down to the lathe motor fan shield. There was no evidence of any problems with electrical interference. My S7 has a 3ph motor and VFD powered from the same 2-gang 240v socket as the display. Static readings on the display were unaffected by any motor control changes such as "jog".

Photograph 12 shows the display unit on its bracket bolted to a wood platform affixed to the wall. The protective covering is still in place on the LED screen.

In the interests of both safety and appearance, the cables were encased in a length of that corrugated, longitudinally-split, plastic tubing and fastened back to the wall with a pipe clip. The final appearance is shown in **photo 13**.

One question arose – would the new cross slide bracket prevent use of a Myford Vertical (swivelling) Slide? In fact there is just sufficient room and the bracket could anyway be cut away slightly without loss of strength to permit the Vertical Slide to be clamped in the centre of the cross slide.

In conclusion, any initial scepticism about the cost of the M-DRO kit was dispelled on remembering the words "Quality is remembered long after the price is forgotten". The quality of both materials used and information provided show care has gone into design and execution of the M-DRO Myford kit.

The assembly and installation of the kit was a satisfying process and devoid of the expected frustrations which often accompany fitting non-original extras to a machine tool.

I did though soon realise that my own neglect of maintaining the cross slide meant that a quick comparison of the S7's micrometer dial and M-DRO output was not possible. The cross slide movement was just too stiff and jerky despite advice to keep the movement tight. Chastened to dismantle the cross slide and readjust with very obvious improvement, I was then informed that M-DRO had developed a new, optional modification. This places the magnetic strip underneath the cross slide but does require machining a shallow slot for it. The result is a clear cross slide surface and much neater arrangement, **photo 14**. This installation, together with a report of the DRO performance on the lathe is to follow in Part 2. ■



MDC700 unit mounted.



Cabling covered and fitting completed.



The new cross slide modification.

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Regrinding Worn Lathe Chuck Jaws



Many an old three-jaw lathe chuck that has been repeatedly over-tightened and bell-mouthed can be salvaged if reground in situ. Pete Barker shows how it's done.



Sparks fly as the bell-mouthed chuck jaws are brought back parallel with a toolpost-mounted hand grinder.

If you have a lathe that is chattering and turning jobs out of parallel, the first thing to check is the condition of the chuck. Many three-jaw chucks suffer from the results of over-tightening. The giveaway clue is often a chuck key handle bent into a subtle S shape from the application of lengths of pipe to increase its leverage. This abuse frequently shows up as bell-mouthing where the chuck jaws are physically bent out of shape and the guiding slots worn, leaving the jaws' gripping profile larger at the protruding right-hand end than at the inner left-hand end. The mouth of the chuck is literally shaped like a tapered bell instead of a cylinder.

Providing there is no collateral damage to the chuck's scroll, which is less common but not unheard of, the chuck can be reclaimed to good accuracy by regrinding the gripping faces of the jaws in situ, **photo 1**. The trick is to make a clover-leaf plate to hold the jaws outwards in the bell-mouthed position under clamping pressure while allowing grinder access to the clamping faces. This dodge has been used for many years. I have modified the traditional design to incorporate three slots to allow for a bit of spring to give better fitment under tension. With this plate holding the jaws in the outwardly stressed working position, they can be reground so the gripping surfaces

are again parallel. To do the grinding, a simple mounting bracket for the workshop Dremel hand grinder is made up and mounted in the lathe's toolpost.

Test for bell-mouthing

Measuring, as always, is the first step. Place a known cylindrical object in the chuck. This may be a length of ground bar, silver steel, or even bright mild steel at a pinch. Milling cutters and drill bit shanks in good condition also work well. Tighten the chuck key just until resistance is felt. Try to wobble the end of the bar, **photo 2**. A bell-mouthed chuck will grip the bar at the inner end but often allow some movement at the outer. ➤



Distorted chuck allows noticeable movement of a test bar lightly gripped in the jaws.



Bell-mouth at right-hand end of jaws is visible and measurable with feeler gauges.

A badly damaged example can even have a visible gap at the front when the chuck key is fully tightened, **photo 3**. This gap may be measured with feeler gauges to give an idea how many thou need grinding off the jaws to bring them back to parallel.

Try this test with different sized bars to get an idea of the problem's scale across a variety of jaw positions. Our test example here, a 60-year-old Burnerd chuck on a Myford ML7, showed 0.003" of gap on each jaw across all sizes tested. This could be measured also as a 0.009" gap on one jaw if the bar was pushed up hard against the remaining two. No wonder the chuck had been struggling to hold any job firmly in place during turning!

Make the clover-leaf plate

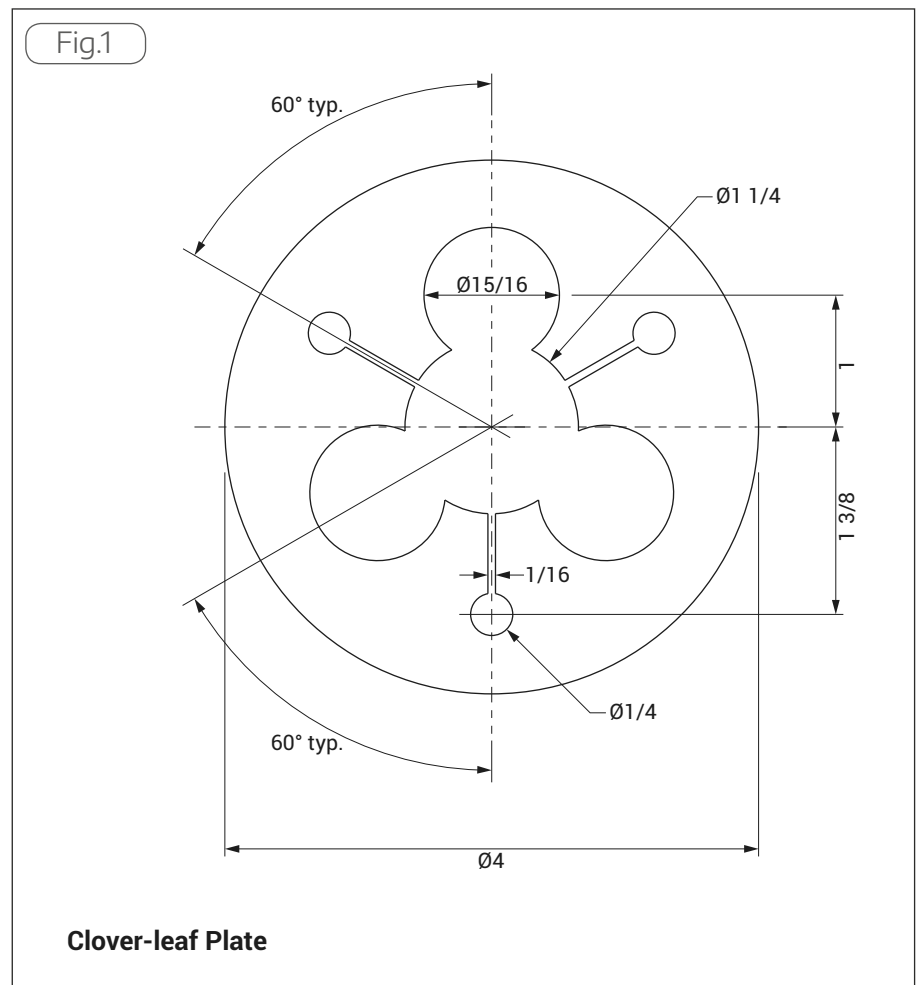
Once bell-mouthing has been determined as the problem, the next step is the making of the clover-leaf plate to hold the jaws for grinding. The dimensions for the Myford's Burnerd chuck are shown in **fig. 1**. It was made from a piece of scrap 3/8" aluminium alloy plate for easy cutting and machining. It could also be made from steel as thin as 1/8".

For other sized chucks on different lathes, the sketch will have to be scaled up or down to suit. Basically, the centre hole needs to be the same or close to the hole size in the middle of the chuck body, **photo 4**. The three smaller holes' diameter is about double the thickness of a chuck jaw. The three holes are positioned

overlapping the centre hole to create a gap about half the width of a jaw, just enough for the angled end of the jaw to protrude through, **photo 5**. The jaws must protrude beyond the chuck body so they can be ground without the stone touching the body. You might want to draw any special plate out on paper, cut out a template and try it on for size before cutting any metal.

The location of the three holes is most accurately established using a dividing

head to drill and bore them in a mill, but if you don't have one, they can be marked out using basic geometry. Use a pair of dividers to final check the spacing between the three holes is equal. The centre of each hole is carefully prick-punched then the job clamped on the lathe's faceplate for drilling and boring to size. The tailstock centre or a wobbler is used to locate the punch mark. As there can be some minor inaccuracy creep into this method, the



Dimensions to make a clover-leaf plate for an ML7's Burnerd chuck.

No wonder the chuck had been struggling to hold any job firmly in place during turning!



Central hole in plate is about same size as hole in chuck.



The three holes allow jaws to protrude for grinding.

three hacksaw cuts and 1/4" drilled holes between each pair of jaw holes allow for a little bit of flexing and spring when the jaws are tightened. This ensures even outward tension on all three jaws.

Before this step, the outer diameter of the plate was marked out with dividers, then cut with a hacksaw -- very easy if you use aluminium alloy. The centre hole can be bored in the lathe and then used to grip the disc while the outside diameter is cleaned up. The knurling shown in the pictures is not necessary, nor is the jewelled finish. Both were just fripperies done to try out various new bits of workshop equipment when I made this plate some years ago.

Mount the hand grinder on the toolpost

Similarly, the bracket to mount the workshop Dremel electric hand grinder was made up from easy-to-work 3/8" aluminium alloy plate, except for the square steel bar that is clamped in the toolpost. Bolt this steel piece to the main bracket base so the grinding stone spindle is held at the lathe's centre height.

The mounting bracket includes a simple U clamp to go around the grinder body. It is bored as one piece on the faceplate, drilled and tapped for the two clamping bolts, then hacksawed in two. The nose of the grinder



Toolpost hand-grinder mounting bracket is cut from aluminium plate and screwed together.

in this case fits into a screwcut hole in the other, smaller, bracket but could just as easily be a scaled-down U clamp. I shan't go into the exact details of the mounting bracket because they will vary depending on the model of grinder. **Photograph 6** shows the basic principle that can be adapted to your grinder. An air grinder could also be used for this job.

In both cases, use an abrasive wheel dressing stick, diamond dresser or the like to true up the grinding wheel before mounting the unit on the lathe. This minimises abrasive grit near the lathe's precision surfaces, **photo 7**.

Grind the jaws

With the clover-leaf plate placed on the far right of the chuck jaws, **photo 8**, the jaws are tightened in the conventional direction as if gripping a piece of bar. Nip them up quite tight to get good tension

on all three jaws. Use the chuck key hole marked with a 0 by the manufacturer. This is the reference key hole used for tightening in the factory. If the chuck has no such marking, use the key hole nearest the manufacturer's name badge or stamp (on chucks where the marking is between two jaws, used the hole opposite the maker's mark -- Ed.). Then in future, when you want best accuracy in workholding, use this key hole again.

The grinder is mounted to the toolpost at centre height. The lathe is set to rotate on lowest back-gear speed, somewhere below 50rpm. It is essential that the grinder be set up so the grinding wheel rotates against the direction of rotation of the chuck. In most cases, this means running the grinder on the front of the circle described by the jaws, the same as if you were setting a boring bar in place.

Before commencing any grinding, cover ➤

It is essential that the grinder be set up so the grinding wheel rotates against the direction of rotation of the chuck.

the lathe's exposed surfaces with damp rags held down with magnets or clothes pegs to stop them getting caught in moving parts. This will help keep abrasive grit out of the bed, carriage, cross slide and top slide surfaces. Carefully remove the rags and discard them immediately the job is finished.

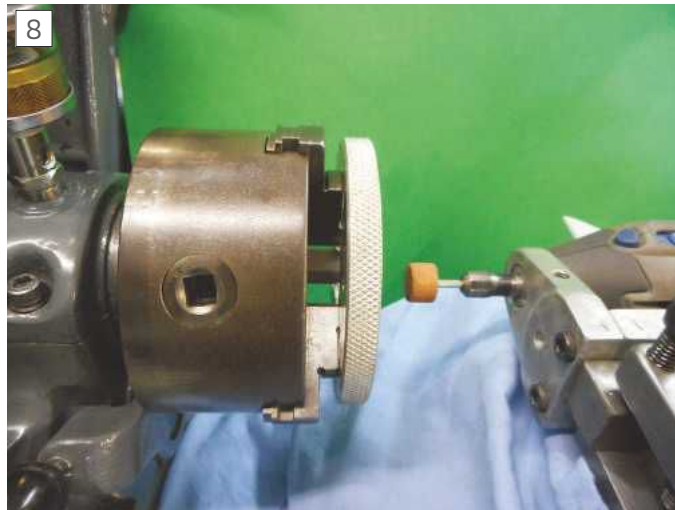
Check that the grinding wheel sticks out enough to reach through to the very rear surface of the jaws. I mount the grinder at a small angle so the leading edge of the stone does all the grinding but still make sure the whole stone clears the rear of the jaws. Set the grinder so the spinning stone is in line with the least worn inner parts of the jaws but is not quite making contact.

With the lathe chuck slowly rotating, wind out the cross slide carefully until the grinding stone just kisses the jaws, **photo 9**, or jaw if one is higher than the others, and produces a tiny shower of sparks. Wind the carriage out so the stone is clear and then engage the fine carriage feed. Let it take the stone all the way through the jaws until no more sparks appear, then wind the carriage back out again.

Add on a thou or less of cut on the cross slide and repeat the process. Grinding



Dressing grinding wheel away from the lathe.



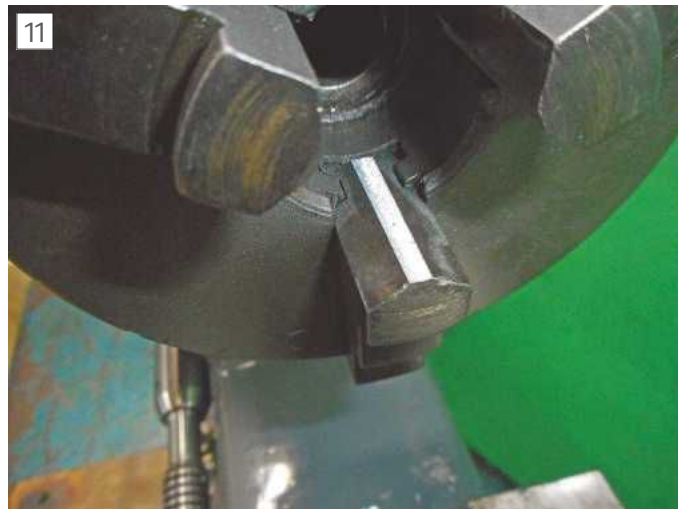
Clover-leaf plate in place ready for grinding to start.



Grinding stone just kisses the high-spots on jaw at start of grinding.



Shiny areas show high spots being removed.



Stop grinding when all jaws are evenly ground.



12 A ring is used to tension jaws for any checking or grinding of outside jaw steps.



13 Result: A .100" deep cut produces no chatter now the chuck grips firmly with no bell-mouthing.

is a finer, slower process than turning so depths of cut are relatively tiny. Try making repeat passes at the same depth of cut until no more sparks appear, then add some more to the cross slide dial.

Stop and inspect your work after each couple of cuts. Usually you will see uneven shiny spots, **photo 10**, where distorted jaws are being brought back true again. Once all three jaws are suitably reground along their full length, **photo 11**, it is time to stop. Keep the grinding to a minimum because the larger the ground flat on the jaw becomes, the more ability to grip small diameters is lost. In the example case, quite a bit of metal needed to be removed. As a result, a 3/32" diameter pin is the smallest the chuck can now grip. For anything smaller than that, we will have to use a drill chuck mounted in the headstock spindle.

Around the outside

The outside gripping surfaces of the jaws on our test example did not need regrinding, somewhat surprisingly. If they did, however, the procedure is to use a ring such as a bearing outer race and tension the jaws against it, similar to **photo 12**. The other outer surfaces may then be ground in the same manner as the inner ones. When one set is done the ring is moved to the other. An alternative is to put a large hose clamp around the outside of the chuck body and tighten the jaws outwards against it.

When you are happy with the result, the chuck should be pulled off, stripped, cleaned and reassembled (an article on chuck servicing to follow soon - Ed.). The rags should be carefully removed, and the lathe given a good wipe down to get rid of any abrasive grit, which can be felt with a finger if present.

Like many of these jobs, the actual

machining time is a fraction of the time to make the clover-leaf plate and the grinder mount.

Check the result

Test the chuck for grip in the same way as used for diagnoses before grinding. No shake or gap between bar and jaws should be discernible.

The outcome should be a chuck that once again grips firmly at all diameters and holds round bar to run true to somewhere between 0.001" and 0.003" (.025mm to .075mm) at varying diameters, as measured with a bed-mounted dial indicator and stand. That runout is as good as a new chuck. Our test example returned readings between 0.001" and 0.002" total indicated runout at varying diameters, a very pleasing result.

The final check is a real-world turning test, as always. A scrap piece of 1" diameter bright mild steel was gripped in our example chuck, with no tailstock centre in place. After a couple of light test cuts to determine all was well, a 0.100" deep cut was taken under power feed, **photo 13**. The job showed no sign of chattering, slipping or movement, indicating the chuck is now gripping like brand new. A light cut under fine feed then provided a nice shiny finish, also indicating good gripping by the chuck.

Conclusion: Chuck good for another 60 years

By making up a clover-leaf plate that holds outward tension on the chuck jaws while leaving the gripping surfaces accessible, a bell-mouthed chuck can be brought back to as-new specification. This provides firm grip and minimises runout on round jobs.

The actual grinding is accomplished with a common workshop hand grinder using a simple toolpost mounting bracket, **photo 14**.

The reconditioned chuck should now provide many more years of good service, provided the chuck key is not over-tightened, which is what causes most of these problems in the first place. ■



14 Chuck grinding requires only simple shopmade equipment.

Quadrilla Variation



Mike Philpott's version of Quadrilla

Encouraged by Michael Belfer's Quadrilla article in the MEW 263, Mike Philpotts decided to tidy up his drill "management" system.

Rather than make a stand/station as suggested by Mike, I decided to re-cycle a TV bracket I knew would come in useful one day. I also wanted to fix it to the column of my pedestal drill that sits to the right of my lathe so working at either machine the drill carousels would be accessible. I drilled the TV bracket to accept a suitably sized pair of exhaust clamps. I also drilled M10 clearance holes into the top plate of the TV bracket to take the drill carousels. I used suitable turned spacers and fitted M10 bolts with self locking nuts on the underside of the table. The lock

nuts were suitably tightened so that the carousels rotated freely. The end result is shown in **photo 1**.

I'm sorry about the horrible plastic holder for the metric drills. I am currently looking for an alternative in metal that holds drills that increase by tenths of a millimetre. I made an adapter for the number and letter carousels so that the letter size carousel sits on top of the number carousel. I now have room for another carousel - but what to put in the empty quadrant?

I am also experimenting with ways to highlight the marking method on



Michael Belfer's original design

the carousels to improve legibility. You can see that yellow felt tip did not help much! Engineers blue and polishing the cast figures helped on the fractional drill carousel.

Many thanks to Michael Belfer for his original idea. ■

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● Little Bertha

James Wells just wanted a book end but decided to make one a little out of the ordinary.

● Warco CNC

Roger Davis converts his WM18 mill to CNC.

● FALCOR

Martin Ranson makes a gas tank for his 32mm steam locomotive.

● Tea Coaster Engine

Tony Wright demonstrates that small is beautiful.

● A Six Inch Burrell

Alan Barnes relates the story of Mick Harrington's Burrell traction engine.

Content may be subject to change.



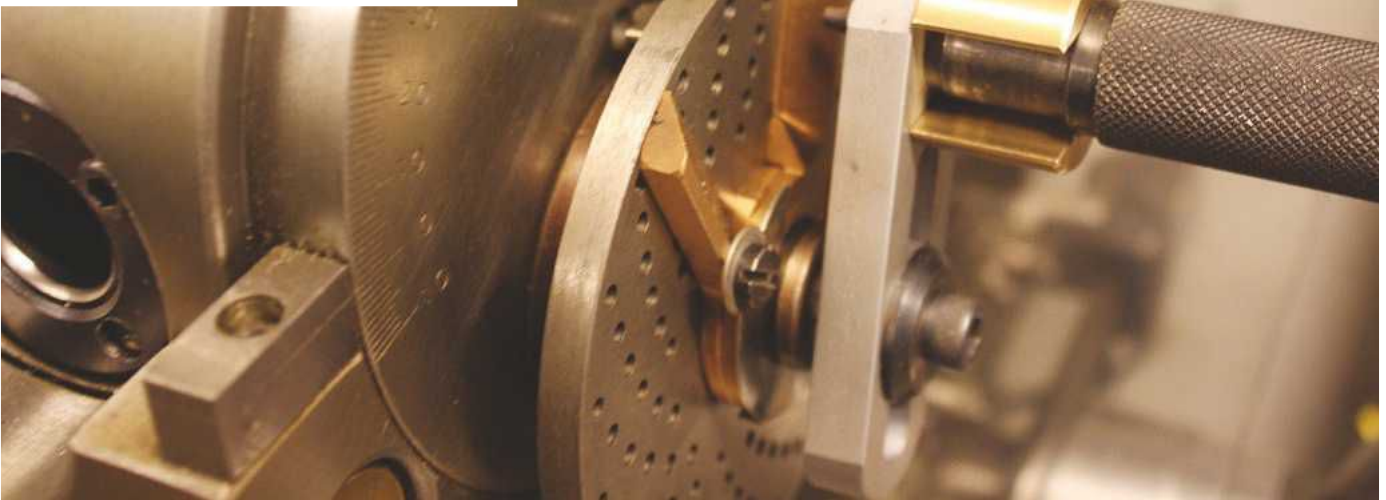
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Readers' Tips



Dividing Head Tweak

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Pete Worden wins May's Chester Vouchers with a simple modification to stop dividing disasters.

Several times when I've used my dividing head I've upset the hole spacer settings when the detent has collided with one of the arms and moved it out of position. This happened because the spring in the winding handle is so strong that if it is not pulled back far enough when making full turns the detent can catch on the spacer arm. If this happens half way through cutting teeth on a gear for instance the correct hole position will be lost, and it'll probably mean going back to the beginning and starting again.

Some way was needed to keep the detent away from the spacer arms when turning the handle. I came up with the idea of the spacer, photo 1, which has a cut-out to enable it to be slipped over the handle spindle after the outer sleeve has been pulled back against the spring, photo 2. It makes life easier when there are no worries about upsetting hole spacer settings when making however many turns are necessary. When the required number of turns is completed it just needs the handle sleeve to be pulled back against the spring and the spacer removed to enable the detent to be inserted in the required hole.

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.chestershobbystore.com to plan how to spend yours!

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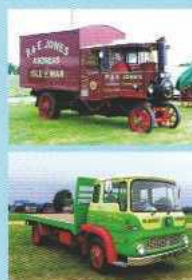


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A High Speed Engraving Attachment



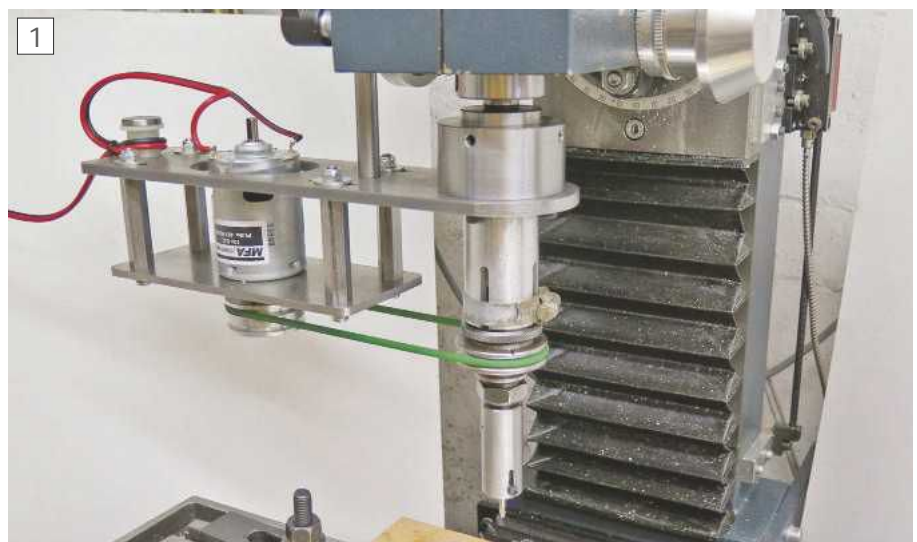
Keith Johnson made this device to fit his CNC Wabeco 1210 Vertical Milling Machine, but it would suit most other CNC mills of similar capacity.

The phrase one thing leads to another is certainly true in my case.

At my retirement in 2002 I purchased a new Wabeco 1210 milling machine, together with all the items to retrofit to CNC specification of the day. The supplied Wabeco software was M-Plus, this required a computer able to run in MS DOS mode. I built a computer with Windows 98 operating system allowing me to run in true MS DOS mode, this combination worked well and was used to machine many items for several years. However, articles appeared in MEW singing the praises of Mach 3, this set the thought in mind to be my next move.

When Microsoft finally stopped supporting the XP operating system I had two good desktop computers that were no longer usable on the Internet, so this was the ideal time to update my toys. A new 3 axis microstepping driver unit together with power supplies and break out board was built, using Gecko stepper motor drivers I had in stock.

Mach 3 was purchased and installed on both XP computers, one located near to the Wabeco mill in the workshop and ready to plug up with the newly constructed driver unit. The remaining computer was set up in my house "office" so that I could learn to use Mach 3 and G Code in comfort. I soon produced a



Completed Attachment

few simple G Code files with the help of previous articles in MEW. The files were copied to a memory stick and transferred to the workshop system where the Wabeco mill faithfully produced my components.

The next requirement was a program to generate G Code from drawings, after looking at various options I decided on "V - Carve Desktop" from Vectric. This program has a good range of engraving

fonts both true type and single line with several styles and methods of engraving which really attracted my attention. Only one snag the top spindle speed of the Wabeco mill is only 3000 RPM

Up to this point in time all my engraving has been manually with a floor standing Alexander Number 2 pantograph machine, which has spindle speeds up to 20,000 RPM. The snag here is I only have one full set of Master Copy, so all projects look similar.

The obvious answer to clear both snags is to combine the best of both systems, **photo 1**, I removed the workspindle from its bayonet housing on the Alexander and offered it in place under the Wabeco spindle. Making note of a few dimensions and with a head full of ideas I returned to the house and Turbocad.

Engraving Machine Workspindle

These spindles are beautifully made, consisting of a main body that is fully through hardened and precision ground all over. The ball tracks are an integral part of the body, being finished to size at the grinding stage of manufacture.



Engraving Machine Spindle

The rotating spindle is similar, again fully through hardened and precision ground with corresponding ball tracks. The front of this spindle has a 20-degree included angle tapered bore for collet location and an external fine thread to suit the hardened collet closing nut. The ballbearings are captive, in simple pressed metal retaining cages being located at each end of the assembly, large at front and small at rear.

Finally, a sliding sleeve at the rear end is secured with two adjustable slotted lock nuts to the rotating spindle, these nuts are adjusted to give perfect rotation with zero play in the bearings. Lubrication is by pre - packing the bearings with low fling grease, **photo 2**.

General Arrangement - fig. 1

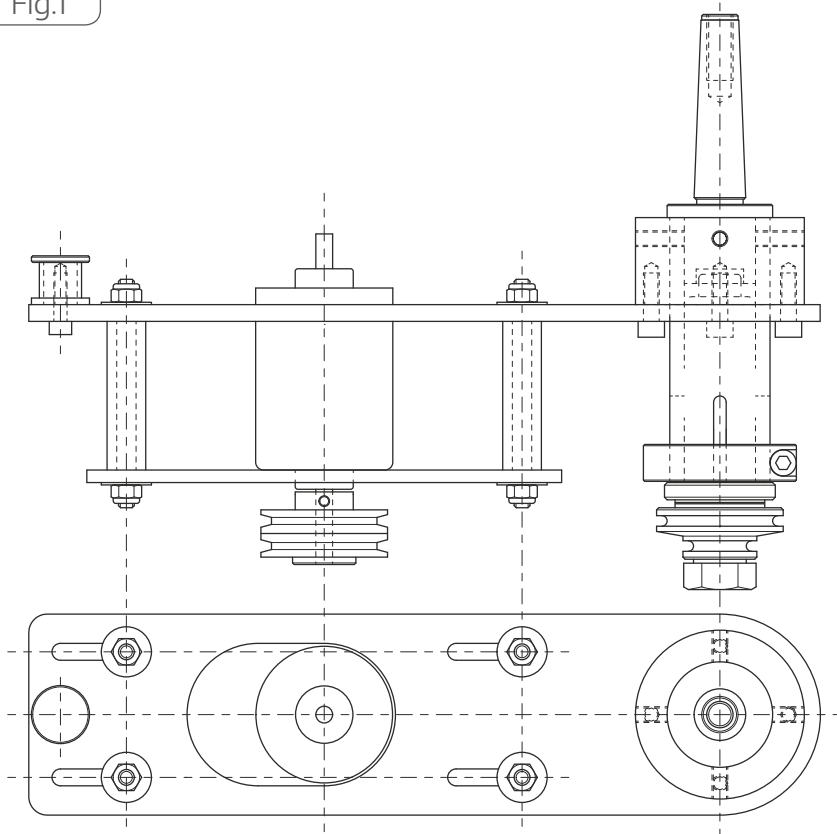
Requirements are to securely and quickly hold the engraving spindle in line and true to the milling machine spindle.

Provide an adjustable mounting point for a 12 volt DC motor to drive the workspindle using a 4mm diameter polyurethane endless (welded) belt.

The attachment consists of a 4-split tube engraving spindle holder, that is held in the Number 2 Morse taper of the milling machine spindle by the machines integral draw/eject bar.

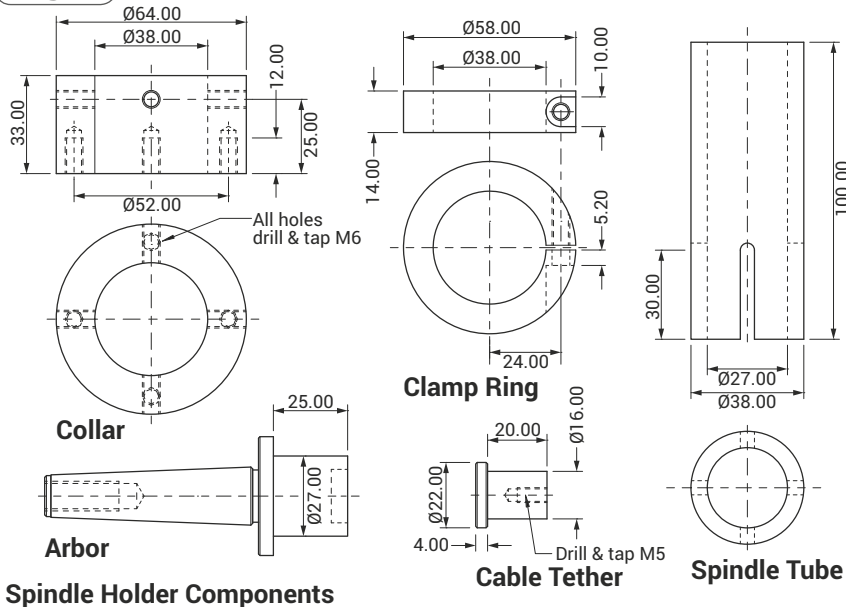
The engraving work spindle is held in this 4-split tube assembly by a split clamp

Fig.1



General Arrangement Of High Speed Engraving Attachment

Fig.2



40mm diameter, and the small one 20mm diameter, fitting a double groove pulley of 40mm diameter onto the motor will give drive ratios of 1:1 or 2:1 producing speeds of approximately 9,000 or 18,000 RPM at the cutter.

I will construct a dedicated AC to DC power supply unit producing 12Volts @ 15 Amps.

Spindle Holder - fig. 2 - Spindle Tube

Material - Aluminium Tube - 40 O/D X 25 I/D X 150 Sawn Blank

Set in a 3-jaw chuck and fixed steady to run true. The only boring bar I have to cover this length and diameter is a piece of 1/2 inch diameter bright bar about 450 long with a tool and clamp screw at one end. This slender bar was clamped in a quick-change holder with about 130mm projection, all the spare bar hanging out the back of the toolholder.

It looked ready to chatter even before I switched the lathe on, however with light cuts and adjusting the spindle speed, I quickly produced a perfect 27 diameter bore on size to suit the engraving machine spindle, **photo 3**.

Carefully remove the steady, turn outside to 38 diameter, face end and part off.

Spindle Holder - fig. 2 - Collar

Material - Bright Drawn Steel - EN1A - 75 O/D X 40 Sawn Blank

Hold in outside chuck jaws, drill and bore to

or jubilee hose clip.

A long mounting plate with 4 motor plate adjustment slots, is secured to the spindle holder with 4 x M6 cap screws.

This plate is also secured to resist rotation, to a bracket that Wabeco use to hold a guard.

A shorter motor mounting plate is secured parallel to the long plate by 4

spacer studs with washers and Nyloc nuts at each end.

The motor is secured to this mounting plate with 4 x 5mm cap screws.

This chosen motor is rated no load speed 9,778 rpm, producing max power of 150 watts @ 12.5 amps, the engraving machine spindle has an integral drive pulley with 2 belt positions. The large pulley is



Boring Tube

38 I/D sliding fit to spindle tube, face front square to bore.

Hold on inside chuck jaws in 38 I/D bore, turn outside to 64 O/D, Face to 33 long parallel, remove all sharp corners.

On the milling machine hold component in a table mounted chuck, set to drill and tap 4 x M6 x 12 deep holes on 52 PCD.

Please note the 4 x M6 peripheral holes are drilled and tapped later.

Spindle Holder - fig. 2 - Arbor Material - Soft End Blank Arbor - MT2 - Head 40 x 30 - M10 Tapping

Set lathe for turning between centres, turn to 27 O/D sliding fit in spindle tube, for a distance of 25. Hold in chuck on 40 diameter portion, drill and bore to clear end of engraving machine spindle, photo 3.

Spindle Holder - fig. 2 - Clamp Ring

Material - Aluminium

Prior to making this item I tried a jubilee hose clip it worked perfectly so I never made the split clamp.

Spindle Holder - fig. 2 - Cable Tether

Material - Steel

Turn to detailed sizes, remove all sharp edges.

With all items on fig. 2 completed its time to use your favourite fitters glue to securely fix the spindle tube to the collar.

Please note and make sure the tapped holes point in the correct direction before applying said glue.

Stand parts vertically on a bit of plastic to keep ends flush, allow to fully set, **photo 4**.

Photograph - 4

Carefully clean off any stray glue, a simple set up on the spin indexer was used to hold this component for milling four slots, drilling and tapping 4 x M6 as per drawing.

A piece of bright steel bar 300 long of 25.4 diameter, with a centrally tapped M8 hole about 30 deep from one end, hold in a collet in the spin indexer.

Turn two aluminium stepped bushes and



Time to Fully Set

a clamp washer to locate the component on the 25.4 tapped bar.

Position all items to clamp against the collet face using a stud and nut in the tapped hole, **photo 5**.



Holding Fixture

Mill 4 slots, set to new position, drill and tap 4 x M6 peripheral holes through both collar and spindle tube, **photos 6, 7, 8**.

Remove all burrs or sharp edges and thoroughly clean, slide the 27 diameter portion of the blank arbor into the top of spindle tube, ensure it is fitting correctly.

Once again, it's time to use your favourite fitters glue to securely hold the arbor in place.

Allow to fully cure with the component standing vertically on the M10 tapped end, this should keep any spare adhesive from creeping down the spindle tube.

When fully cured fit 4 x M6 grub screws into collar. I used dog pointed screws tightening them hard against the steel arbor, ensuring a solid joint.

Mounting Plate - fig. 3

Material - Bright Drawn Steel Flat - 75 x 300 x 6.35

When machining components of this type I always use a table cover made from MDF 18mm thick. This protects the table from machining damage and provides somewhere for drilling dowel locations for the component, I use this method for both CNC or manual milling and drilling.

A cover board lasts for ages and can be turned over for a second lease of life, it also encourages set ups at different positions along the table, which evens out wear along the total range of table movement, breaking the habit of always putting a vice central and wondering why there is more backlash in the middle.

Start with a piece of MDF cut to match the full table size, mark and draw full length lines to match Tee Slot centres (3 lines for the Wabeco). On the centre line, mark end hold-down holes 25mm from each end and drill through 16mm diameter.

When drilling MDF grind the drill with zero rake angle (as per brass) and run at a slow speed, with a correctly ground drill this produces an accurate size hole and minimises flying dust, but always use a mask for protection and vacuum up any dust immediately.

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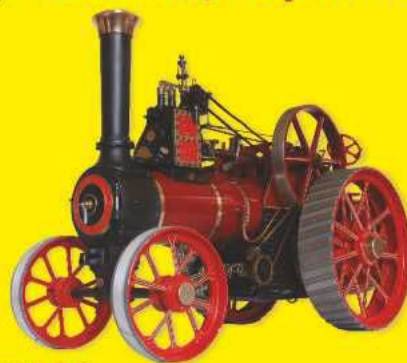
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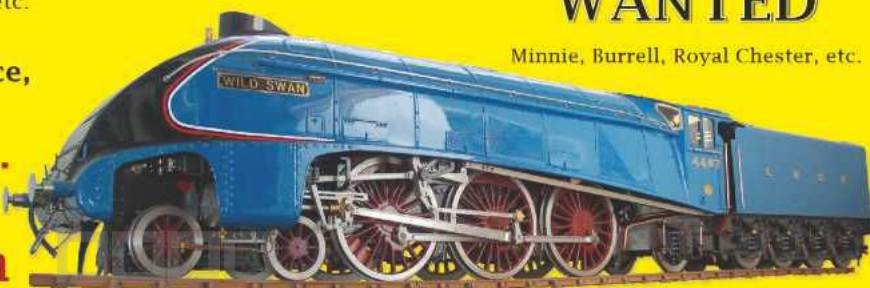
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