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MAY 2009

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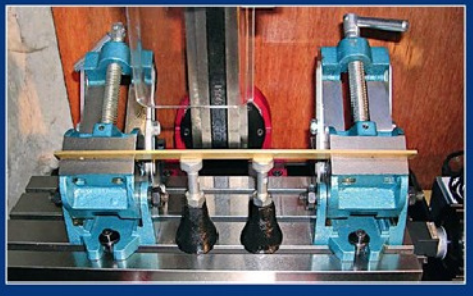

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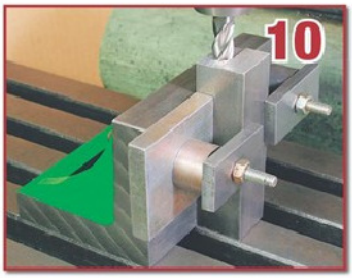

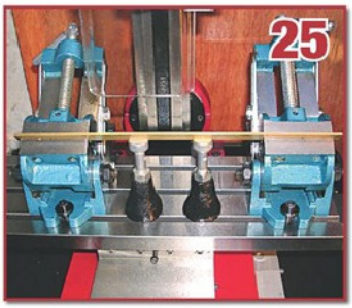

ON THE COVER

Ken Willson's Harrison M300 lathe. This lathe will be converted to inverter control in a future issue of MEW. Photo by Ken Willson.

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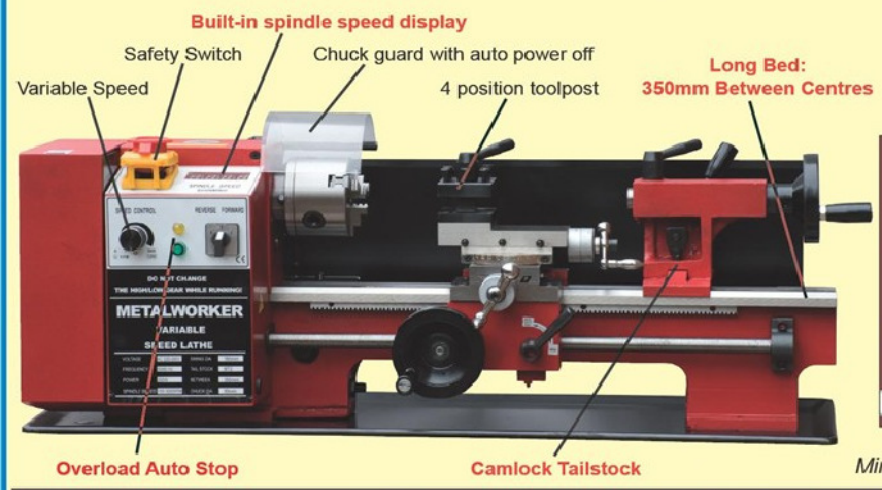

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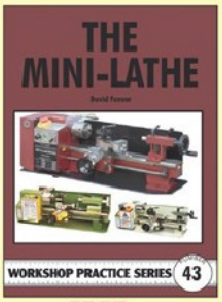

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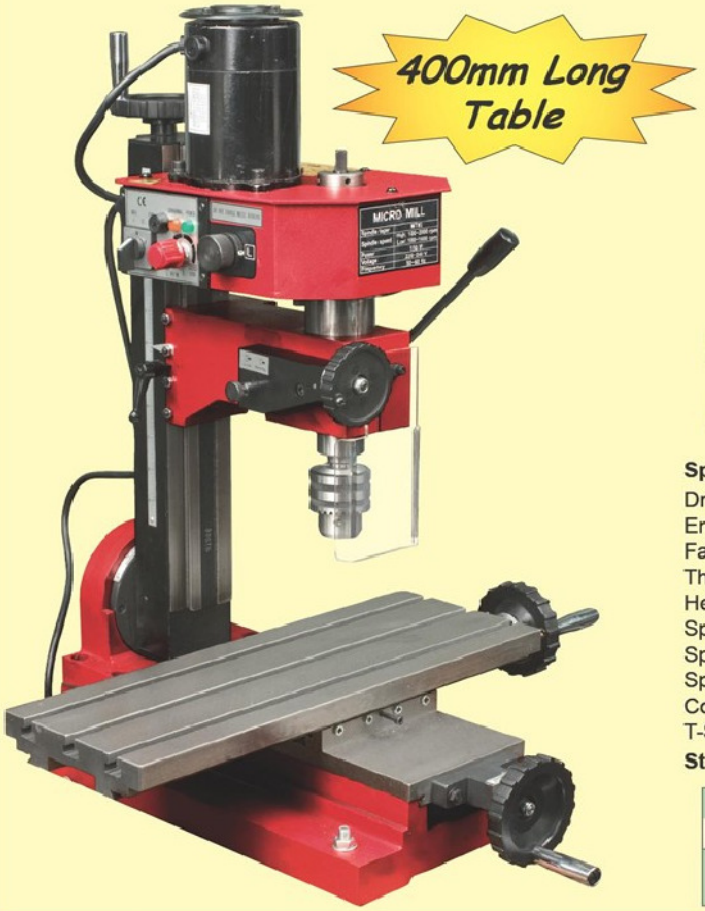

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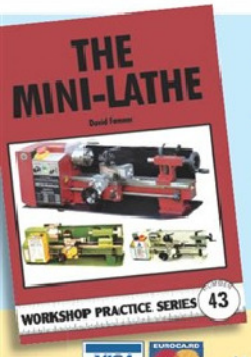

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ON THE EDITOR'S BENCH

Supply of Model Engineers' Workshop (also Model Engineer)

W.H.Smiths are rationalising a lot of their magazine stocks. This means that if a magazine does not sell a certain amount of copies they may drop it from some of their stores. Loosely stated, if a magazine sells 2 or less copies per issue, Smiths will drop a title from their shelves. They are not bothered if the two people can't get their favourite magazines. This means that possibly 100 Smiths stores will no longer stock either Model Engineers' Workshop or Model Engineer; that is around 200 customers who can't buy their magazine. This does not only apply to MyHobbyStore Ltd. magazines, it applies to all companies magazines.

We are trying to negotiate around this and that is one of the reasons for the special magazines. It is seen as supporting our brand through adding special magazines on a regular basis. The unfortunate side to this is that Smiths insist on exclusive rights to the specials. That would be ok if all branches of Smiths stock the special but they don't.

Still the best way to get your magazine is by subscription, and direct debit is the easiest way to do this. I have arranged a very special subscription gift for this issue. It is Harold Hall's new Metalworkers Data Book. I have organised this as the book really is an excellent buy and it will be very useful in everybody's workshop. So, subscribe today, get your free Metalworkers Data Book, save money and get your magazine about 5 days earlier.

The good news is that the latest Special should be on sale during the shelf life of this magazine. Readers' Workshops should hit the shelves in early May. You can preorder a copy via www.myhobbystore.com or from customer services on 0844 8488822. Full details should appear on page 57 of this magazine.

The bad news is that I have been asked to do three more specials next year. It is my own fault, if I do a special, it sells well. Suggested titles for next year are British Narrow Gauge Railways, Model Engineering For Beginners and The Best of Model Engineer Volume 2. (The best of Model Engineer Volume 1 is due out in September this year.

European and Australian subscriptions

European and Australian magazines are now sent by airmail from the UK. This means they arrive within a few days of printing. Never have they arrived so quickly. Combined with the new larger size printing of the addresses, everyone should receive the magazine with minimal disruption. Perhaps we can look at US subscriptions direct from the UK. I will ask the question but don't hold your breath yet.

A short holiday

I am taking a working Holiday during Easter week so will not have been answering phone calls or emails so please be patient. I will be visiting several places of interest including Model Engineer exhibitions and other attractions, some of the advertisers in MEW and ME (the Myford open day) and various Tramway/railways. Hopefully some readers will have come up and said hello.

The Harrogate Model Engineering Exhibition

This exhibition is one of the best if not the best exhibition on the circuit. It is on from the 8 to 10 May at the Great Yorkshire Showground, Harrogate North Yorkshire, HG2 8PW.

Contact Phone Number: 0844 3573464
http://www.eventsandexhibitions.net/
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info@eventsandexhibitions.ne

The Exhibition site is off the main road and is down the side of Sainsburys supermarket. Leaving the event on Friday night, you might be stuck in the queue for an hour or so if past years are anything to go by. Saturday and Sunday will probably be easier.

More visitors go on Friday than the Saturday or Sunday. It has been suggested that there are bargains on the Friday if you get there early. This is probably incorrect. The bargains are much more likely to be on the Sunday when traders don't want to pack up their goods to take home.

The other reason for visitors to come on a Friday is also a fallacy. Contrary to opinion, Saturday and Sunday are not overridden with children. So, the best day to visit the exhibition will be the Sunday, the Saturday or the Friday in that order.

This is probably the only exhibition that Arc Euro Trade attends. It is reasonably local to them so is cost effective. Because their stock control is tied in to their web site, they have to close the web site down for the exhibition periods so if you attend, have a look at their stand. A lot of their products will be on display and they will almost certainly be demonstrating their CNC mills.

I shall be at the exhibition for all three days this year and you are all welcome to come and talk to me. If you can't find me, use the tannoy. Hopefully I won't get struck down by a mystery bug like last year.

During exhibition week, I will not be taking phone calls or answering emails from the Wednesday till the following Monday inclusive.

Larger than usual lathes

Ken Willson's Harrison M300 lathe is on the front cover. I have a couple of articles in hand about this larger than usual lathe. It has been mentioned in some emails received that we tend to concentrate more on the Myford style lathe than some of the larger lathes like Boxford's and Raglan's. I can only publish articles that are received. If no one writes about the larger lathes, they won't appear in MEW. I have received no articles about the Unimat or similar small lathe either recently. Over to you, the readers.

Free catalogue

A few readers rang to say that the free catalogue from MSC/J&L was not free as they were charging £5.95 postage for it. I rang MSC/J&L and asked them why they were charging post and they said they had decided to charge for postage as they were in danger of running out of catalogues. I asked them to drop the postage price to ME and MEW readers as there was no mention of postage when we agreed the free catalogue. They would not drop the postage charge. The original agreement was a free catalogue with no postage charge. I am sorry they changed the agreement after a couple of weeks but I had no control over it.

Machine Mart has a new Spring Summer catalogue out. 29 of the Machine Mart stores are now open on Sundays. The catalogue has over 800 new lines and some massive price cuts. Tel: 0844 880 1265 for the catalogue request order line. Order online at www.machinemart.com

Open evening

Scarborough & District Model Engineering group will be having an open evening on Tuesday 21st April 19.00 onwards, all are welcome. The College is on Scalby road (Whitby direction) next to the hospital. When arriving at the College entrance turn right, then to the end of the short road, then left and left again, where you will find the workshops. A display of this and previous years work will be on view. For further details phone 01723 362537.

WORKPIECE CLAMPING

Harold Hall makes a welcome return and looks at clamps and clamping

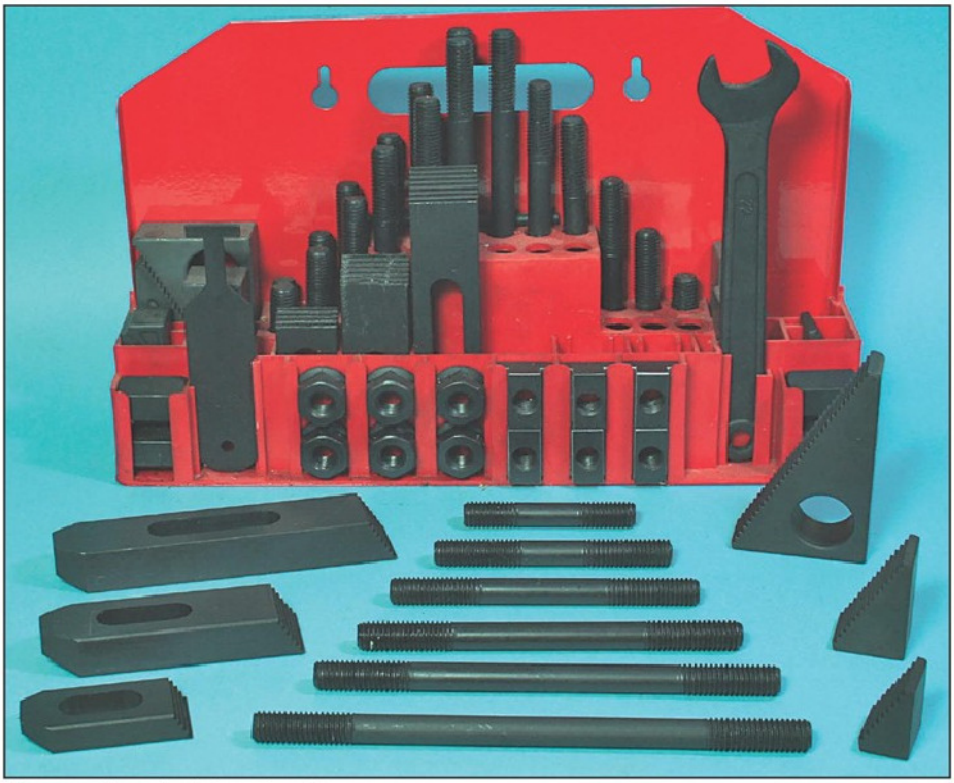


Photo 1. A typical clamping kit.

It was a chance hit on a metal working forum on the Internet that prompted me to write this article. In this, a correspondent had purchased a milling machine, together with the usual accessories, drill chuck, tilting vice and a face cutter and as cash remaining was limited, enquired if one of the clamping kits was really worth purchasing, no doubt thinking in terms of that seen in **photo 1**. Many of those who replied suggested that a milling machine vice would be a better buy, whilst one said save your money and make them yourself.

For my part I felt that the replies left much unsaid and that if money really was limited, a milling cutter chuck was far more important than a vice, as most work can be done without one, and certainly more important than a clamping kit. However, I visited the forum a number of times to catch up on the answers being given and considered that it would be worthwhile putting together some thoughts on the subject of workpiece clamping.

Vices

Readers may remember that in my series of projects for the milling machine, I made very little use of the vice for workpiece holding, not using one till the last project in the series, the grinding rest in issue 89, page 18. It would be false economy to attempt permanently to do without one. Unfortunately milling vices are expensive and often more robust than the average home workshop owner requires. However, there is no other option unless you purchase a drilling machine vice, one or two of which are suitable for light duty milling, typically the "Neal Drill Press Vice" **Ref. 1**. Do take care though in making such a choice as the majority of drilling machine vices are totally inadequate for milling duties.

The advantage of using a vice over any other method is the speed of clamping. Even so, placing the vice with its jaws perfectly in line with the table's axis can be a time consuming task and a deterrent from adopting this approach if for a one off component. It has also advantages when very small components need to be held as these can be a problem when other methods are considered.

A major disadvantage when machining a number of identical parts is the problem of getting the second and subsequent parts in the same position as the first so that when using the table stops, or working to the same dial readings, all parts will be dimensionally the same. However, this is easily achieved by adding a fence, or two, to the angle plate or the machine table direct. Attachments for adding to the vice are available to assist in positioning parts but I suspect they will not meet the need in many instances.

Table Clamps

We return now to the main subject of this article, table clamps and at this stage those in **photo 1**. Whether these will suit your requirements will of course depend on the type of work being undertaken as they tend to be on the large size for the average home workshop activity. This should be evident from the mock up shown in **photo 2**. I should add at this stage that to minimise the number of photographs, some setups show a range of possibilities and are not for any particular application. Others, whilst showing an application, are a simulation having been taken with workpieces already made and completed earlier.

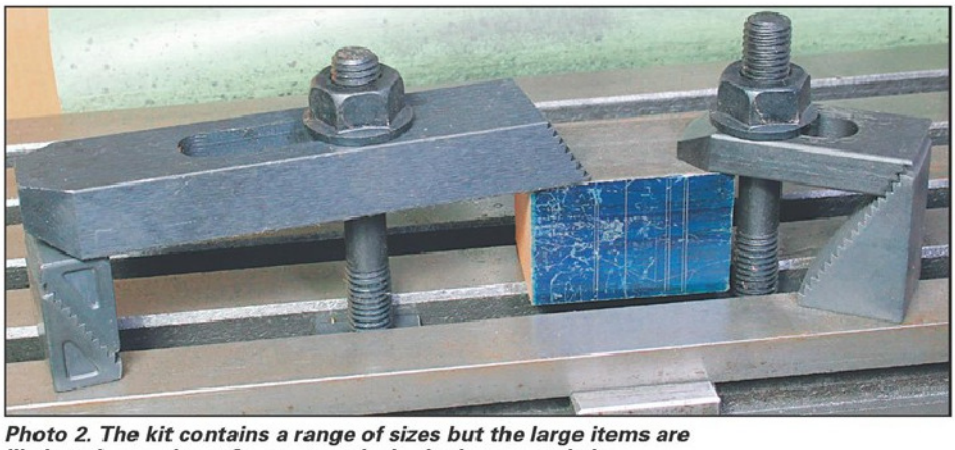


Photo 2. The kit contains a range of sizes but the large items are likely to be too large for most tasks in the home workshop.

Photo 1 showed the kit having three sizes of stepped blocks, three sizes of clamps and six lengths of studs from 75 mm to 200 mm as well as T nuts, etc. There are also stud couplers for use when a longer stud is required though these are unlikely to be a requirement in the average workshop. To complete the picture, the T nuts in the featured set are for 16 mm slots and the studs are 12 mm diameter. Even a smaller set for 14 mm slots still has 12 mm studs.

Unless you are into restoration work with full size projects, machine tools, steam engines, traction engines and the like, or perhaps model making at the very large scales, I consider that these kits are over robust for the vast majority of the tasks likely, **Photo 2** I feel shows this, particularly the larger clamp on the left. Not only are they too robust but their large size will often require more room than is available on the average home workshop mill.

For the reader who is not conversant with stepped blocks these can be used in pairs as on the left or with a clamp bar as on the right of the photograph. The steps, at 3 mm spacing, are sawtooth in shape ensuring that the two parts firmly lock together.

Lighter weight clamps

Suppliers to industry do supply individual items, clamps, stepped blocks, etc. to the same design as those above and down to an 8 mm stud size. Even these though are probably too robust for the majority of the tasks undertaken on the milling machine and there would seem therefore no alternative but to make one's own. In any case, the stud size will be dictated by the size of the T nut required for the T slots on the machine. They are M12 for my machine.

An important advantage of making one's own is that they can be economically made in a wide range of widths and lengths. **Photo 3** shows some typical clamps and I would suggest a minimum of four of each size made. Also shown in the photograph are some T nuts, also shop made. Of particular interest are those shown at the extreme left and right in the front row. These it will be seen are tapped off centre and they provide some flexibility in the positioning of the stud providing greater reach or spacing. This I find often gets me out of an otherwise difficult situation where the limited size of the average mill/drill table can sometimes make mounting the workpiece, or larger machine vice, more difficult than anticipated, occasionally, even impossible.

I am not including any dimensions for the clamp bars but obviously the longer the clamp the greater should be the thickness. As a rough rule of thumb, up to 50 mm long use 25 x 6 mm section, up to 75 mm long use 32 x 8 mm and over 75 mm long use 35 x 10 mm.

Studs will be required in a range of lengths but I suggest you standardise on a thread size of M8, or say M10 if you have a larger size machine. When I purchased my machine and made my own T nuts, I equipped it with both M8 and M10 sizes, the latter are only vary rarely used. Studs are one area where I consider it worthwhile you purchasing your requirements. "MSC/J&L Industrial Supply", **Ref. 2** supply a wide range of industrial clamping devices but being for industrial use they are on the expensive side. However, the studs are not overly expensive and I would suggest at least four of each length, these being 63 mm, 100 mm and 160 mm.

The rules

Much has been written regarding the principles of workpiece clamping and I am therefore going to keep my comments very brief.

1) The packing must be slightly higher than the workpiece.
2) Arrange the clamping stud nearer to the workpiece than to the packing wherever possible.
3) Do not use a single clamp unless the task is a light duty one and that the workpiece is further restrained by supporting pieces. At least two and preferably three clamps should be aimed at.
4) The clamp must be thick enough to prevent it noticeably bending.
5) Do not use an unstable pile of odd size pieces of material as packing.
6) When using slotted clamp bars do support the nut with a heavy duty washer, say 25mm diameter by 3mm thick for an 8mm stud, rather than standard washers. This applies equally to fixings in angle or faceplates.

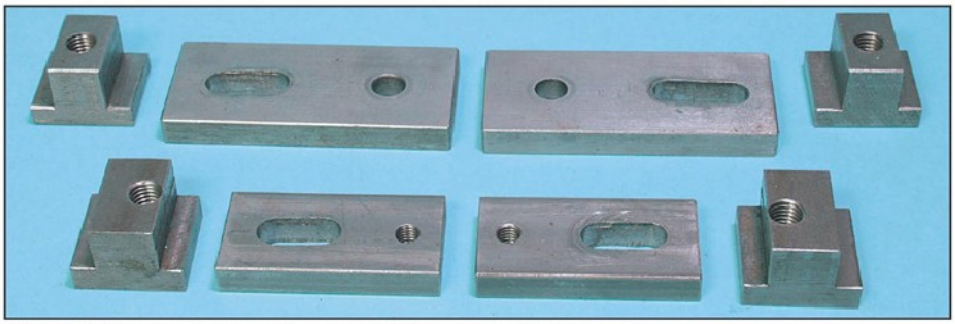


Photo 3. For most tasks, shop made clamps are likely to be more suitable than those commercially available.

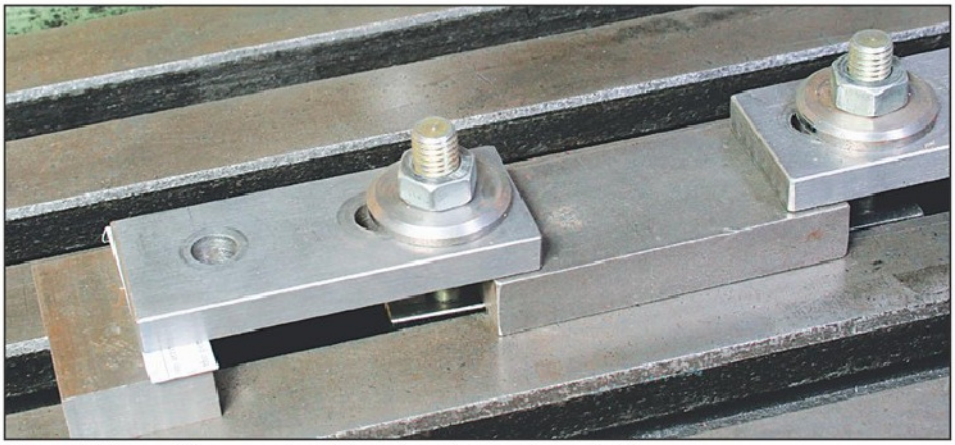


Photo 4. The packing must be higher than the part being held. If using a piece of the same stock bar as the part being machined as packing, a piece of thin card will provide the difference.

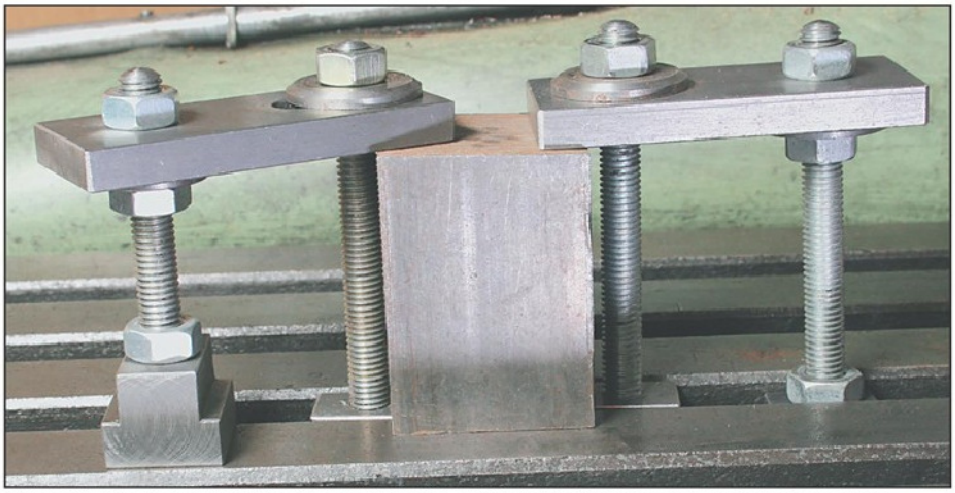


Photo 5. Studs nutted into Tee nuts make setting the height of the clamp bar easy.

The packing

The height of the packing under the outer end of the clamp is critical and I would suggest this to be within one to three millimetres higher than the workpiece. The closer the packing is to the workpiece the smaller should be the difference. What form this packing takes will depend on the situation.

If the item being clamped has been made from a piece of stock bar then a piece off the same bar, maybe another part also being made, can be used as the packing by adding a piece of hard card under the clamp at the packing to provide the difference required. **Photo 4** is an example of this with clamps at both ends of the workpiece. Do not attempt to use this approach without the additional thin packing as the inevitable bow, even if minute, will result in the clamping force being only at the workpiece edge. A piece cut from a discarded credit card is ideal for this task.

Another form of packing and one that provides considerable variation to its height is a jack. For shorter heights you do not need to spend time or money acquiring jacks for this purpose, a T nut with a screw threaded into it will provide an adequate alternative. Facing the top of the screw head to remove the raised lettering often present would though be a good idea. I would recommend that the height of this makeshift jack should be no more than three times the length of the T nut's base, perhaps a little more if the T nut is placed in the machine's T slot.

Another method that provides continuous adjustment of height and one that I use extensively can be seen in **photo 5**. In this a stud is screwed into the T nut

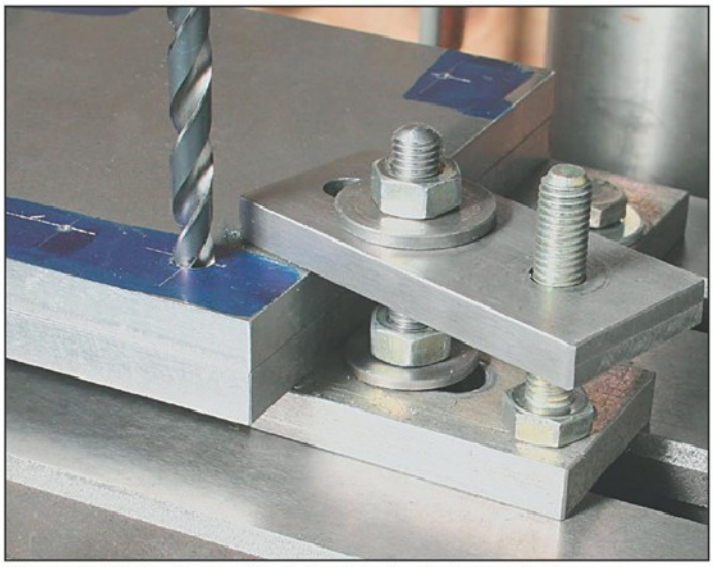


Photo 6. With a tapped hole in the clamp bar a single screw will act as a jack to set the clamp's height.

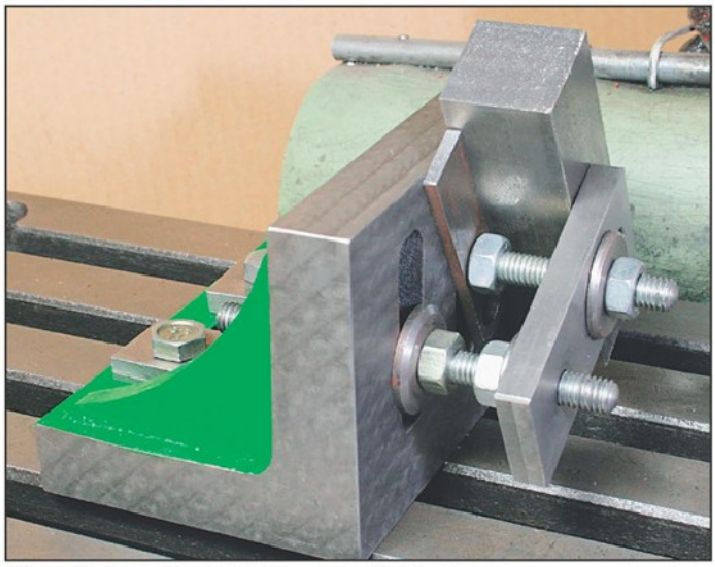


Photo 7. A stud nutted into an angle plate can be used to set the clamp's height.

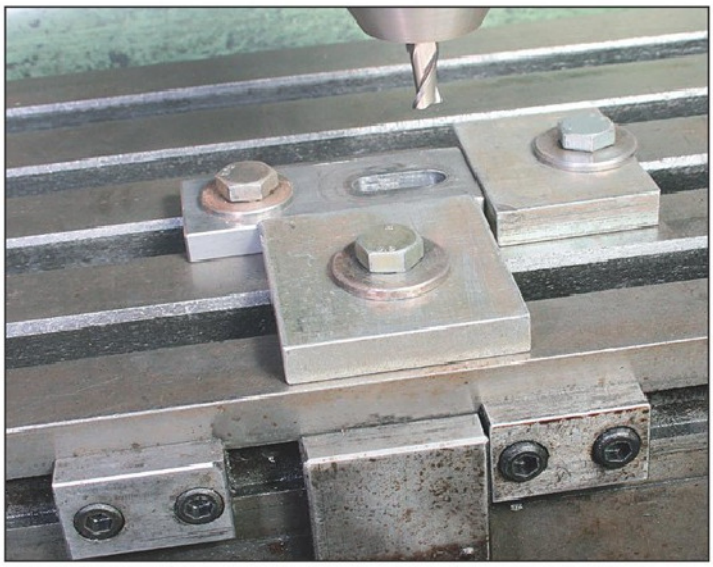


Photo 8. Holes in the part being machined can often be used to anchor the part onto the machine's table. This can even be a single hole if further supported, as the picture of some clamp bars being made shows.

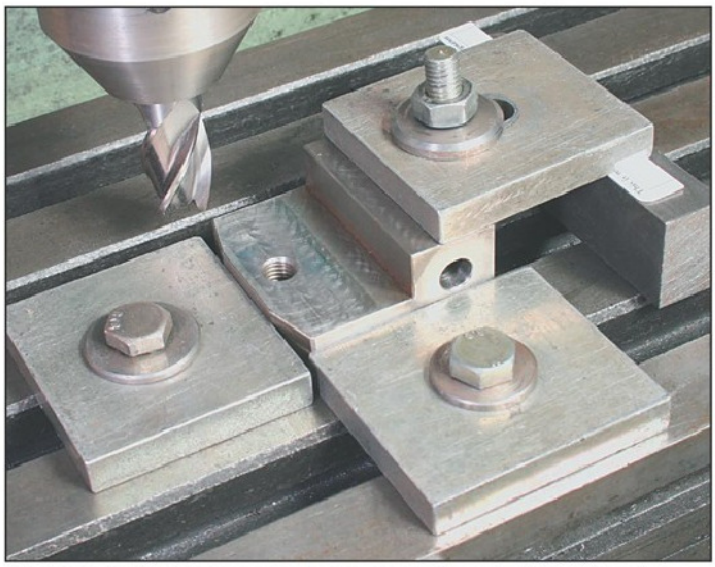


Photo 9. A single clamp is not ideal but if used with correctly placed support pieces, quite heavy machining can be undertaken.

and locked in position with a nut. A nut and washer are then placed on the stud and adjusted to the height required (workpiece height plus a millimetre or two). The stud passing through a hole in the clamp then has a nut and washer placed on top of the bar and tightened in place. Whilst this nut may be superfluous I consider it adds to the stability of the set-up. If the clamp is positioned so that the T nut can be placed in the T slot (right of photograph) this is preferable. However, if this cannot be done then standing the T nut on top of the machine table as seen on the left is perfectly acceptable. Once again note how the clamping studs are closer to the workpiece than the packing.

Yet another version, having continuous adjustment for the height of the packing, is for the clamp bar itself to have a tapped hole with a screw added to act as a built in jack, **photo 6**. This method is particularly good for low packing heights. Again, machine away the raised lettering on the head of the screw. To prevent the drill hitting the worktable note how in this example a clamp bar has also been placed under the workpiece to raise it from the machine table.

Using a stud to provide the adjustable packing is equally at home for mounting items onto an angle plate as **photo 7** shows. In this case though, the packing stud can be firmly anchored in the slot of the angle plate before the height of the clamp bar is set. A major advantage of this method if multiple parts are being made is that the clamp will remain firmly in place between removing the finished part and fitting another. It will only be necessary to loosen the clamping nut as flexibility in the set-up will be sufficient to permit parts to be removed and replaced with ease. In this setup it is worth taking notice of the fact that the clamping stud is also being used to hold in place a fence for setting the angle of the part being machined. The angle of the fence can be accurately set even before the angle plate is brought to the machine table making it an easier operation.

I think that this example clearly illustrates the advantage of using an angle plate, rather than a vice, for such operations.

Additional Supports

Working with a single clamp should normally be taboo, certainly when the part being held does not provide for easy and secure clamping. In some cases though, access for clamps can be limited and getting more than one in place can be difficult. In this case, providing the part is not over complex and the machining operation not too arduous, additional support around the part will ensure a sufficiently secure mounting is achieved. **Photo 8** shows a simple example of this, it shows the slot in a small clamp bar being made and illustrates another possibility, sometimes holes in the component itself can be used for securing it for machining. Actually, in this case, the two supports have added benefits in that subsequent parts can be positioned so that the groove can be made in the same place without the need for measurement or reference to the leadscrew dials. All that is required is that the table stops, seen in the lower part of the photograph, are suitably set. You can see that there is no reason why you should not make a quantity of each size of clamp.

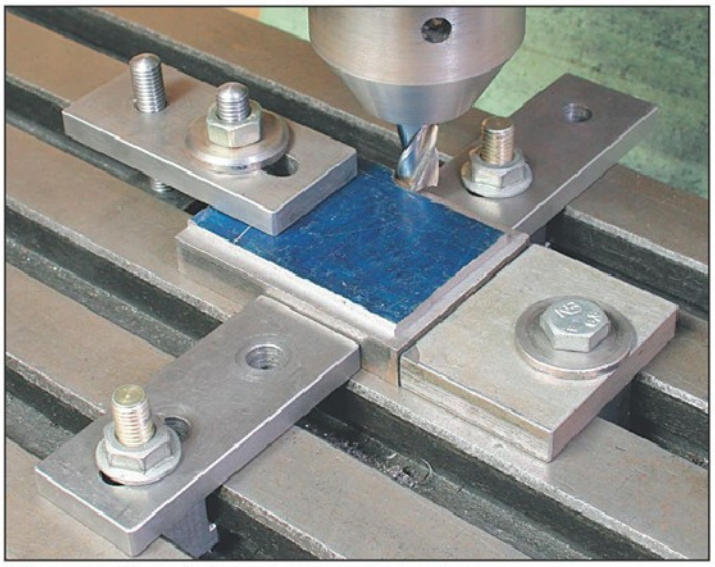


Photo 10. Slotted clamp bars can be used as supports and permit adjustment of position to suit the size of the part being machined.

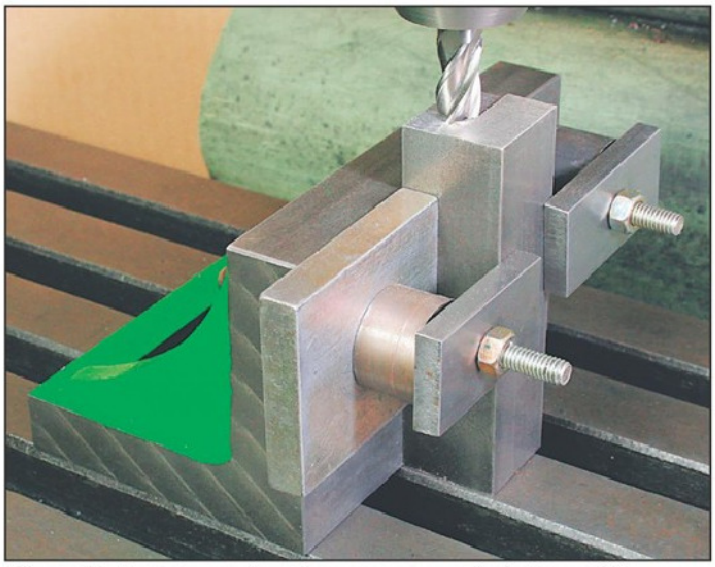


Photo 11. A compact clamping system, particularly useful on small angle plates and faceplates. The assembly also includes a fence to set the workpiece upright.

With care, even relatively heavy machining can be undertaken with just a single clamp and some support pieces. It is though essential that the support pieces are positioned to oppose the forces created by the cutting action. In **photo 9**, the rotation of the cutter will attempt to force the part towards the bottom of the photograph and if a sufficiently wide cut is taken, to pull the part from under the clamp. With two supports being positioned to resist these forces the task was undertaken without undue concern, even though there was a fair amount of material to be removed and relatively heavy cuts were taken because of this.

You may consider that this would have been a natural candidate for using a vice but this method was just as quick as adding the vice to the machine table.

Photo 10 shows a part requiring a recess to be made around three sides and illustrates that clamp bars themselves make excellent supports. They are essential for supporting a part across the width of the table as their slots provided the adjustment to suit the width of the part being supported.

Compact clamps

Another form of bar clamp that I developed, initially for use on the lathe faceplate is also very useful on the confined space of an angle plate, especially a small one as **photo 11** shows. I have featured this a number of times in my articles **Ref. 3** so it would not be appropriate to go into detail yet again. However, note that I have again incorporated a fence into the assembly and am sorry to keep referring to them but they do make it easy to position the part for machining, even in the case of a one off.

Stepless clamps

This is the name given to this form of clamp in my catalogue but I am sure that other suppliers will have other names for them. Their main feature is that they avoid the need for packing, achieving this by virtue of their shape. Whilst made in a number of forms they all work on the principle illustrated in **Sk. 1**. They are also made to suit a number of stud sizes, but with 12mm appearing to be the smallest they are best suited to heavy duty applications. In the case of the 12mm size the maximum height clamped is around 40 mm, though of course this could be increased by adding a packing block at the non workpiece end.

Toggle clamps

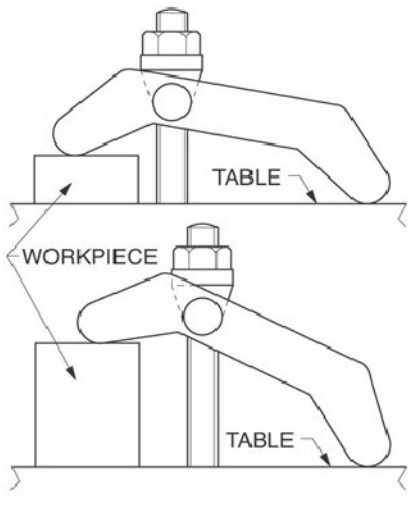
Another form of work table clamp that can prove very useful is the horizontal toggle clamp being especially useful for batch production due to the speed in which the clamping force can be applied and removed. However, on the minus side they cannot cope with variations in the distance between the faces being clamped, it is therefore only appropriate for parts that are dimensionally consistent. Even so they can be beneficial in some cases with just a single or a few parts where it would not be too daunting to adjust the clamp for each one being machined.

They are always used on one face with a fixed jaw supporting the opposite face of the component, as seen in **photo 12** but being capable of a considerably force the fixed jaw must be firmly fixed as should the jaw move, if only very slightly, subsequent parts will be held much less securely. Because of this the fixed jaw should be fixed with screws passing through it rather than an overhead clamp and the clamp itself should similarly be securely clamped, maybe with additional rear supports as seen in the photograph.

Vertical toggle clamps are also made but I would be hesitant to use these for milling operations unless they were very heavy duty clamps and then only if side support was added by some means. They would though be useful for drilling applications where, if used with a fence or fences to support the part, multiple parts could be made without having to mark each one out individually, **photo 13**.

If you would like to make these toggle clamps they were featured in MEW **Ref. 4**.

Sk. 1



STEPLESS CLAMPS

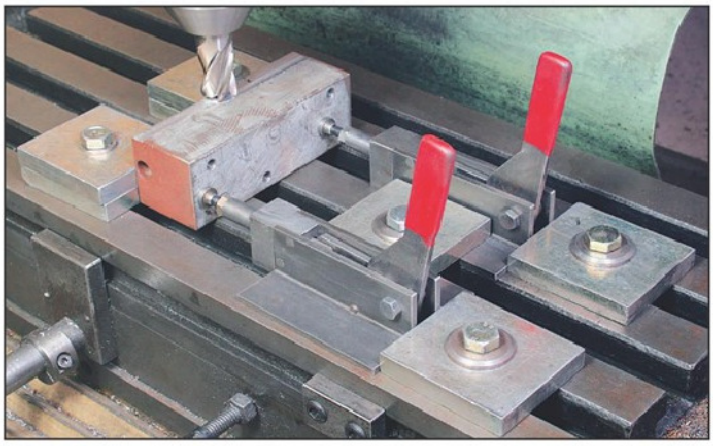


Photo 12. Toggle clamps are capable of considerable force. Because of this the fixed jaw must be firmly fixed as must the clamp itself.

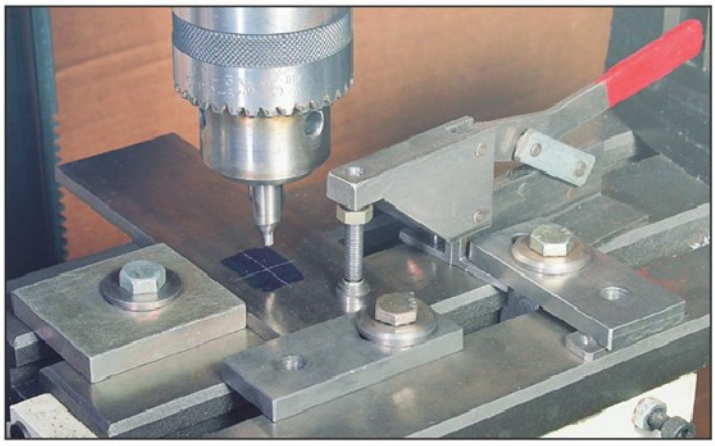


Photo 13. A vertical toggle clamp with guides being used to produce a batch of identical components on the drilling machine.

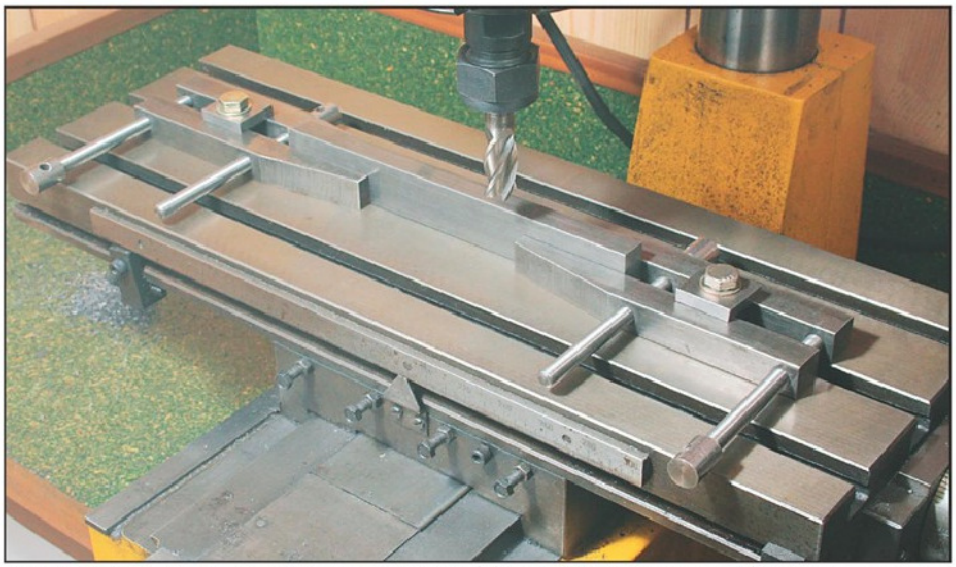


Photo 14. Requiring to reduce a one inch bar along its length to twenty-five millimetre, toolmaker's clamps made the top surface fully available for machining.

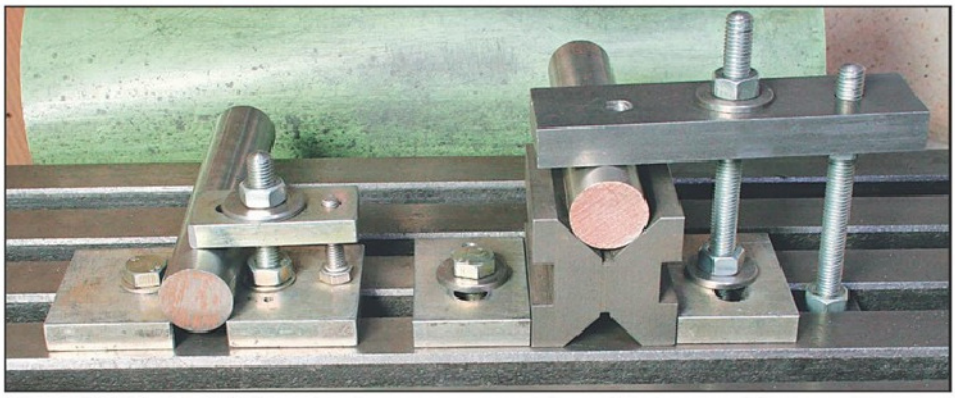


Photo 15. The setup, left, makes it easy to accurately position a round item on the machine table and has the advantage of being able to work with a very wide range of diameters from a few millimetres up and also longer lengths than a Vee block can.

Toolmaker's Clamps

These are frequently used to hold a workpiece to an angle plate or some other table mounted item, using them either exclusively, or together with other clamping devices. However, using toolmaker's clamps needs to be done with considerable caution as this is one situation where the clamping force is not just applied at the clamp's tip but equally along the whole length of the jaw.

If the jaws are too far apart the clamp will pivot about the jaw's end whilst with the jaws too close the jaws will contact the workpiece near the centre screw and the clamp will pivot about that point, it may even slide off the workpiece. It is therefore, essential that the clamp is set accurately, adjusting the width between the jaws using the centre screw and applying the pressure with the outer one. Vary these adjustments until the clamp cannot pivot either at its tip or adjacent to the centre screw.

Another method of using the toolmakers clamps is to use them as low level vices as is shown in **photo 14**. In this case the bar had to be reduced from 1 inch to 25 mm, requiring it to be surfaced along its complete length. With the two clamps fitted and adjusted as above, they were held to the table with the two clamps making the task a simple one.

Holding round items

When round items require holding, the vice will first come to mind. If this is just to machine a small flat to take the end of a grub screw for holding a pulley then this is probably the way forward if the vice is already on the table. If though a keyway is required needing to be axially in line, the vice will need to be accurately positioned, a task as mentioned earlier that can be time consuming.

The set-up shown in **photo 15** (left) will overcome all these problems. Mount first the left hand plate using a square off the table front edge to position it accurately. Then mount the right hand plate using a suitable width of parallel to ensure the two edges are parallel. Note that the right hand plate is held by the stud that also secures the workpiece. Just one comment is worth making though. If this is the first time you are using a square off the front edge of the machine table then check that the setting is parallel with the machine's axis using a DTI just in case the edge of the machine table and/or your square have major errors. Having checked and accepted the result once then the method should be considered acceptable for future applications providing the process is carried out with care.

If you are considering using a Vee block as an alternative be warned. The force from the overhead clamp will be attempting to force the Vee apart and it is known for this to split the block into two parts. Even if you are confident of the strength of your Vee block, getting this accurately positioned can be a problem. Setting the Vee block between two plates in a similar manner to that proposed above would suffice, **photo 15** (right).

If attempting to use a Vee block for a small diameter item, then this may fall below the top of the block and clamping the part could be a problem. With the method proposed, a wide range of sizes can easily be accommodated from as little as 3 mm up.

Using a part from the assembly being made

Do not overlook the possibility that some other part in the assembly being made could be used to hold another for machining, being particularly useful where angles or complex shapes are involved. Having to machine the edges of a gib strip for use in a dovetail slide, setting up the

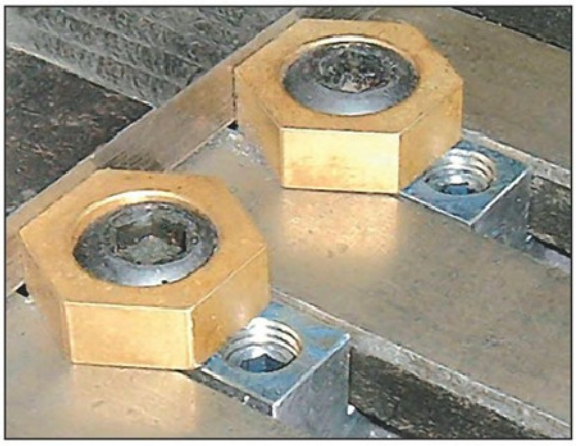


Photo 16. Two low profile clamps. The cam action of the off centre head screw makes it possible to hold thin parts to the machine table.

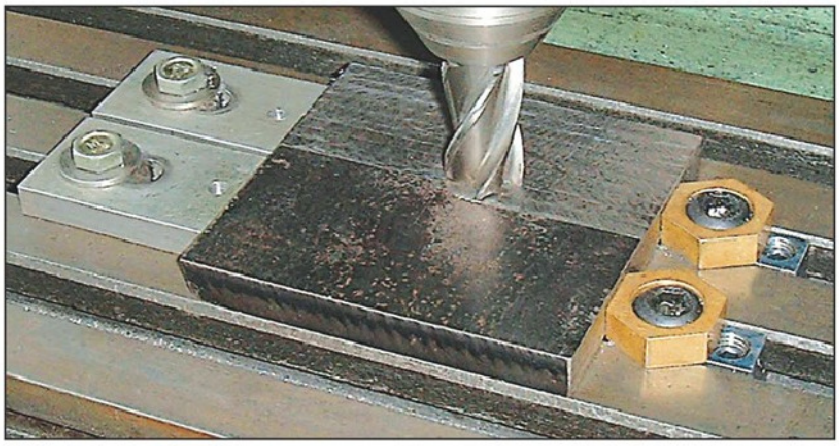
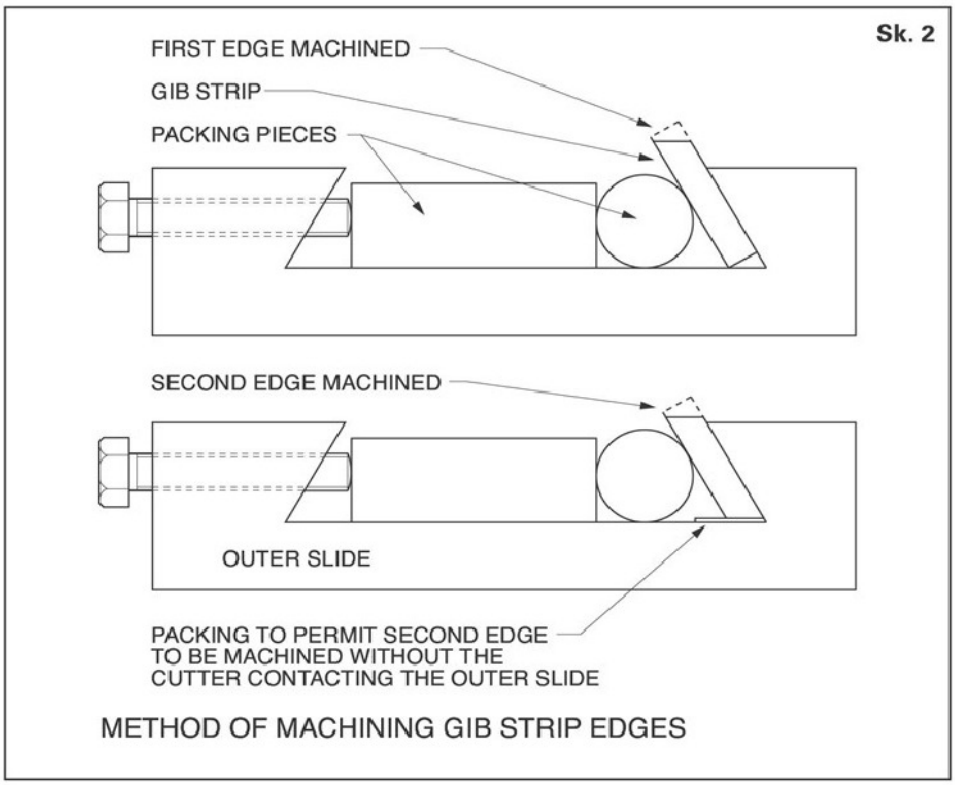


Photo 17. Two clamps being used to hold a piece of black iron whilst it is being reduced to the thickness required. The clamps are always used with fixed opposing jaws.



tilting vice looked inevitable but the length of the gib strip was much longer than the width of the available vice. Having some reluctance to the method I hit on the idea of using the outer dovetails to act as a jig for holding it whilst having its edges machined, I no longer have a photograph available of this setup but **Sk. 2** should indicate the process adequately. This avoided the need of accurately setting up the tilting vice, and yet guaranteed that the angle was precise.

Low profile clamps

Reference to an industrial suppliers catalogue such as that for "MSC/J&L industrial supply" **Ref. 2** will show that there are a number of specialist clamps intended for the purpose of clamping relatively thin items to the machine table whilst still leaving the workpiece top surface free for machining. **Photo 16** shows a typical example.

The Tee nut itself is fixed firmly in place by the grub screw seen at the right hand end being tightened onto the base of the T slot to fix the nut's position. The head of the main screw is off centre from the thread and rotating it will, as a result of the head's cam action, advance the hexagon clamp piece to provide the clamping pressure. One advantage of these is that if a number of clamps are employed, irregular shapes can easily be held as the clamping action does not need to be axially in line with the T slot holding the nut. However, for rectangular parts just two clamps will suffice when used in conjunction with a fixed jaw as seen in **photo 17**. Where batch work is being undertaken the clamps have the advantage of being able to cope with a fair range of variation to the size of the parts being machined.

Their main advantage is that they make some tasks easy that would otherwise be difficult to perform without them, perhaps even impossible. **Photo 18** shows 5 types for construction in the workshop. They were featured in a previous issue of the magazine, **Ref. 5**. Of course, not all five types are necessary and the reader can choose which one that suits his or her needs best. I would though suggest a minimum of four, all the same type or two and two.

The requirements for mounting workpieces onto the machine table are very varied and the suggestions in this article can only cover a small number of them. However, the basic principles will be the same for almost all situations so hopefully will help to give the workshop owner some confidence about even the most complex set-up. ■

References

1. Neal Drill Press Vice ref. DPV004. Available from CHRONOS LIMITED, Unit 14 Dukeminster Estate, Church St, Dunstable, LU5 4HU. Tel: (01582) 471900 E-mail **sales@chronos.ltd.uk** Web site www.chronos.ltd.uk/
2. MSC/J&L Industrial Supply, 7 Pacific Avenue, Wednesbury, West Midlands, WS10 7WP. Tel 0800 663355 E-mail **sales@wscjlindustrial.co.uk** Web site www.wscjlindustrial.co.uk
3. Faceplate/angle plate clamps, MEW issue 20 page 24, update issue 25 page 67
4. Vertical toggle clamps, MEW issue 9 page 33. Horizontal Toggle Clamps, MEW issue 10 page 54.
5. Low profile workpiece clamps, MEW issue 118 page 12

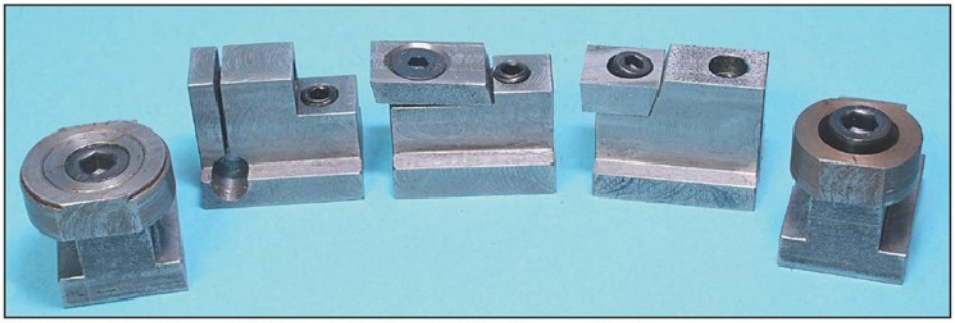


Photo 18. Five forms of shop made low profile clamps. Ref. 5.

BUILDING A CNC ROUTER 3

John Rutter continues construction of his Mk2 router.

The machine frame

The frame is made from 75mm x 50mm pine, not as mentioned in the drawing in the last issue. Do try to find some straight stuff without too many knots. I had to settle for some with a few longitudinal "shakes" because it was straighter than the rest in the hardware store. In my case the entire unit is to be attached to pulleys to hoist it into a ceiling space in an attic dormer window, **photo 38**. In your case it might be better to buy more material to make legs.

I learned the hard way with my Mkl machine that flat surfaces "ring", so for the MkII I wanted to use as little flat area as possible. This meant arranging for cross members to fit at intervals along the frame, so for this purpose I used a friends table router to cut a groove about 12mm deep and 19mm (half way) lengthwise in the timber. This in turn meant that some 50mm x 25mm could be cut to slot into this groove reasonably accurately and be moveable if desired.

Again, I had limitations you might not have. I couldn't go beyond 1250mm in length to fit the space the machine was to be used in which gave a bit of head scratching in order to get in the desired 915mm cutting length. The frame itself is held together by 4in. long no.10 screws, I didn't bother with glue, **photo 39**. It should give no difficulty in construction but do make sure you get it "square". I found that putting the frame together was the easiest way of getting the holes for the X supports in the right place too. Just put the brackets into the corners and mark off where the holes should go. Disassemble the frame to make drilling easier and reassemble after fitting the lengths of M6 captive thread, **photo 40**. If you drill the holes 5mm and put a slot into the end of the steel thread then it can be screwed straight into the wood with an electric drill/driver to the required depth. Don't glue the threads in place as this makes them VERY hard to remove and makes assembly of the X drive components difficult too. Guess how I know about this?

I primed and painted the frame with household paint as it's quite a large object and the paint was handy. Once the moving parts are fitted to the frame the X drive belts can be connected up. They are tensioned carefully to keep the Y slide "square" to the X but otherwise setting up is simply a matter of threading them through their respective slots and pulling the belts tight while tightening the M4 Allen head cap screws to retain them. It has to be said that this is easiest done with another pair of hands but it isn't impossible on your own.

For the electronics I initially used boards from www.routoutcnc.co.uk as I'd taken them from the Mkl machine.

Editor's note

This series of articles came about because John offered me an article about building a brushless motor. The article was published in MEW issue 135. Most reader's will not want to build their own motor so I suggest you have a look in a copy of RCM&E where you will find some advertisers who sell brushless motors and the ESC controller. You will also need a servo controller to control the ESC instead of the more normal radio control controller. In the "Model Engineer's and their Workshops" Special on sale in May, there is a photo of Stuart Walker's under construction Quorn tool and cutter grinder fitted with a brushless motor. It looks like there might be a future for brushless motors in model engineering circles.

Photo 38. The router in the raised position. The electronic board is on the right.

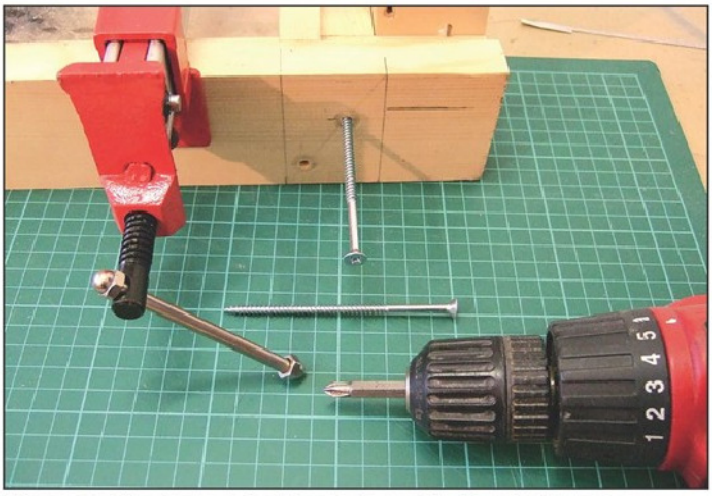


Photo 39. The frame is held together with 4in. No 10 screws. The frame is clamped with cheap sash clamps.

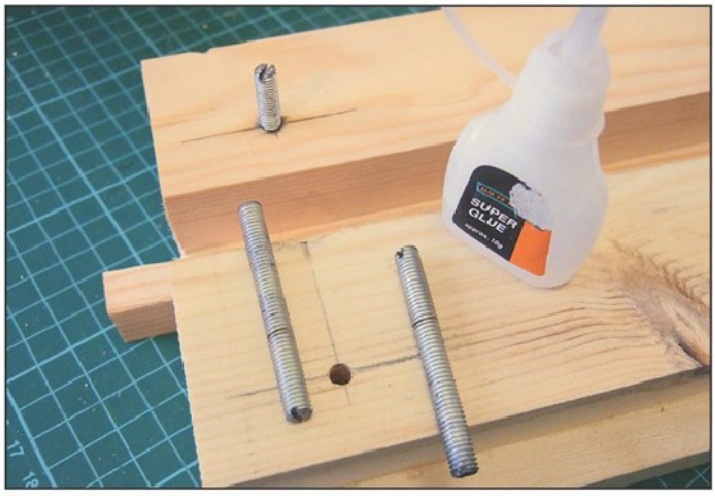


Photo 40. The 5mm studding is screwed into the frame to retain the X mountings. The studding has a saw cut to enable them to be screwed into place. Cyano glue is optional.

They work well with the 180 Ncm motors from Arc Euro Trade but they are a little bit bulky so I also bought a kit of parts from www.hobbycnc.com and made up a 3 axis driver that is more compact and capable of using a higher voltage input too. The electronics are mounted under the right hand end of the board, **photo 41** and they drop down for maintenance, **photo 42**.

I used a pair of fairly tired 12V lead acid batteries (originally fitted to an electric bike!) to drive the system at 24V and 2 to 2.5A. The computer was a left over from one of my sons. Routout software will work on pretty much any operating system but the more capable Mach 3 only runs under windows 2000 and XP.

The Routout system is a little more expensive than the HobbyCNC/Mach 3 combination but works well enough if you don't know your way around a soldering iron and don't need the features of Mach 3. Support from Mike Gaylor at Routout is only a Skype phone call away and very useful.

Both systems support home and limit switches but I only used the handy "home" switches. These give a definite starting point for cutting but both programmes can be configured to drive past them when cutting (the software seems to ignore the signals from the switches other than when homing) so I didn't fix the switches too strongly, hot glue or small screws are fine allowing the switches to move rather than break.

Y and Z switches were easily placed by fitting them to small ply plates glued in position on the appropriate bit of framework but I ran out of room for the X switch near to the X motor so initially put it on the other side of the machine, again fastening to a small plate first, **photo 43**. I then realised this would give problems with wiring so eventually moved it onto the travelling X section, again on a small plate, where it now works well. Wiring to the switches can be the same 16/0.2 equipment wire used for the motors but using 7/0.2 wire makes wire identification easier at the board end.

Remember though that one of the Z motor retaining bolts is left deliberately long to give an adjustable Z home switch trigger height. This is useful for speeding up operations if you tell the programme to go to Z home between drilling/milling operations (set it for minimum movement) but is easily adjusted out of the way if you use other commands and only go to home at the end of operations.

I've found the wiring can be a headache. Don't get me wrong, getting the wires to the correct connections is simple enough, getting them there *and able to move about without jamming or catching* is the hard bit. I was rather sloppy with the wiring on the MkI, using twisted equipment wire that dangled around all over the place but made an effort with the MkII. Commercial machines use a sort of linked track to carry the wiring, called cable chain (amongst other things) but it isn't cheap. It can be obtained from www.igus.co.uk for around £18/metre + VAT + delivery if you want to go that way but I made my own from an 8ft length of wooden conduit, bought from B+Q for £9.02, quite a saving in money but not time. I bought the smaller of two sizes on offer (it's 18mm deep), cut lengths at

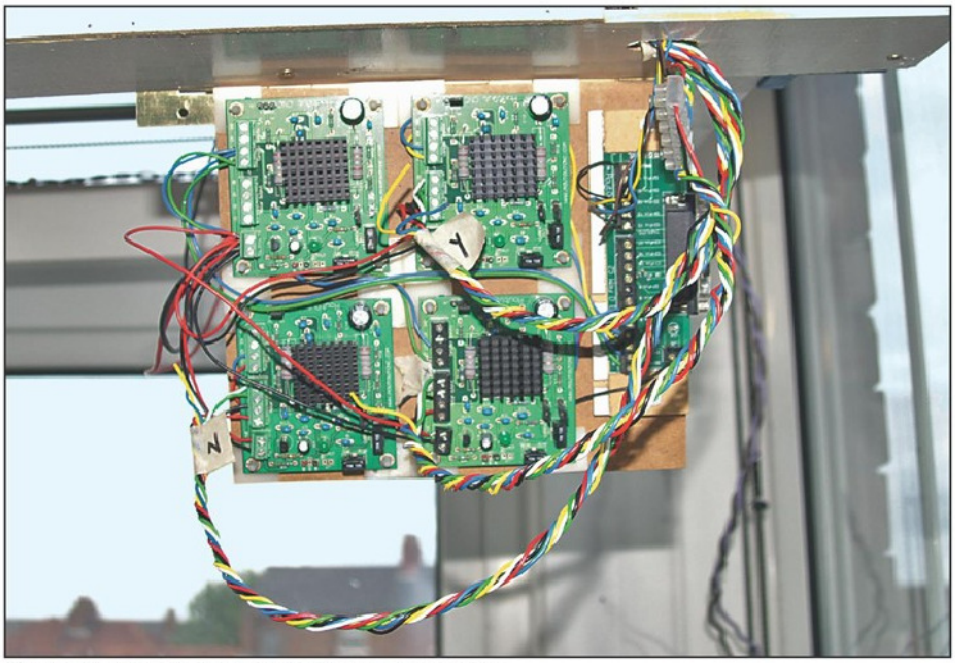


Photo 41. The electronics in the raised position.

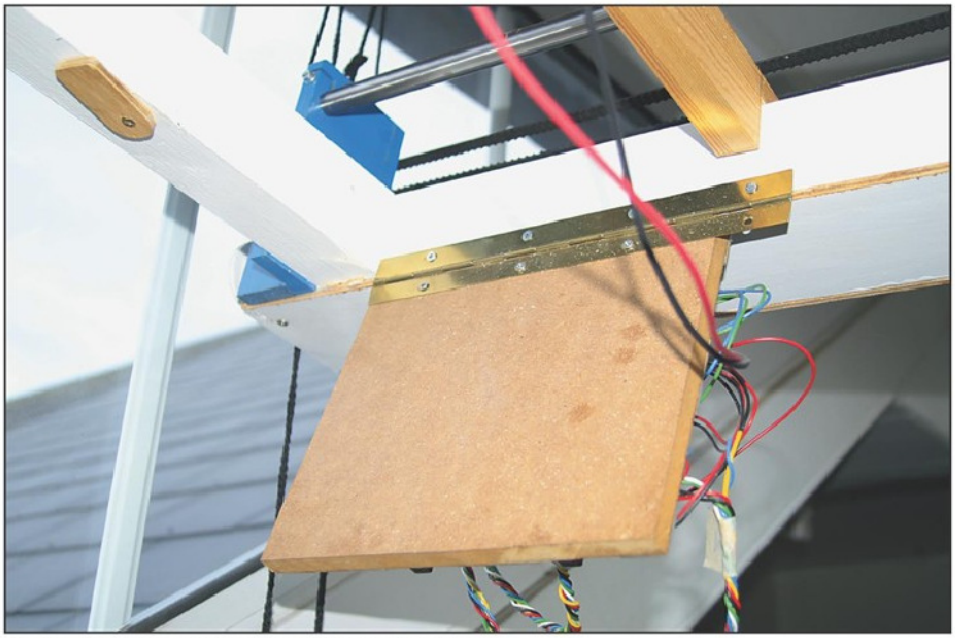


Photo 42. The board is hinged from the frame.

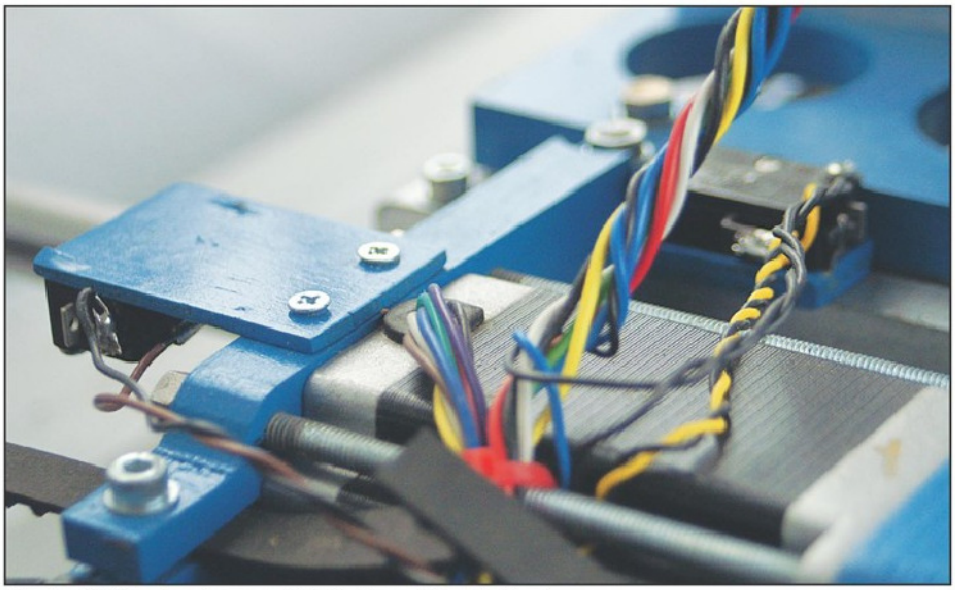


Photo 43. X axis micro switch (left) and Y axis (top).

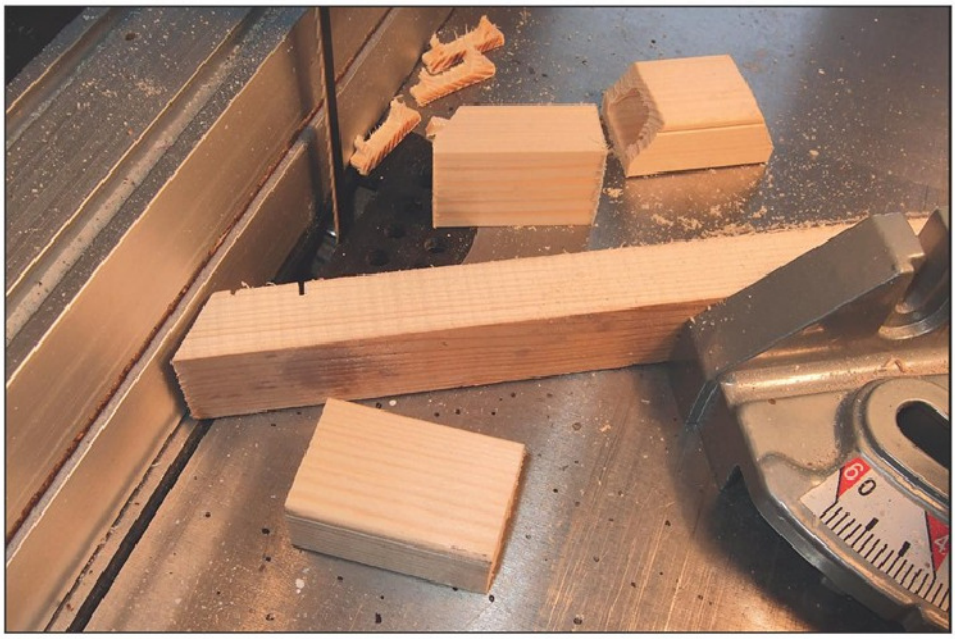


Photo 44. Cutting the wooden trunking to make the cable tracks.

40mm long on the band saw, **photo 44** then set the guide at 30 degrees in order to cut off just enough material for the cut to touch the top edge of the base, leaving the base entirely "square", **photo 45**. I "touched up" all edges later on a sander with a nice new disc. Take all the bits apart, clean up with glass paper and then spray paint with a coat of primer and whatever colour you fancy, **photo 46**. To link the sections together I used glass reinforced tape but could only find it in 50mm wide rolls. To use this, clean a long section of Formica work surface or similar with degreaser (acetone does fine) and lay out some glass reinforced tape on it (600mm+). Use a long straight edge and a craft knife to cut a strip 16mm wide. Lay out your open links of chain and tape together on the inside with the tape, **photo 47**. If the sections are painted then the tape should have no trouble sticking.

If you *do* have problems then a thin layer of contact glue (Evo Stick or the like) on the links, allowed to dry and a fresh bit of tape should do the trick. A simple jig such as a couple of lengths of wood nailed to a bench, suitably spaced apart, should make life easier. The end result should bend easily in one direction to roughly 75mm OD but not sag much in the other direction, **photo 48**. It's also hard to make it deviate from a straight line when laying back down, just what's required. Wire can either be threaded through the covered links or the coverings can be left loose until the wire is in place. The covering sections should keep in place by themselves, glue if they don't. A length of thin ply attached to the bottom of the frame supports the cable chain on the X motor side. In order to keep electrical interference to a minimum I put a chain on either side of the machine, one for the Y/Z steppers and home switch wiring, the other for motor wiring. The latter chain should be able to rest on the edge of the machine without the need for an extra shelf but a ply extension sheet is needed to attach the chain to the Y movement as it's dimensions don't allow it to attach directly.

Technically speaking the wire to an ESC for the spindle motor control should be as short as possible, no more than a foot (300mm) but I needed rather a lot more than this, around 6 to 8 feet, **photo 49**. To minimise back EMF pulses (the problem) I twisted very heavy duty wire, connected a 3.5mm plug and socket to one end (standard stuff for model aircraft use) and used a large (2200mf) capacitor across them using heat shrink tubing to keep everything together. The other end is merely bared for connecting to a 12V lead/acid battery, 24Ah in my case or fitted with whatever plugs you prefer.

I was going to use short cable chains to take the wires needed for the Z axis and motor power across the Y direction but the wood trunking would have been too big and clumsy here and in the end I decided to just let the wires hang from a small T shaped hanger, **photo 50**. The actual connections to the motors are given in the data sheet with the motors, with the

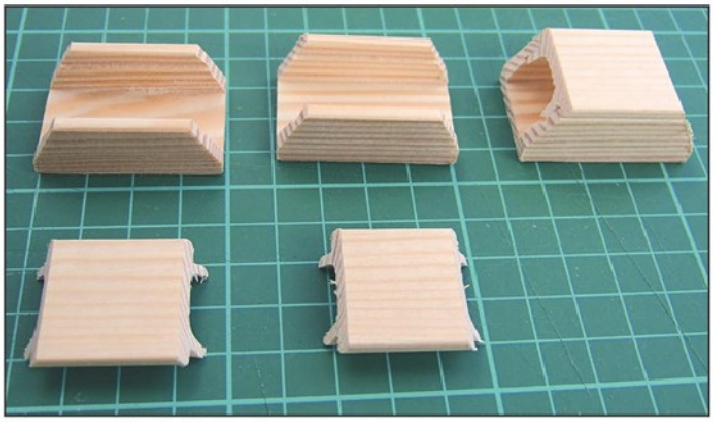


Photo 45. The individual parts....

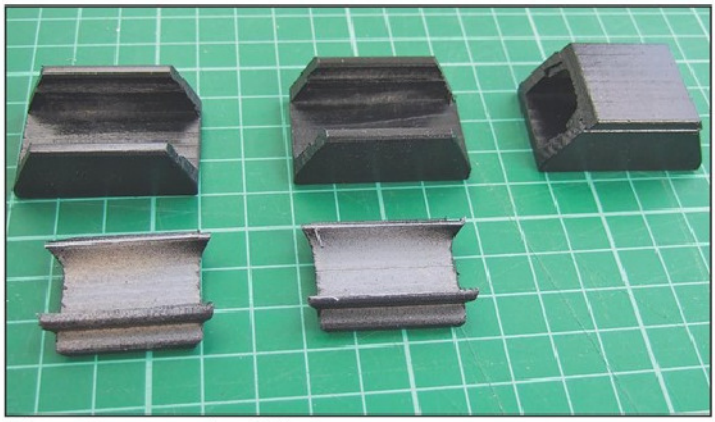


Photo 46. ....are painted black.

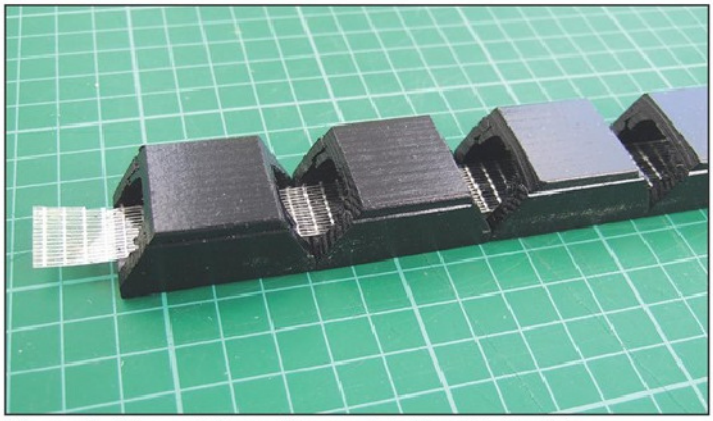


Photo 47. Glass reinforced tape cut to fit cable track inner.

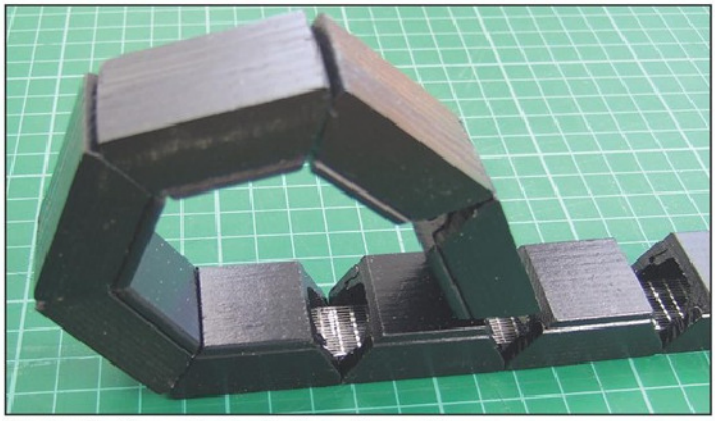


Photo 48. The cable track at maximum flex.

instructions from Routout or with the instructions from Hobby CNC if you use their equipment so I'm not going to repeat them here. As already mentioned, I used 16/0.2 equipment wire for the motors and 7/0.2 wire for home switches. All this sounds a bit complex but it is easier to do than describe and keeps things neat and tidy without costing a fortune.

To set the machine up initially, I'd suggest using a block or blocks under the X axis bars to raise them to the desired height after loosening the retaining nuts. Re-tightening the nuts after adjustment is finished of course. The motor holder itself can be adjusted for height and the Z axis can be set at any height in its range in software to give further adjustment. As I generally pierce the work I cut, this is usually accurate enough for me but if you wanted to engrave something for instance you'd need to make sure the cutter didn't vary in height across the machine. Probably the most accurate thing to do in this instance would be to set up as mentioned then use the broadest cutter available to mill out an area (pocketing) of a piece of sacrificial material (MDF is ideal) to which your work can be attached.

Once the assembly and wiring is complete, its time to get the computer fired up. Make sure your parallel port is set to standard parallel port (SPP) and not EPP or anything else. This will be set in the computers BIOS (hold down the Del key during boot up to get into BIOS or find a teenager to do the work for you).

Load up whatever programme you intend using such as Routout CNC or MACH 3 and load whatever setup screens you need. I set my electronic driver boards to give 1/8 micro steps. Done like this and with the pulleys specified, X and Y need 21 steps per mm. Z due to its screw thread needs 1600 steps per mm. This is why Z is slow in comparison to X and Y but as it doesn't have to move much it isn't really noticeable. Make sure the drives move in the correct direction by playing with the jog screens. If they are moving in reverse then change either a software setting or swap a pair of wires on the appropriate motor.

Routout boards use 4 wires in 2 pairs at the board end, other wires being joined at the motors if using 6 or 8 wire motors. Swapping any pair of wires but not both pairs, changes direction but this can also be done in software. If using MACH 3 software and the Hobby CNC hardware it's easier to change the software settings. Set your cutting speeds (around 6mm/sec is fine for ply but this will vary from material to material of course) and transitioning speeds (around 50mm/sec is ample, it'll go much faster but missed steps become likely) as well as acceleration (ramp move in Routout) to suit your preferences. Lots of acceleration (low ramp) risks missed steps; too much delay (ramp) makes things slow. It's probably worth defining the maximum number of steps available or size of the table to avoid the software trying to drive the hardware past the end stops. Limit switches can be used to this effect too. MACH 3 in particular makes lots of mention of emergency stop buttons, always a healthy option but this machine isn't exactly "industrial" powerful.

I draw my designs in a CAD drawing programme, save them as .HPGL (Routout seems to prefer this format) or .DXF and then import them into the appropriate

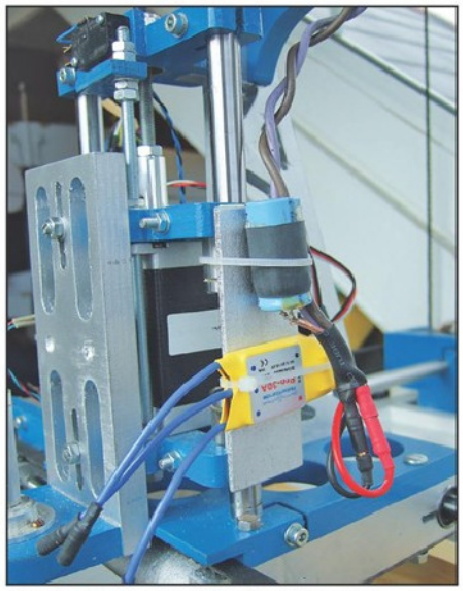


Photo 49. Heavy duty flexible wire motor power to the (yellow) ESC via a big capacitor.

Photo 50. The servo tester (black box with red tipped knob) to control the ESC/motor. Not the wires to the Z axis suspended by an elastic band from the cross arm and the micro switches for Z (top) and Y (lower left). Also note the pencil holder in the motor mount. This is handy for "proofing" files before committing to material.

programme. Routout uses Viewer to set things up for Manager, the cutting programme. For Mach 3 Lazy CAM does a similar job. Tool offsets can be set in either programme but it's often easier and quicker to use a "contour" tool to draw inside or outside your original lines in the CAD programme, exporting only these lines into the CNC programme for cutting.

That's about as far as I want to go on software as there are just too many variables as well as lots of different programmes out there. Mike Gaylor (Routout CNC) is happy to talk you through things, especially via Skype phones; otherwise it's a matter of reading the manuals, contacting the supplier or looking at web forums to solve whatever problems arise. Here I have to admit to finding some software problems as I'm not particularly "hot" with computers. An early incarnation of the router, used with Routout software under Windows ME produced wildly inaccurate results (up to 12mm out at the end of the run) a problem I cured by running MACH 3 under Win XP on a different computer. I put the poor Routout results down to a rogue file eventually.

The final version of the machine, as presented, initially gave inaccurate results with Mach 3 under Win XP but worked fine with Routout! It turned out that the machine had a pronounced "creep" under XP with MACH 3 due to the WIN programme generating extraneous "blips". There's a Yahoo group site for MACH 3 and from comments posted there my problems aren't unique and are nothing to do with the machine. There is an "XP optimisation" file on the Artsoft (MACH 3) website which is basically intended to make XP run nothing but MACH 3 so if you can, use a clean computer setup with as little software as possible (IE, NOTHING ELSE) on it. From my experience MACH 3 seems the more capable software (and is free for small file use) but it gave me the accuracy issues mentioned. Routout is simpler to use in lots of ways, gives excellent repeatability (usually) but is dreadful at "pocketing" (milling out areas) and seems to prefer slow speeds for the Z axis, even the damper didn't avoid the dreaded "squeals" here.

During the time I've been compiling this article the editor has been publishing a series on the use of MACH 3 and the information is just as applicable to this machine as it is with any other but I don't fancy writing G code from scratch personally. Lazy CAM simplifies the job for me but getting to know the programme still takes a bit of thought and practice.

So having finished the machine and used it is there anything I might have done differently? Thicker or shorter bars would make for increased rigidity, important if you want the machine for cutting metals, though not actually a problem even with the present design when cutting ply. Chopping the main (X) bars down to give a cutting area of around A3 size would help here.

After completing the machine I discovered that the STEP 4 router I used to use at work, of similar size, used 16 and 20mm diameter bars, more rigid than my 12 and 16mm diameter bars but more expensive both for the bars and bearings; I was doing my best to keep costs down. On a smaller machine, screw threaded drives are fast enough, especially when fitted with a damper device. They give a better theoretical accuracy but involve more parts (as used on my Z axis). A compromise might be to use a worm gear train to drive the belts and I nearly did this before deciding the extra complexity wasn't needed. I even got as far as buying two start, 20T worm and pinion gears (1:10 ratio) from RS Components so I might look into this in future if I feel I need a different machine.

Using metal to replace the wooden components would give more rigidity too of course but also take a LOT more work and money, don't let me stop you if that's your thing though and I'd be very interested in knowing how it turns out should you wish to go down that path. To be continued...

To Die, Now! (Better than 'Yesterdie'?) 2

David Piddington continues his looks at dieholders

I made three taper shank arbors, **Figs. 9 and 10**, one for me, and two more with a few pre-set dieholders for good friends. One of them used his before I had tested mine, only because I had not completed the machining of my dieholders. He telephoned me a day or so later to say he had made two modifications, a minor but important one which I really ought to have noticed but didn't. This was that the small drive key requires a flat on its outer end so that when the dieholder slides to its end, it will rotate and not bind while attempting to push the holder out of alignment while negotiating the curved end of the key. Observant readers will remember I have already mentioned this.

His second modification came about as he was making a stud, which required 3mm of thread on one end and 5mm on the other. He had graduated the top surface of the key into millimetres and after locking the tailstock, had used the gauge lines to set the lengths of thread and it worked for him. I gave further thought to this and have modified my prototype with two full length flats on the sliding diameter which you will see later and I graduated these, one in millimetres and one in one sixteenths of an inch.

To make the arbor there are two options as shown in the drawings. Machine it from solid or fabricate. I chose the 'chicken' principle - "Don't cross the busy main road unless you absolutely have to" and chose fabrication. My main reason for not machining from the solid is the length of the No. 2 Morse taper at 2½in. There are several methods of making this part.

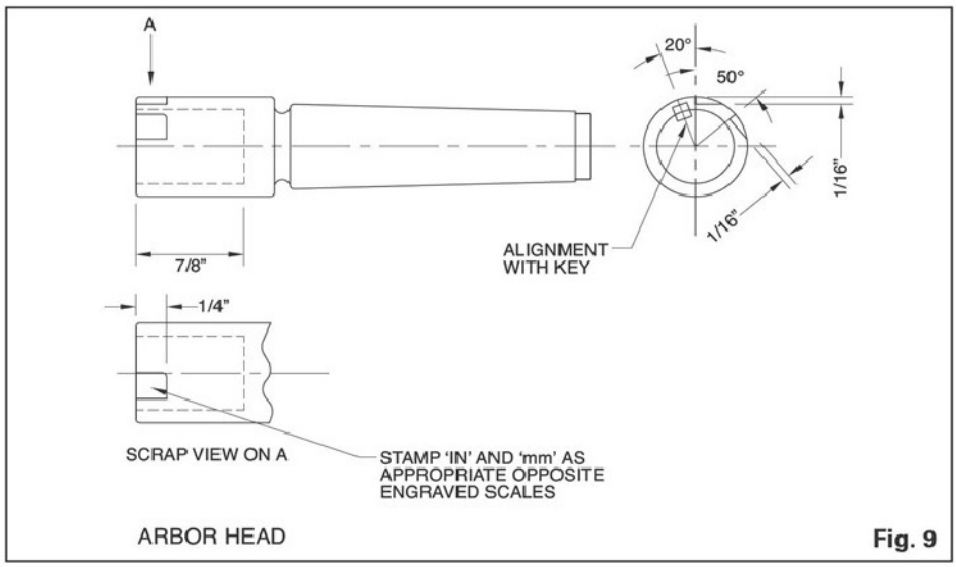


Fig. 9

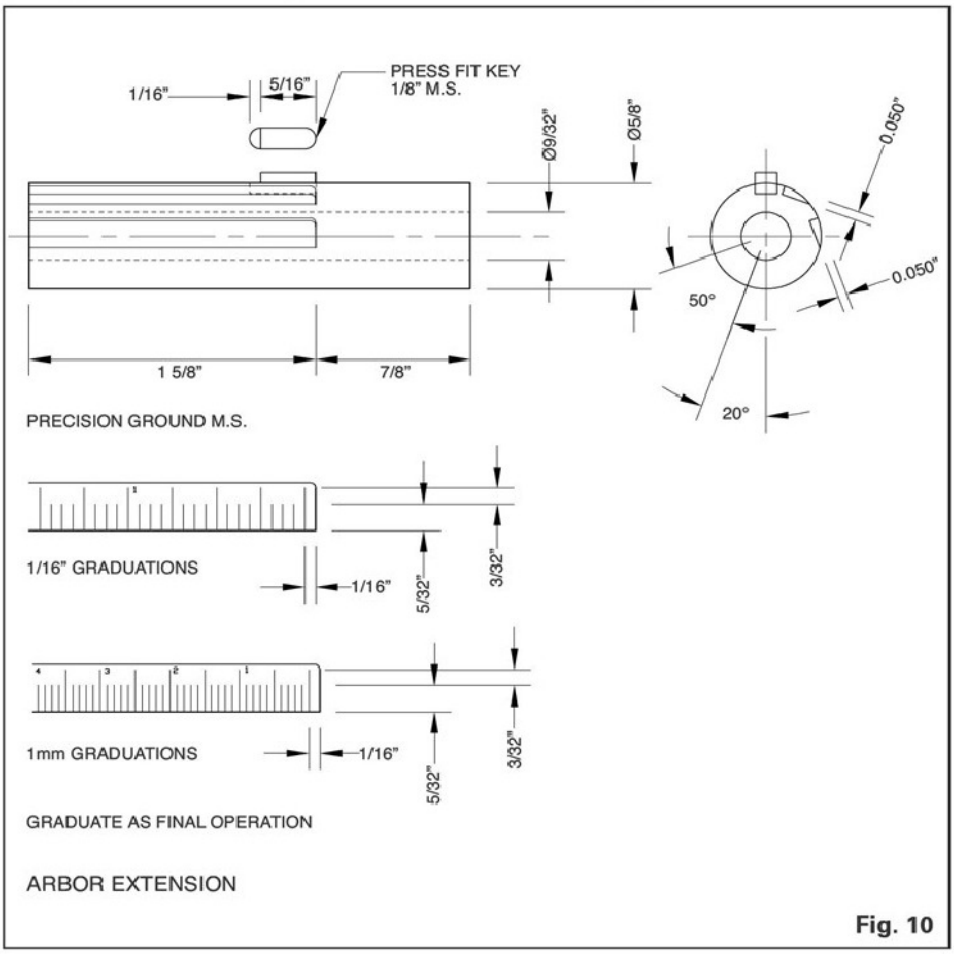


Fig. 10

Firstly one can set over the topslide but this in itself presents difficulties in setting the exact angle. Secondly the tailstock may be set over and adjusted after trial cuts to get the angle exact into a known hole. I recommend this to be avoided at all costs as it is equally difficult to set it back parallel again. Thirdly I have seen a device, which plugs into the tailstock and has a sideways slide with centre points, which may be used as method two above. In all these trial and error is required to get the angle exactly right.

My 'rough and ready' method for setting the angle is to remove the top slide itself leaving the swivel base in situ, position two 5/16in. diameter rods into each Vee and on the side away from you put an additional piece of ¼in. thick (minimum) MS plate about 2in. long and 2½in. high against the inner rod, and carefully clamp over the four components ensuring that the plate is exactly vertical. Then put a hollow lathe centre into the headstock spindle; a male centre into the tailstock and, between the two, your second male centre with the small end of the Morse taper towards the tailstock. This of course assumes that your lathe head and tailstocks are exactly in line, which should be checked on a regular basis according to the maker's operator's handbook.

It is now possible to wind in the cross slide until the MS plate touches the taper along its length. Lock the topslide base at this position and the subsequent taper turned should be accurate. If not it can be adjusted with emery cloth to be a better fit in your tailstock using marking colour to show high spots. The snag here is that it is very difficult to keep the relatively tiny top slide feed screw turning slowly and evenly. Much practice is required, but it can be done. If you have followed this method successfully, then inserting the taper into the headstock will make machining of the

parallel parts much easier provided that your lathe turns parallel.

As I said above, I preferred the 'chicken' approach and fabricated mine from a readymade accurate commercial blank end adapter with a ground finish. There are plain ones, cheaper ones, and more expensive ones. The latter usually are drilled and tapped at the small end for use with a drawbar and the 2MT sizes are usually threaded ⅜in. BSW. If you choose the cheaper version, then I recommend drilling and tapping the tapered end ⅜in. BSW for a drawbar, even though it may only be used for the machining processes. Your fixed steady will be required even though its contact bearings will be only on an edge, but should give enough support to keep the small end of the taper running truly while the hole is drilled and tapped. The three steady points may leave a 'ring' mark on the taper but this can be locally 'hidden' by careful polishing later.

Before fitting the arbor and drawbar into your headstock, take a piece of ground finish mild steel and turn it to the desired length of the extension piece, and break its corners. It will first be used as a plug gauge to test its fit inside a hole to be bored in the head of the arbor. It is assumed that your lathe 3-jaw chuck is accurate. If not, and before inserting the arbor and drawbar, machine out soft chuck jaws in this chuck to a parallel fit 0.003in. diameter smaller than the extension piece.

Insert the arbor and secure with a threaded drawbar through your headstock spindle with sufficient 'lock' on the nut to hold it in position, but not so tight that heavy hammering is needed to remove it again. A "light 'tap' to remove it" fit is sufficient.

Machine the head of the arbor to the drawing dimensions paying particular attention to getting the bore exactly right. A very sharp boring bar set exactly on lathe centre height is essential. As you approach the final diameter, take as many cuts as necessary: do not attempt to hurry this and note that cuts as small as 0.0005in. may be required. If your initial hole has been made with a ½in. drill then let the drill cut about ⅛in. deeper than the desired depth, leaving a shoulder for the extension to bed onto at its periphery only. The ideal fit for the extension bar into its hole is a sliding fit so close that when withdrawn sharply, you should hear a loud 'POP' as it leaves the bore and air rushes in to fill the hole. Both components are then cleaned ready for assembly. **Photos 31 and 32** show the procedure with the chuck gripping the extension held into the tailstock with the special Myford Morse taper chuck adapter which will test the accuracy of your lathe's axis, for if the tailstock is not in line, the parts will not slide together. If they do not, then you MUST first adjust your tailstock until it does. Then apply 'Loctite' to both surfaces, insert the extension with the tailstock and revolve the lathe spindle a couple of turns by hand to ensure all the liquid has filled the joint. Wipe off any excess and leave to cure for at least thirty minutes before removing from the lathe.

The two long flats to be graduated are machined as shown in **photo 33** and need no special mention except that more than one pass will be required by a cutter no larger than ¼in. to get tight into the corner.

When you are certain that all is well, release the tailstock end 3-jaw chuck, and slide back the tailstock. Rotate the lathe spindle and check with a dial gauge that there is no significant run-out. There shouldn't be any, but it is as well to check. A thou or so will not affect the accuracy of the finished threads as there has to be a minute amount of clearance on the components or they will not slide smoothly. Now centre drill the end and drill 9/32in. diameter and 23/4in. deep for clearance on longer, smaller threads of maximum ¼in. diameter. It is not possible to drill larger than this if we are to follow the next operation to put two lengths of graduations on the extension. A larger hole would weaken the extension.

Next the arbor was put into the rotary table in the same manner as **photo 33** and using an edge finder set its axis in line with the heads cutter spindle. Make sure that you have set your feed screw dial to a zero so you can return to this later. Set length stops to mill in the ⅛in. keyway approximately ⅜in. long overall right up to the arbor's main head diameter. With your arbor tapped at the small end, rig up a drawbar to add extra security to the grip inside the Morse taper but as before with the headstock, do not over tighten. **Photo 34** shows the method of milling away the rounded end of the key after it has been fitted tightly in its slot.

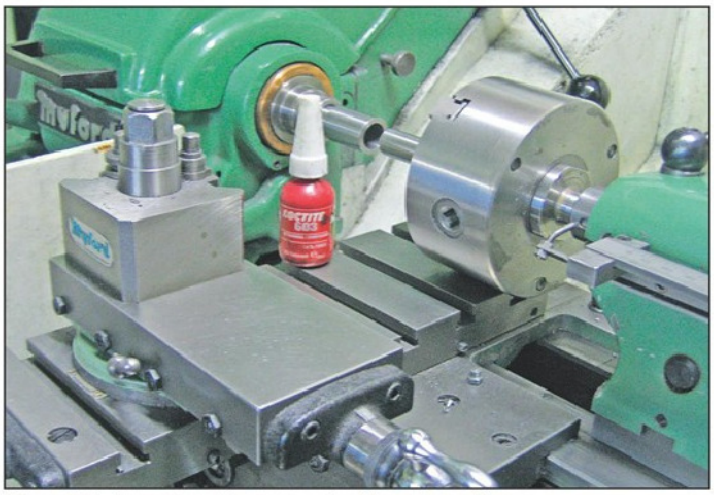


Photo 31. Inserting the extension into the arbor.

Photo 32. Arbor inserted and secured with Loctite 603.

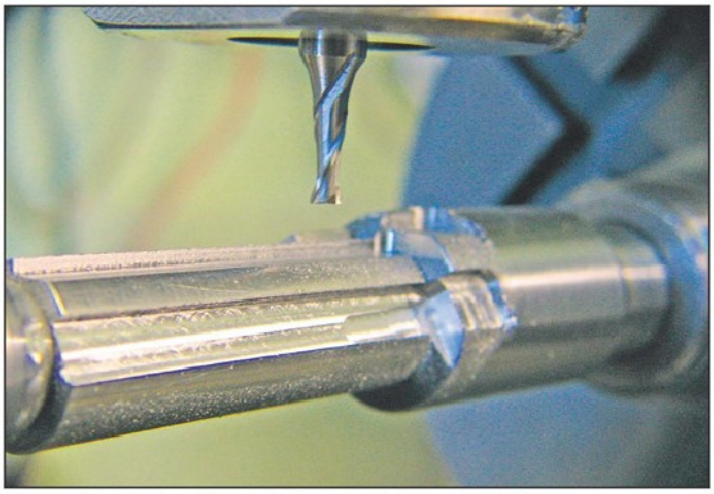


Photo 33. Milling flats prior to graduating, note the error.

Photo 34. Machining the end of the key.

Return the table to its original zero Y axis setting and then move it so that the axis is now 0.125in. towards the rear of the machine. Rotate the arbor 20deg. noting that the keyway moves away from you. Using a ¼in. diameter end mill, or a slot drill, mill a flat along the top front of the arbor extension to 1/16in. deep and at the same setting mill a second similar flat on the edge of the larger diameter but not more than 3/16in. long. This process was shown in **photo 33.** Repeat this process of long and shorter flats after revolving the arbor a further 50deg. These angles need not be precise and mine were different anyway as my dividing head did not have on it the correct hole plate for angular dividing - a 42 hole circle - and I was too lazy to change it. However it did have a 60-hole circle and I used this with 5 complete turns for the first flat and a further 10 turns for the second. When the flat has been produced and with the cutter against the larger diameter, wind the table away from you to complete the cut. This is difficult to describe but obvious with the work in front of you.

On the flats, I graduated one in 1/16ths and the other in 1mm increments. However depending on your machine feed screw you may have difficulty in marking one or the other. My Senior "E" has Imperial 10 threads per inch screws and so marking accurate 1mm divisions would not be easy due to accumulative error as 1mm equals 0.3937in.. Estimating that 0.0007in. would be very difficult each time and,

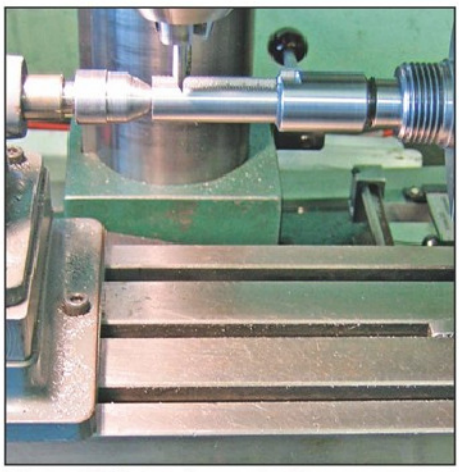


Photo 35. Setup for graduating the arbor extension.

furthermore, it would be next to impossible to reset back to the original zero should this be necessary if you lost count. Fortunately I had already fitted dual reading linear scales to my machine. Now measurements are so simple that regardless of the screw's pitch, one presses a button and there is an immediate and direct conversion from metric to Imperial and back again and without losing the original zero datum setting.

The process is shown in **photo 35.** The engraving tool is ground very similar to those used in screwcutting on the end of a ¼in. diameter HSS tool bit. It is set by eye exactly in line with the flat's end edge on the larger arbor diameter. Ideally the wiggler should be used to locate the exact zero but the contact area is very small and due to the spindle's rotation direction, the stylus end is prevented from flipping out by the rear step of the flat. In the unlikely event that you have a reverse on your mill, the wiggler could be used successfully. Put the tool into your drill chuck which in turn is held on your mill spindle and lower the point to just touch the top of the flat, and set a zero on your down feed dial. Wind the table away from the graver and bring down its tip a further .001in. (or 0.02mm), which will give an adequately deep visible line.

The flats on the extension are wide enough for us to mimic a rule with short lines and longer lines of which the latter will be put at ¼in. (or 10mm) increments, and the shorter lines at 1/16in. (or 1mm) increments. If you do not have Y axis table stops, then set a zero at the point where the shorter lines will stop at 3/32in. (or 2.40mm) and remember, by careful counting, to exceed this by 0.062in. (or 1.6mm) where required. Get everything ready for this exercise including persuading your family to go on a day trip, shut out your pets and switch off your telephones and in-house entertainment systems, and then relax. Just one line out of position, or the wrong length, will result in great sorrow, howls of anguish, gnashing of teeth, and uttering of highly expressive profane words! I have been there too! I know! I am asking you to make every possible precaution before setting out on the engraving road. My rotary table was graduated into 360deg. with appropriately longer lines at each 10deg. I then decided also to put the numbers on by dividing. To my ever present annoyance there is just one zero 1deg. out of position. I struck with the hammer just too late to prevent the error after realising I had miscounted.

At the inner end of each line there will be left a 'curl' of swarf. Leave all of these until you have finished each row of lines and then with a fine needle file, carefully remove them and the other miniscule burrs along the edges of each.

Photo 36 shows my method of stamping the "IN" and "MM" on the appropriate flats adjacent to the incised scales. A Vee block is clamped to the rear of the cross slide, and into this is further clamped the main column, or a shorter length of the same material, of the George Thomas Tapping and Staking machine together with its upper arm. George described how to make a special bush internally spring loaded to grip ¼" square number stamps of which the "Pryor" make are undoubtedly the best having each character exactly central to its punch making precision stamping of words, or numbers in line, easier. It will be noted that one of the chuck jaws grips on the outer diameter of the extension between the two graved flats and that there is a 'jack' beneath the larger diameter to absorb the hammer blow. I used a 2lb pein hammer holding it just behind the head and hitting the punch's upper end squarely from about 6 inches, twice only - except for the "I" which being a single line like a chisel, needs only one blow.

A similar setup is used to put the 'length' numbers on to the scales except that the arbor has its taper inserted into the headstock spindle and the outer end supported by the tailstock. To prevent the arbor rotating, engage the back gear.

A "1" can be stamped adjacent to the fourth longer line on an Imperial scale, and/or a "1", "2", "3" and "4" alongside each alternate long line on the metric scale. It is essentially important to remember that the numbers MUST be inserted into the holder UP SIDE DOWN for, unlike a standard rule, the dimensions on the finished arbor must read from right to left. Ideally 1mm numbers should be used, as I felt that the 1/16in. stamps used for the "IN" and "MM" were a bit large for the scales.

For the metric scale, carefully position the "1" punch to the left of the second longer line, i.e. at the first full centimetre, remembering that the other number characters are wider.

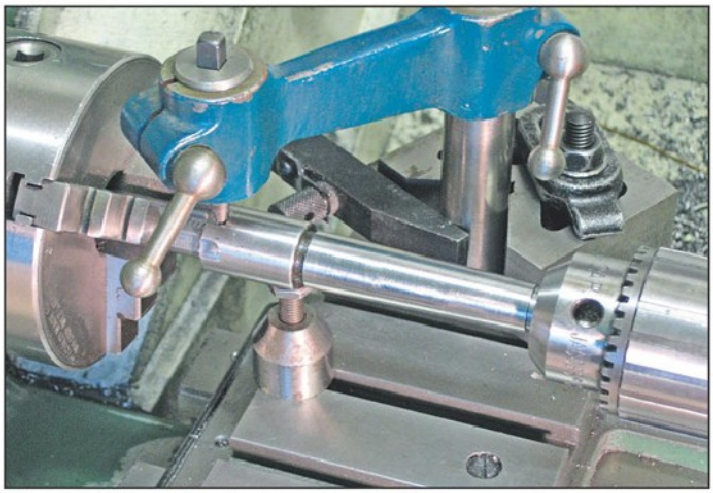


Photo 36. Stamping inch and mm indicators on arbor.

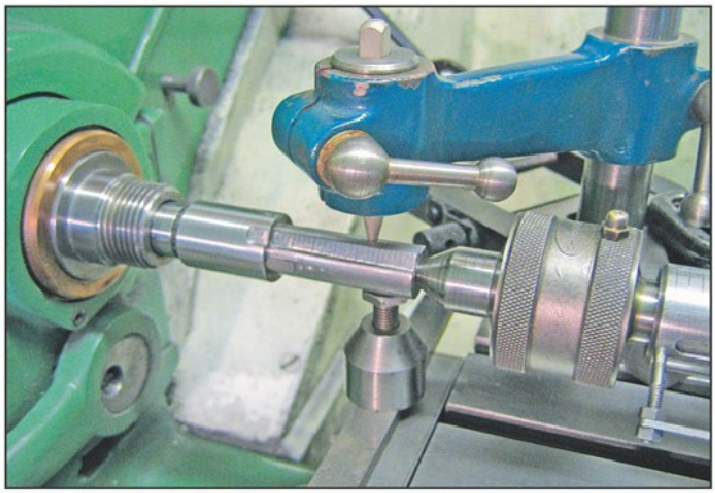


Photo 37. Numbering the arbor after graduating. Note the jack for support.

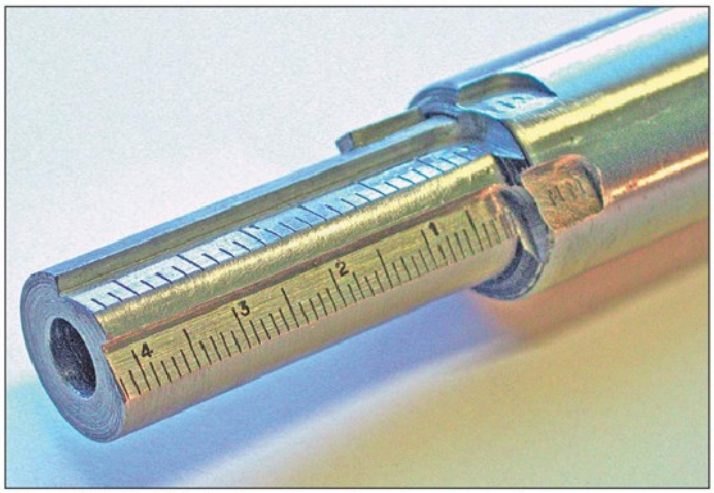


Photo 38. The finished graduated and numbered arbor.

Photo 39. A large batch of finished dieholders.

To do this, engage the saddle with your leadscrew so that as you wind the saddle away from the headstock, the punch is in a suitable position and its handwheel dial is at a convenient full number. Mine was at "80" for the Myford S7 which has an 8tpi leadscrew and 125 divisions = ⅛in" = 0.125in. on the dial. If your "1" is close to the line, the "2" will probably intersect with its line and that will spoil the overall effect. For the 1mm character punches, one hammer blow will be sufficient not forgetting to put the jack underneath to absorb the impact. For the inch scale, only a single "1" is required at the full one inch longer line.

Having marked the "1", now wind the leadscrew handwheel 0.394in. in order (a) not to have an estimate of the extra .0003" and (b) more importantly to finish on an exact indication line. I turned the handle three times (3 x 0.125 = 0.375) plus 19 divisions to stop at "61" on the dial and then stamped the "2". Repeating the process for the "3" the dial number was 42 and for the "4" it was "23". Pen and paper are also an essential requirement for this sort of work. If you are uncertain, do a 'dry run' first to check your calculations.

Photo 37 shows the setup for stamping the numbers. Note the toolmakers jack supporting the arbor and to absorb the hammer blows of the punch process. **Photo 38** shows the finished arbor. **Photo 39** shows the batch of holders lined up with most waiting to have their dies fitted.

Storage

I mentioned this early on in the series. With three different diameter holders and the probability that these are not in a direct sequence for a series of thread diameters, e.g. BSF from ½in. down to ¼in. in five sizes gave much food for thought. I then considered where in my workshop I would be storing them, which at time of typing these notes number forty two, including four left hand dies which may never be used, but are set and ready for action 'just in case'.

The only convenient spaces were some shelves six inches wide and fifteen inches long. By using the largest dieholder as the standard and staggering them I could put three rows of holders lengthwise in an open topped tray of that width. The visual 'downside' is that the smaller sized holder bodies will be widely spaced apart in comparison with the larger sized ones. I regret I am unable to give a definitive solution. **Photo 40** shows a finished tray of dieholders with holes drilled at 13/16in. diameter to accept the small end of the holder bodies with the die sizes uppermost for ready identification. If you have a larger quantity of the smallest size of dieholders, then an alternative arrangement such as that shown in **photo 41** could be considered.

To secure the tray components, MDF board 12mm base and 6mm sides, use 1mm diameter x 15mm long steel pins tapped into pre-drilled holes 12mm deep to allow the pin to hold securely without splitting the inner part. It is better, and neater, to have the sides longer than the base and trap the end piece between them. This is particularly important for pinning the 6mm sides to the ends ensuring that the drilled hole is central into the end pieces. Before final pinning, apply wood adhesive to the whole length of the joints, and run a fine fillet of adhesive along all internal corners once the pins have been hammered home.

The final job, in my instance anyway, was to make some identification numbers and add all the sizes and locations into my workshop index described in MEW issue 137.

I had finished this manuscript for some months before I realised that there was one shortcoming with this system especially for those of us with Super 7s and other machines with 'solid' tailstocks. We will be unable to cut threads larger than ¼in. diameter and longer than about 2in. and still retain the concentricity given by the mandrel. However in my final years at "Birmingham's model engineering suppliers" I had been using the works Myford ML7 to make 22½in. long lengths of all-thread (studding) using a "Coventry" diehead, possible only because the tailstock barrel had a ⅝in. hole right through.

Remembering my apprenticeship days when I had 6 months on the centre lathe section - I was using a Ward 3A capstan lathe from which the capstan slide had been removed and replaced with a 'normal' centre lathe tailstock - the machine immediately behind me was a very old geared headstock centre lathe of at least 12in. centre height. What was particularly interesting was the boring and reaming of the flanged-end holes. This was done with a 'floating' self-aligning adjustable reamer in the tailstock but between the internal bed shears there was a hook and link, which enabled the self act of the saddle to 'tow' the tailstock, with reamer attached, very slowly into the bore.

On this elderly machine the operator did all the final machining of headstock spindles, also the processes not then possible by grinding due to insufficient machining capacity such as the threads for locking collars and the internal bores at the chuck end described above and for boring bar support bushes used on the firm's products of combination turret lathes. One of these bars may be seen in

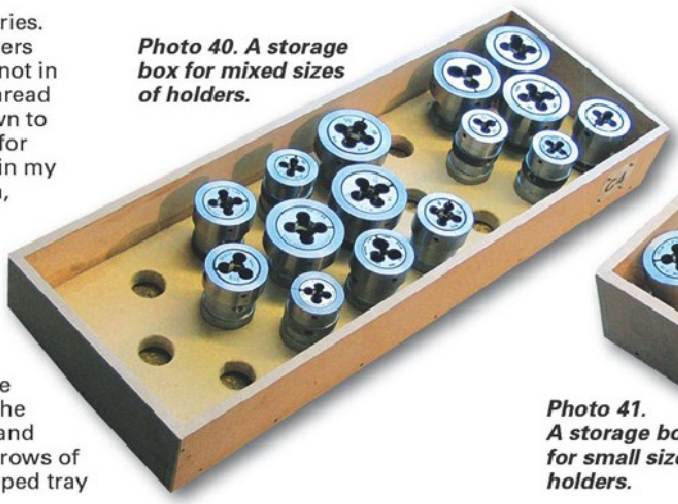


Photo 40. A storage box for mixed sizes of holders.

Photo 41. A storage box for small size holders.

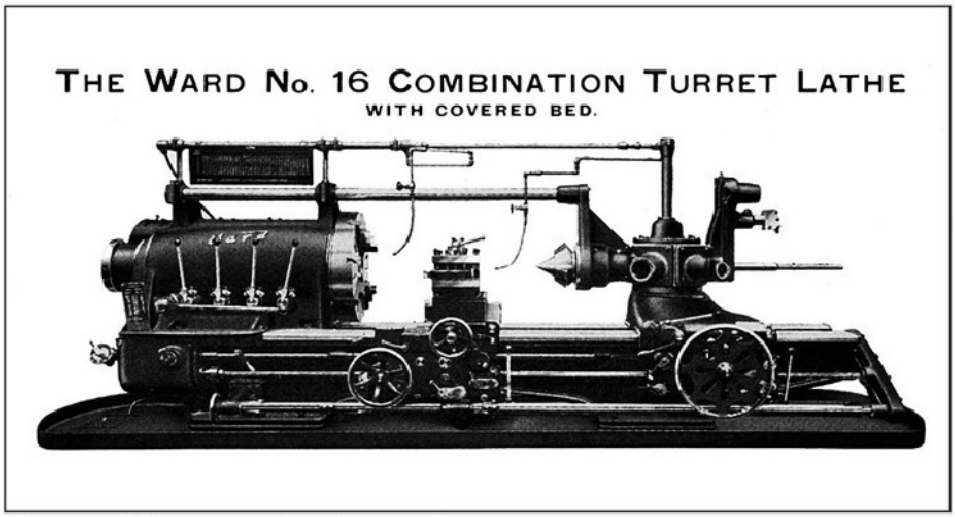


Photo 42. A Ward 16 combination turret lathe.

photo 42 protruding from the hexagonal turret at the right. This was the largest machine made by H W Ward & Co. Ltd., of Selly Oak, Birmingham; a 'whopper' with an 8¼in. hole through the headstock spindle and a 30in. diameter Pratt chuck. Its 12in. square revolving tool post had five Whitworth bolts 1in. diameter along each face to secure the turning tools. My Super Seven would sit quite happily on the cross slide.

Fifty years later the possibility occurred to me that a similar device could be fitted to 'tow' a modified tailstock along the Super 7 bed. Noting adverts on the Internet "www.homeworkshop.org.uk" site from "machine breakers" offering spare parts I acquired an ML7 tailstock, **photo 43** which had had the barrel and handwheel removed and which I determined to adapt to suit my dieholder system and cut longer threads up to ½in. diameter.

However, by measuring the thickness of the inner shears on my own machine, **photo 44** it became clear that normal under-retaining strips, as for a saddle, could not be used as the under-surfaces between the shears is not ground and is uneven, though by only a few thousandths of an inch along the length. As an amount of lift prevention is desirable and I could not, even with difficulty, find a way to accurately finish the bed under the shears, I proposed to discard the lever bed clamp and fit a spring-loaded under-plate for the full length of the tailstock instead of the rather shorter piece of the standard lever operated clamp. This should take up most of any discrepancy yet still allow the tailstock to slide freely and resist upward lift should there be any.

My purchase duly arrived and I set about converting it to my purpose. After dismantling and cleaning I had difficulty in removing the bed clamp lever. Eventually after removing the base and the side adjustment screws I discovered a concealed slotted screw which had a peg point running in the groove in the locking spindle. Your own purchase may already have had this fitting removed. Mine did not.

On the tailstock's base there is a detachable adjustment block, **photo 45** used for adjusting the fit between the bed shears the holding screws of which also secure the upper and lower tailstock main parts. The adjustment block is thicker than the under blocks of the casting and it must be milled down to the same height before the new spring loaded slide block is fitted. I had to remove 0.047in. from mine, achieved on my mill with a small flycutter as in **photo 46**. The upward projection, which locates the upper tailstock body, was gripped in my machine vice as shown. To be continued. To be continued...

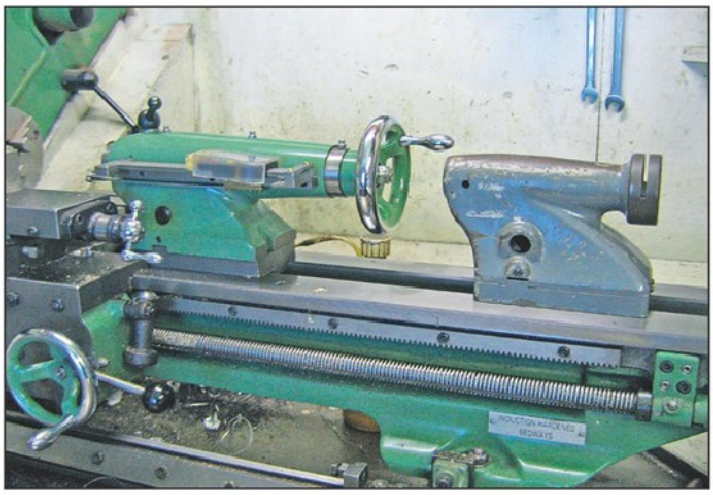


Photo 43. The ML7 tailstock as bought.

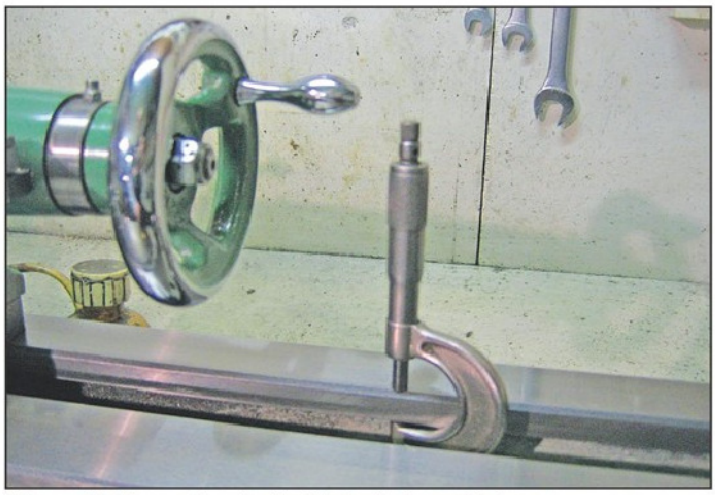


Photo 44. Measuring the inside bed shear thickness.

Photo 45. Underside of tailstock showing released adjustment bar.

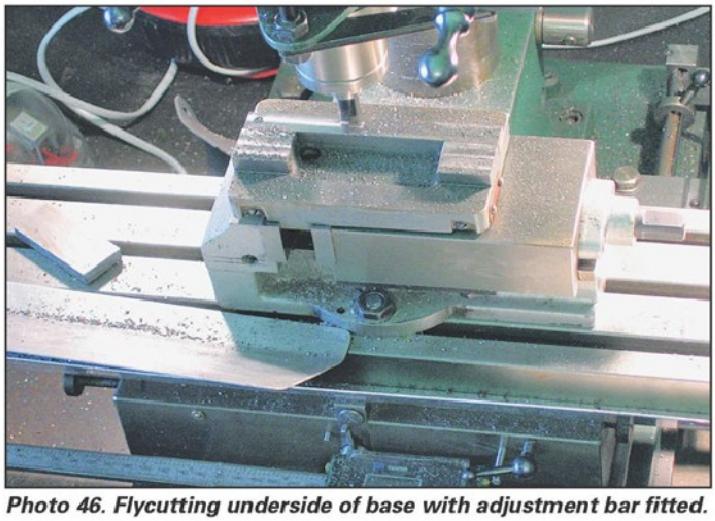


Photo 46. Flycutting underside of base with adjustment bar fitted.

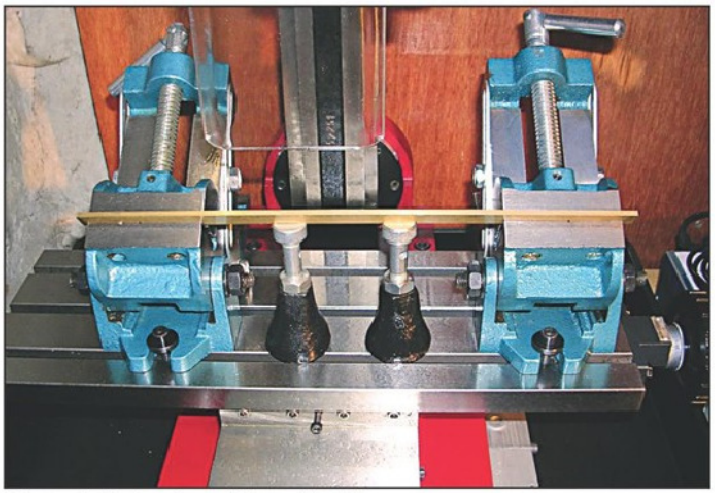


Photo 1. Setup for milling gib strips.

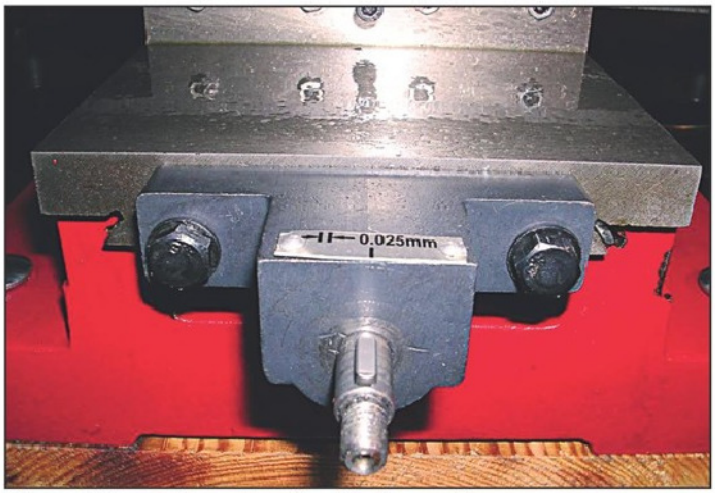


Photo 2. Front view of bearing block on mill.

X1 MILL MODIFICATIONS

David White does some basic modifications to his mill.

Introduction

The Sieg Super X1L micro mill is quite a capable small machine as it stands. The basic features are all pretty well implemented, but as you might expect with an introductory level machine there is plenty of scope for improvements. I have already described the basic features of the machine and how to replace the geared spindle drive with a more versatile belt drive. This article will describe some further modifications that I made to my mill.

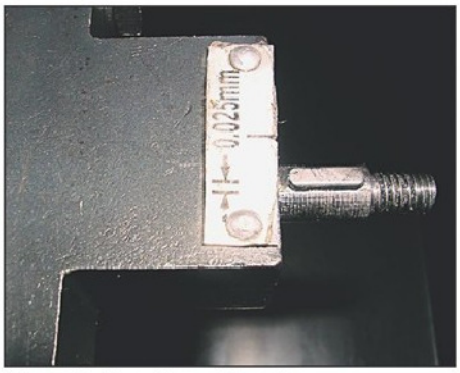


Photo 3. Top view of bearing block on mill.

Lapping the ways and gib Strips

I described how to lap the ways of the compound table for the Sieg X0 Pico mill in a previous article. Exactly the same procedure can be applied to the X1 table and results in a worthwhile reduction in friction as well as additional smoothness in use. The X1 table is pretty good to begin with so the improvement is very obvious but perhaps not quite as marked as that for the X0 table.

I described how to make new brass gib strips for the X0 table in the same article that dealt with lapping the ways. The brass gib strips for the X1 table can be made in exactly the same way as described for the X0 compound table. The gib strips are made from 3.2mm x 12.5mm brass flat. The X axis gib is 120mm long and the Y axis 255mm long. The method described for making the X0 gib strips uses the X0 saddle as a template and assumes that you have access to another milling machine. If the X1 is your only milling machine then an alternative procedure will have to be used. Perhaps the simplest method is to cut a kerf 8 or 9mm deep in a strip of wood using a circular saw where the blade has been set over at an angle of 35deg. from the vertical. Notice that the set over is 35deg. rather than 30deg. because the X1 dovetails are 55deg. rather than 60deg.

The raw stock for the gib is then superglued or clamped into the kerf and the whole assembly mounted on the X1 table. The top of the gib can then be milled flat, the gib turned over, refixed, and the top milled flat again, making sure that the finished gib has the correct width. Alternatively you can invest in a couple of cheap tilting vices, such as the Clarke CTV25B Tilting Vice available from Machine Mart at £13 each. These are always useful and a good investment regardless. I used a setup like the one shown in **photo 1**.

Begin by setting the vices to 35deg. with a protractor or angle gauge and then place them on the X1 table the correct distance apart and clamp opposite ends of a flat bar in each vice. Now line up the vices so that the bar is parallel to the X axis of the table and clamp the vices down. The gib strips can now be milled as before. The Y axis gib is sufficiently long that the unclamped parts will need to be supported in some way; a couple of machinists jacks work well. Don't forget to lap the new gib strips in when they're finished. You should find that lapping the ways and making new brass gibs for the compound table results in a considerable improvement in ease of use and smoothness of operation.

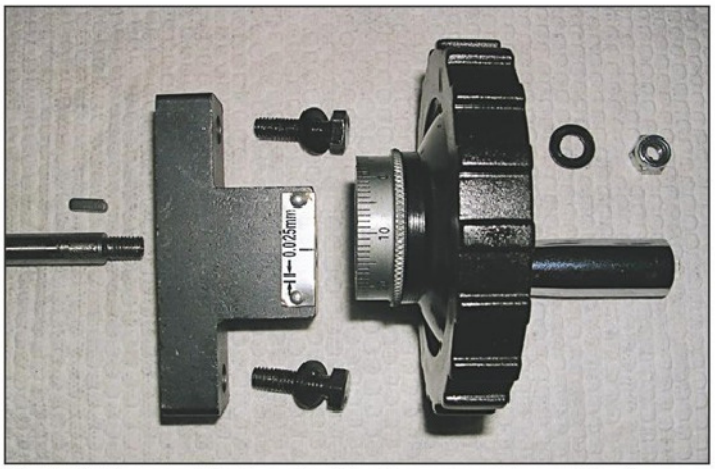


Photo 4. Disassembled bearing block, components, and leadscrew.

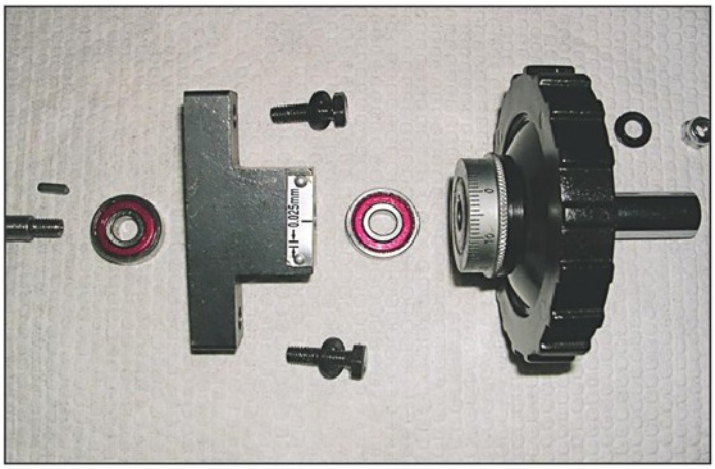


Photo 5. As photo 4 but showing position of ball bearing.

Leadscrew bearing blocks

The bearing blocks for the X1 compound table, shown in **photos 2 and 3**, are made from cast iron and implement a simple sleeve bearing with "preload" set by the leadscrew handwheel retaining nut. The complete assembly is shown in **photo 4.**

This arrangement is quite adequate for occasional manual use but not really optimal for heavy manual or CNC operation. The ideal arrangement of a ball bearing sandwiched between a pair of thrust bearings is overkill for this application. So are thrust bearings recessed into opposite sides of the bearing block, as found on the larger Sieg mills, given the cost of 8mm id thrust bearings. What is really required is a cheap bearing arrangement capable of taking both the radial and axial loads likely to be found with these leadscrews when working fairly hard. I claim no credit for coming up with the idea that cheap and readily available 8x22x7mm roller skate bearings fit the bill admirably. **Photo 5** shows the idea and **photo 6** shows the 13mm diameter by 10mm deep recess already bored into the inner face of the bearing block.

The idea is therefore to bore ball bearing housing recesses into each face of the bearing block and to bore out the through sleeve to greater than 8mm so that the leadscrew will be supported on the inner bearings of the ball bearings. If you are brave and confident you can bore out the existing bearing blocks to house the ball bearings. If, like me, you are chicken, you can make new bearing blocks out of aluminium safe in the knowledge that you have a fallback position if all does not go well. Making new bearing blocks can also facilitate the addition of stepper motors for a CNC conversion.

At this point I would like to make a small digression regarding spare parts for Sieg machines. Suppose you had decided to bore out the existing bearing blocks and all didn't go as planned. You're left with a useless chunk of cast iron and an inoperable mill; unless you can get spare parts or make another bearing block. I got my X1 from Arc Eurotrade but they can't stock every spare part. I'm sure most readers of MEW will be aware that Little Machine Shop in the US has a pretty comprehensive stock of spares and accessories for the Sieg X1 to X3 mills as well as the C2 and C3 Mini-lathes. However, in many cases the cost of shipping all but the smallest spares from the US is prohibitive. An idle glance at the back page of their catalogue whilst waiting to be served in my local Machine Mart led me to a very useful chance discovery. They sell versions of the Sieg X1 and X2 mills as well as the C2 (short C3) Mini-lathe and have a dedicated spare parts department.

I phoned up the spare parts department and had a very useful chat with them. It turns out that they stock a very comprehensive set of spare parts for all of the Sieg machine tools that they sell, and furthermore they are more than happy to sell to anyone, not just existing customers. This source of spares seems to be a very well kept secret, but I was assured by the spares department that they are more than happy for this publicity. As you will see later I quickly availed myself of this treasure trove of spares. It may well be that there are other undiscovered comprehensive stockists of spare parts for Chinese machine tools in the UK - if so could they please let us know about it!

I decided to make new bearing blocks starting from 1½in. square aluminium stock, mainly because it would make the subsequent mounting of stepper motors easier when I did the CNC conversion. If you only intend to do manual machining, you can modify the existing bearing blocks safe in the knowledge that you can get spares from Machine Mart if necessary. Obviously if the X1 is your only mill you'll need to do the same as me or buy a set of spare bearing blocks. Before I discuss machining the bearing blocks let me say that it is necessary to get the two ball bearings to be a snug fit in their recesses and also very accurately co-linear with the axis of the leadscrew. This calls for some fairly careful machining. If you don't get it right then the leadscrew will bind. I chose to make the bearing blocks so that the X1 could still be used manually, with the existing handwheels, in the interim before CNC conversion. I cut a 77mm length from the aluminium stock and trued up the ends with a face mill to give an overall length of 76mm. I then reduced the thickness between one pair of long faces to 35mm, corresponding to the thickness of the original bearing blocks. One of the original bearing blocks was clamped to the aluminium blank and transfer punches, 7mm for the mounting holes and 8mm for the leadscrew hole, used to mark the centres for drilling. This is shown in **photo 7**.

Transfer the marked aluminium block to the milling machine and carefully clamp square to the jaws and bed of the milling vice. Make sure that the rear vice jaw is accurately aligned with the X axis of the mill before you start. Use a wiggler to accurately position the mill spindle above each hole and drill the 7mm mounting holes and 8mm leadscrew holes right through the block between the 35mm spaced faces. Start with something like a 3mm drill and re-drill with increasingly larger sizes until the target size is reached. This minimises drill wander. You can counterbore the holes for the mounting screws at this point. I must admit I just use an appropriately sized end mill to do this. At this stage it is useful to push a piece of 8mm silver steel though the block, push on the bearings, and mark their approximate positions on the block with a scriber or fine point felt tip pen.

The bearing recesses can be bored either on the X1 itself using a boring head, or on a lathe using a four jaw chuck. I prefer to use the lathe for boring wherever possible as I find it much easier to get an accurate result this way. Centring the bearing block on the four jaw chuck, ready for boring, presents something of a problem because the inner surface of the 8mm drilled hole will be neither smooth nor round. I chose to make two 7mm pins, which were a very tight fit in the mounting holes, and use these to fix the original bearing block accurately on top of the one to be bored. The inner bearing surface of the original bearing can them be used as a reference to centre the aluminium block in the four-jaw chuck. **Photo 8** illustrates the general idea.

None of this is a problem if you're modifying the original bearing blocks. With the bearing block accurately centred in the four-jaw chuck go ahead and bore the first one 22mm diameter and 7mm deep. If you wish, you can bore the recess 6.9mm deep so that you can use a small clamping plate on the bearing block to hold the ball bearing in position. I did not find a clamping plate to be necessary. When

Photo 6. Inner recess of bearing block.

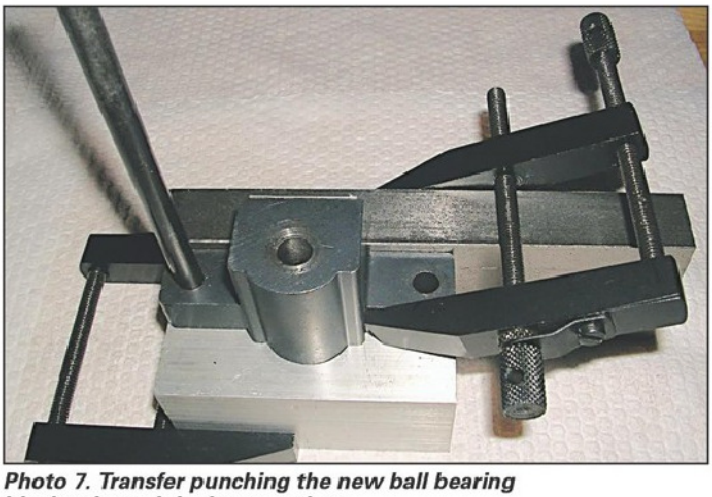


Photo 7. Transfer punching the new ball bearing block using original as template.

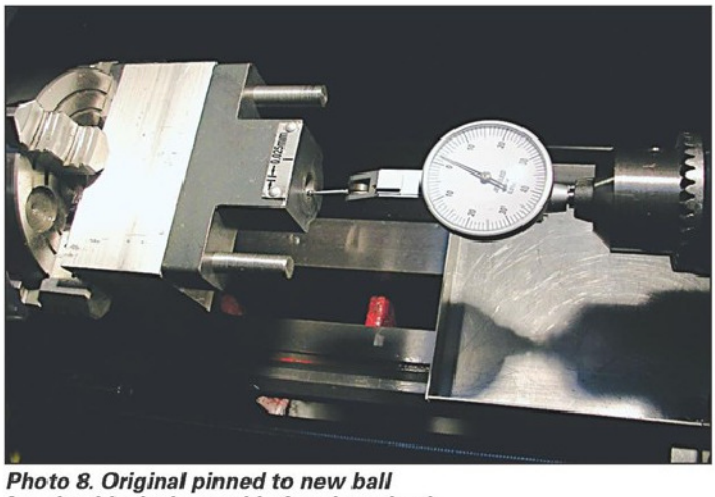


Photo 8. Original pinned to new ball bearing block clamped in four-jaw chuck.

Photo 9. Front view of completed new ball bearing block.

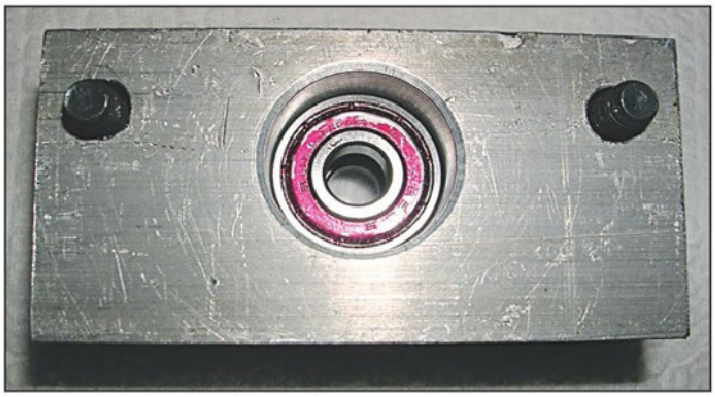


Photo 10. Rear view of completed new ball bearing block.

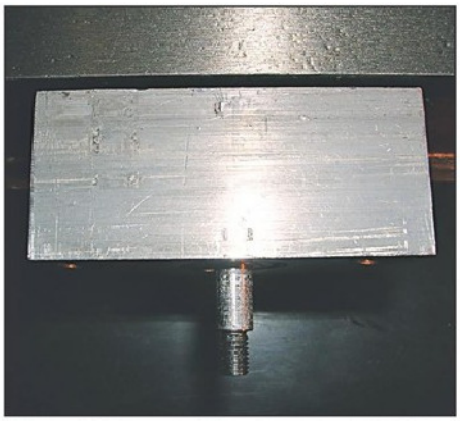


Photo 11. New ball bearing block lightly fitted to mill. Note constant width gap.

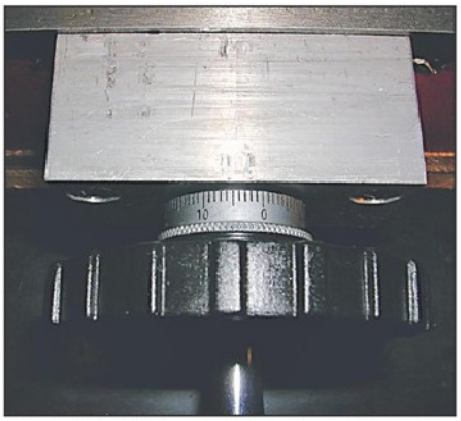


Photo 12. Ball bearing block mounted on mill with handwheel in position.

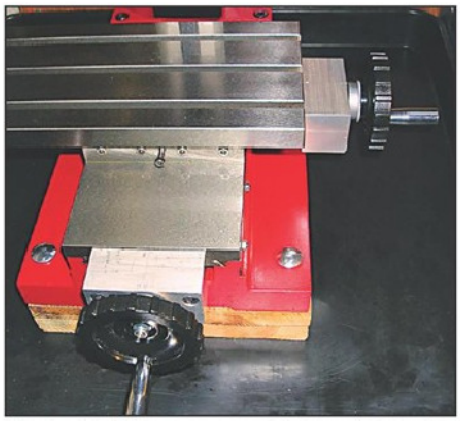


Photo 13. The compound table with both new ball bearing blocks fitted.

boring the hole measure often and when you get close to 22mm keep trying the ball bearing for fit. Make sure that your finishing cut is taken down the side of the bore and then subsequently across the face at the bottom. This will ensure that the bearing sits flat in the bottom of the bore. The remainder of the 8mm drilled hole should now be bored out to 15mm without removing the block from the chuck. The 15mm diameter bore ensures that it clears the inner bearings when the ball bearings are mounted. Now loosen each jaw of the four-jaw chuck just enough so that you can remove the bearing block. Turn it over, and reinsert almost exactly in the centred position. Use your dial test indicator to accurately re-centre the 15mm bore in the four jaw chuck. You now need to bore a 22mm diameter recess 17mm deep (10mm depth of original recess + the 7mm thickness of the ball bearing) in order to position the leadscrew in the same position as it was with the original bearing. Again aim for the bearing to be a snug fit in the hole which should have a flat bottom. Front and rear views of a completed bearing block are shown in **photos 9 and 10**.

Now comes the acid test. Fit the bearings as shown in **photo 11**, support the bearing block from underneath, and fit a pair of M6x40mm cap head screws in the fixing holes, but don't tighten them right up just yet. Now slide the bearing block towards the edge of the compound table and watch the gap between the table and the bearing block. It should be of uniform width all along its length. If it's not then either the drill for the fixing screws has wandered or the bores are skew. Enlarging the fixing holes slightly may help, as might rechecking the bores and flatness of the bore bottoms and shaving miniscule amounts of the bores as appropriate. Assuming that all is well, tighten up the cap head mounting screws and mount the thin 8mm washer, the key, and the handwheel as shown in **photo 12**.

The 8mm washer stops the face of the handwheel from fouling the bearing outer bearing. Fit the handwheel washer and fixing nut and tighten the latter to give an acceptable preload to the bearings. Well I tightened the nut to snug plus an eighth of a turn and that seems to work ok. You should find that whilst lapping the ways and fitting new gibs made the handwheel easier to turn, fitting the bearings makes it even easier again. If the handwheel turns, but less freely than after lapping the ways and fitting new brass gibs, then you have a minor misalignment problem somewhere. If you've made the bearings a nice tight fit in their recesses, and assuming that the bottoms of the recesses are both flat, you should be able to cure the problem by enlarging the diameter of one of the bearing recesses by a tiny amount (0.01 to 0.02mm). Take care here though, because if the bearings are too loose a fit in their recesses then you'll get slop when operating the handwheels. If all else fails you may need to start all over again. This description is deliberately detailed to emphasize the need for great care in order to ensure optimal alignment - it's not difficult work but it does need to be taken slowly and carefully.

Depending on your machine you may find that you have to mill a couple of mm off the bottom of the Y axis bearing block so that it clears the base casting and allows full Y axis travel away from the operator. The finished result with bearing blocks fitted to both X and Y axes is shown in **photo 13**.

Fixed column

There are several possible variants of the X1 micro mill, three of which are available in the UK. The first has a small compound table (240x145mm) and a fixed column, the second has a small compound table and a tilting column, whilst the third has a larger (400x145mm) compound table and a tilting column. The fixed and tilting columns are shown in **photo 14**.

The version with the larger table is obviously the most useful from the work handling standpoint but I have never been a great fan of tilting columns. If you use the feature then you have to laboriously re-tram your machine after use, and I'd always re-tram if I'd knocked the column heavily in an accident, say. All in all I find it much easier to angle the workpiece than the column of the mill. With a fixed column

Photo 14. Fixed and tilting columns side by side.

Photo 15. Column adaptor block milled to size.

you shim it up once and then forget it (at least for a while). Unfortunately, to the best of my knowledge, you can't get off the shelf Sieg X1's with a large table and fixed column. However, you can buy the fixed column itself from the spares department of Machine Mart as I mentioned earlier. It is then necessary to obtain an adaptor plate so that the fixed column can be fitted in place of the tilting one. These plates are obviously manufactured somewhere as Little machine shop sell them as part of their X1 extended Y axis kit, but not separately. Therefore if you want to retrofit a fixed column to a tilting column mill you must make the adaptor plate yourself.

I purchased a fixed column from Machine Mart for about £30 and made an adaptor plate to fit it to my X1 in place of the tilting column. In retrospect I could have saved myself some money by reusing the tilting column to make a fixed column, as the column proper can be completely separated from the tilting mechanism. I could have then used two right angle supports to fix the column to the adaptor plate. That said the route I took involved less work.

Ideally the adaptor plate would have been made from cast iron as this is very good at damping vibration. However, buying the cast iron by mail order would incur shipping charges probably in excess of the cost of the metal itself. I chose therefore to use locally available black mild steel. The adaptor plate sold by Little machine shop is 12mm thick but I wanted to use something rather more substantial both to maintain rigidity and gain a little extra Z axis travel. Accordingly I purchased a 160mm length of 75mm wide by 40mm thick black mild steel, milled it flat and parallel on all sides using a 63mm face mill on my big milling machine and lapped the top and bottom surfaces to ensure flatness (and hopefully parallelism). The finished block of steel is shown in **photo 15**.

This work could have been performed on the X1 itself using either a fly cutter or a smaller face mill but obviously would have taken longer to complete.

The next step was to place the new fixed column on top of the adaptor block and use an 8mm transfer punch to mark the positions of the mounting holes on the block as shown in **photo 16**.

The block was transferred to the milling vice preparatory to drilling the four 6.8mm mounting holes to a depth of 25mm, and tapping them M8 as can be seen in **photos 17 and 18**.

I prefer to be cautious by starting with a small drill and working up to larger holes, rather than drilling the hole in one go, particularly with mild steel. It takes longer but places less strain on the machine as well as giving a better quality hole. I used the base of the original tilting column as a template to transfer punch the locations of the holes for fixing the adaptor block to the X1 base. These 9mm holes were then drilled right through the block and counterbored with a 14mm end mill. I routinely use end mills to counterbore holes that accommodate cap head socket screws, particularly as counterbores proper are quite expensive. This isn't really an option if you only use a drill press, but I can see no downside to doing things this way if you use your milling machine for drilling the holes. Perhaps a more knowledgeable reader will confirm or contradict this for me. The finished adaptor block, complete with M8x50 cap head socket screws and M8x40 hexagonal set screws plus washers and spring washers is shown in **photo 19**. The adaptor block and fixed column fitted to the X1 base is shown in **photo 20**.

Obviously the column has to be trammed to set it square and true to the table before the mill is used in earnest again. This can be done either by inserting shims between the column and mounting block or scraping the mounting block. I always feared for my DTI when tramming the mill, as its tip bounced up and down far too violently for my liking when traversing the table T-slots. But no more! I picked up a very useful tip from the internet some time ago - use a motor car unventilated brake drum! Just buy the smallest and cheapest that you can; you may have to search a bit to find only one rather than a pair. You can see the general idea in **photo 21**.

The upper and lower circular tracks are ground flat to well under 0.02mm and you can sweep the DTI tip around the upper one without interruption.

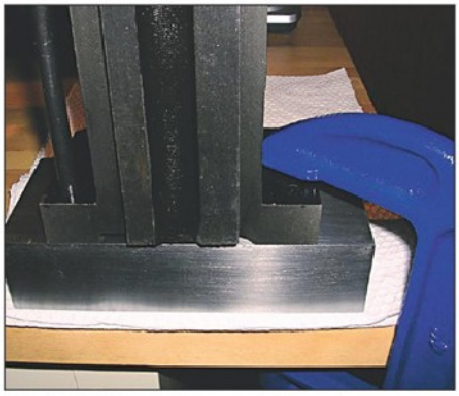


Photo 16. Transfer punching column mounting holes.

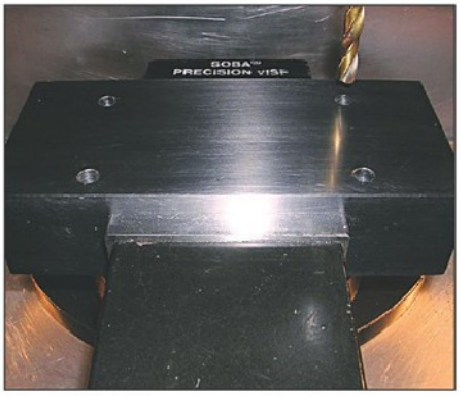


Photo 17. Column mounting holes being drilled in adaptor block.

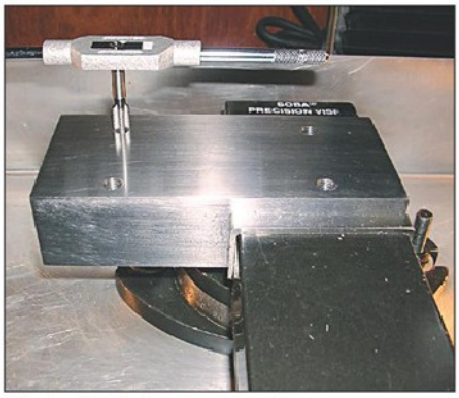


Photo 18. Column mounting holes being tapped.

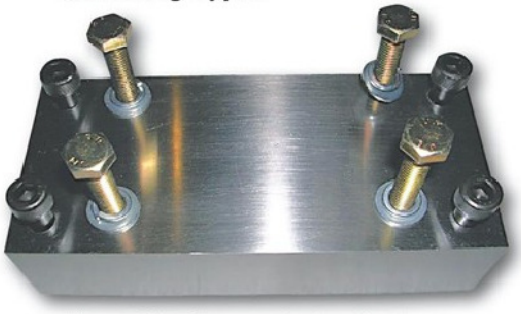


Photo 19. Column adaptor block showing screw fixings.

Photo 20. Fixed column on adaptor block mounted on X1 mill base.

Gas strut

The Z-axis travel of the X1 mill is quite stiff in operation for three reasons; the steel gib strip, now replaced with a lapped brass alternative; the lack of any counterbalance for the weight of the head; and the use of a simple sleeve bearing to house the leadscrew. The latter is of particular importance because the top working surfaces of the sleeve bearing take the entire weight of the head. This will be dealt with in a later article, but for now a counterbalance, to take some pressure off of the sleeve bearing will be described. The weight of the mill head can be counterbalanced

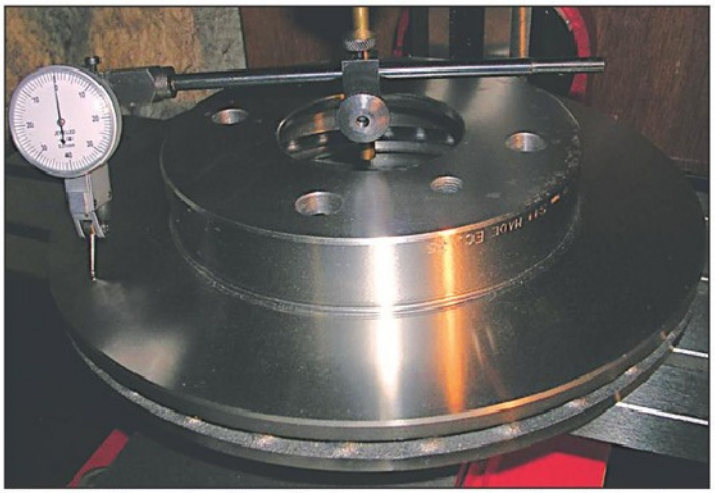


Photo 21. Tramming the mill using an unventilated car brake drum.

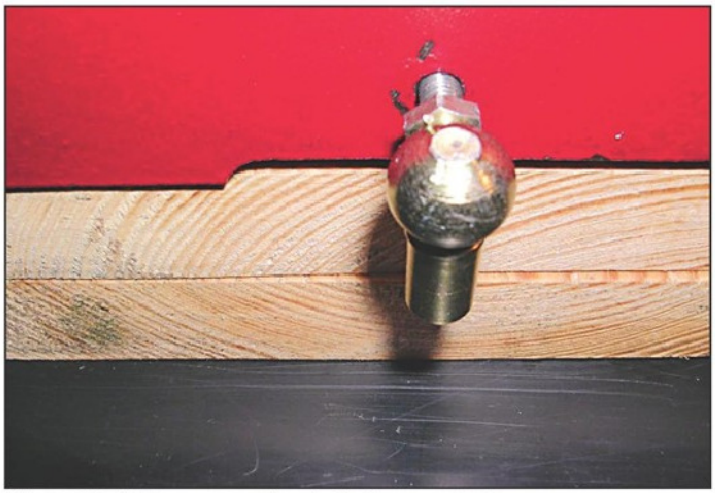


Photo 22. Bottom mounting hole for gas strut.

either by a torsion spring, a system of pulleys and a weight, or a gas spring. I must admit to not being very keen on handling the tightly coiled spring steel strip involved in a torsion spring setup. The pulleys and weight system, whilst excellent in operation, always seems a bit Heath Robinson to me and are not really portable to boot.

So my personal prejudices left me with only the gas strut (often called a gas spring too) option. So how to obtain a gas strut and which one to buy? Well the first is a bit of a no brainer - go to Gas Struts Direct - www.strutsdirect.co.uk - where else! Do you want a fixed force or variable force gas strut and what do these terms mean? Fixed force gas struts are completely sealed and non-adjustable thereby proving a fixed upward force. They are available in a range of standard forces but can be set to whatever you specify at the time of assembly. Variable force gas struts on the other hand have a small vent operated by a hex key which allows you to vent gas from the cylinder. Variable force struts are always supplied at maximum pressure so that the force can only be adjusted downwards - go too far at your peril as the struts cannot be pumped back up again. I used a variable force strut because it allows you more control over the installation. A variable force strut it is then, but what force do you need? Force is equal to mass x acceleration and the mass of the X1 head is roughly 10kg whilst the acceleration due to gravity is 9.8msec^2. The force required is therefore 98N. The stroke of the gas strut is decided by the headstock travel of the mill which in this case is 235mm. The headstock travel will be a little longer if you've fitted the fixed column with a 40mm adaptor block like me. You can't actually use all of the theoretical headstock travel so I chose the SD01 gas strut which has a force of 30-400N, a stroke of 60-200mm, and cost around £18. Notice that the panel weight guidance given in the SD01 data assumes that the gas strut raises a panel and then holds it in place with reasonable force. We are just looking to exactly balance the weight of our "panel" which will require less force. The gas struts can have a range of end fittings and I chose to have ball type fittings on each end. The catalogue specified that the mounting threads on the shafts of the ball fittings are M6 but mine were actually M5. Check before you drill and tap any holes in your X1.

Begin the installation by taking the entire headstock assembly off of your X1 and weighing it. This is important if you've made any modifications which altered the weight of the standard headstock, for example fitting a belt drive. Now you need to adjust the gas strut so that the force more or less exactly balances the weight of the head. The simplest way to do this is to push down on a pair of bathroom scales with the gas strut, note the weight at which the strut starts to contract, release a little gas from the strut, and repeat the process until the strut exerts a weight equal to that of the X1 head on the scales. Initially you'll find it almost impossible to get the gas strut to move (unless you're very strong), but let the gas out in 1 or 2 second bursts to start with until you can exert enough force to get the strut to contract. Then you can be more cautious as you approach the correct force. Be sure to measure the force at roughly the middle of the strut's stroke, as there is extra damping at the beginning and end of the stroke. Be sure to push the rod of the strut against the scales and hold the barrel in your hands when making these adjustments. If you don't you run the risk of losing damping and/or hydraulic fluid from the strut. The gas strut needs to be oriented in the same way when mounted on the X1. The internet is littered with pictures of gas struts mounted upside down; they look prettier but their lifetimes are shortened.

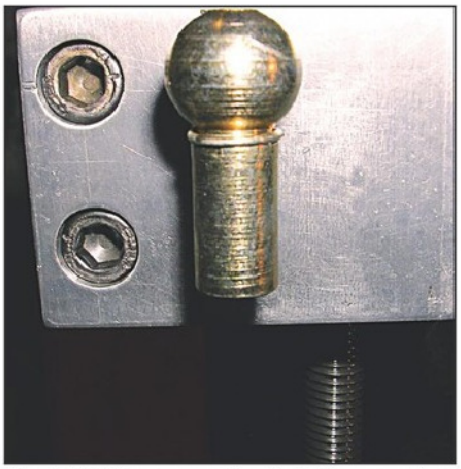


Photo 23. Top mounting hole for gas strut.

There are several possibilities for mounting the gas strut on the X1. I chose to mount mine on the back. I drilled and tapped an M5 hole in the base for the bottom gas strut fixing as shown in **photo 22**. The top fixing screwed into an M5 hole in a 50 x 40 x 19mm aluminium block fixed to the back of the headstock nut block with a pair of M6 cap head socket screws as shown in **photo 23**. **Photo 24** shows the complete gas strut assembly fixed in place on the X1 mill.

Screwing the gas strut into position is one of these jobs where three hands would be a decided advantage. The bottom ball end fitting is simply a question of screwing it in to the base of the X1; the top fitting requires that you hold the spring in compression as you screw the fitting into the aluminium block. If you make the fixed column modification and use a thick adaptor block like me, you should be able to get a bit more Z axis travel by using the SD02 gas strut which has a stroke of 250mm. ■

Photo 24. Gas strut fitted behind column of X1 mill.

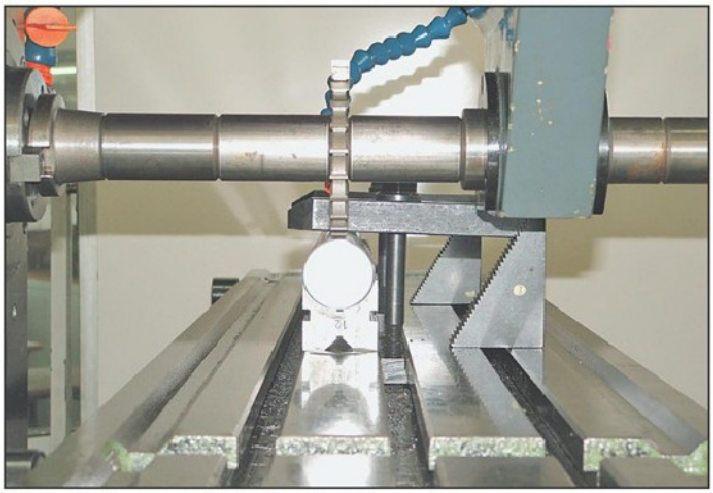


Photo 1. Unsupported arbor kept to a minimum.

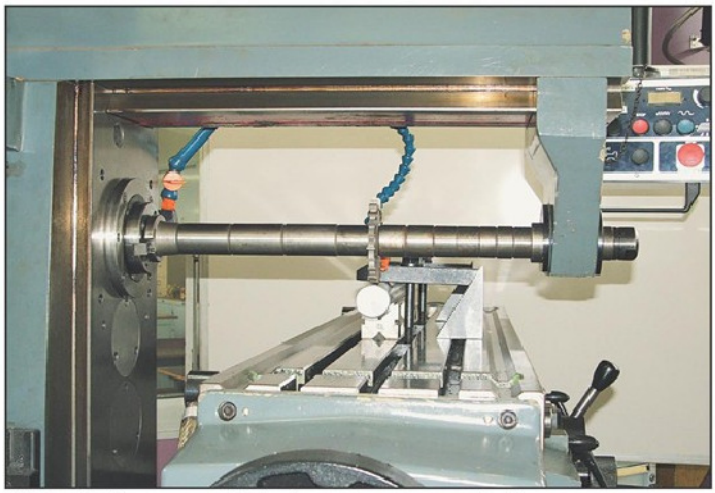


Photo 2. Always avoid the long unsupported arbor.

AN INTRODUCTION TO MILLING 3

Donald Brymer looks at positioning milling cutters relative to an edge or centre line of a workpiece.

There are numerous designs of mechanical/laser edge finders commercially available, all of which are useful machining aids if used correctly. However, the methods described in this article are simple and accurate and do not rely on edge finders as such.

Horizontal machining of slots and grooves

The task is to produce a slot or key seat in a 40mm diameter (the actual shaft measurement is 39.98mm diameter), using a 9.5mm side and face cutter in the horizontal position.

Consider the following; Mark out your work if required to act as a machining guide and align the work to the machine column while being supported with matched vee blocks.

Clean the arbor taper and the machine spindle mating surfaces and mount the arbor. Clean all the arbor spacers and the mounting surfaces of the side and face cutter.

Place a suitable number of arbor spacers on the arbor to set the cutter in a suitable position that will give maximum rigidity to the arbor and as close to the machine column as possible for the job at hand. Keep the number of arbor spacers after the cutter to a minimum; this includes the arbor support bearing, **photo 1**. Always avoid long lengths of unsupported arbor, **photo 2**. Spacers placed on the arbor after the bearing are only to fill the arbor, but the arbor thread must engage a full nut. If a short arbor is not available the set up shown in **photo 1** is quite acceptable. Tighten the arbor nut by hand only at this time and mount the arbor yoke. A couple of points here; no arbor key has been used to drive the cutter, for light machining it is not necessary as there is sufficient friction between the cutter and spacers to drive the cutter. If the cutter will be revolving clockwise as you are looking at it, the forces apposing the cut with be anticlockwise, what happens when the arbor nut is turned anticlockwise? Does it tighten or loosen? If it tightens OK, if it loosens you have two choices; 1: change the arbor to a left hand threaded arbor, or 2: remove and replace the cutter to give anticlockwise cutting rotation. Either way the forces apposing the cut need to be tightening the arbor nut.

Editors note: *you can always put a key on an outside spacer. This will stop the spacers spinning and the nut from coming undone and will not affect the cutter.*

Once the arbor yoke is in position the arbor nut can be fully tightened. Do not fully tighten the arbor nut with an unsupported arbor. You risk bending it.

Start the machine and check the cutter for any form of runout or wobble. If any runout/wobble is detectable, this problem can often be overcome by loosening the arbor nut, rotate the cutter somewhat and retighten the arbor nut. Try this a couple of times and if the cutter is still running out, maybe the arbor, spacers or cutter are damaged or debris has entered the setup. Rectify before continuing.

Cut a strip of newspaper (thickness is 0.072 mm or 0.0028in.) the full width of the sheet and about 25 mm wide.

Position the side of the work to within 0.5 mm of the cutter.

Start the machine spindle, place the strip of newspaper between the cutter and work and slowly move the work toward the cutter, one division of the cross feed graduated collar at a time by hand. When the cutter begins to pull the paper in but does not cut it, **photo 3** stop the feed and zero the graduated collar.

Editors note: *I would put the arbor out of gear and rotate it by hand for safety.*

Photo 3. "Picking up" the diameter of bright round bar with paper and revolving side and face cutter.

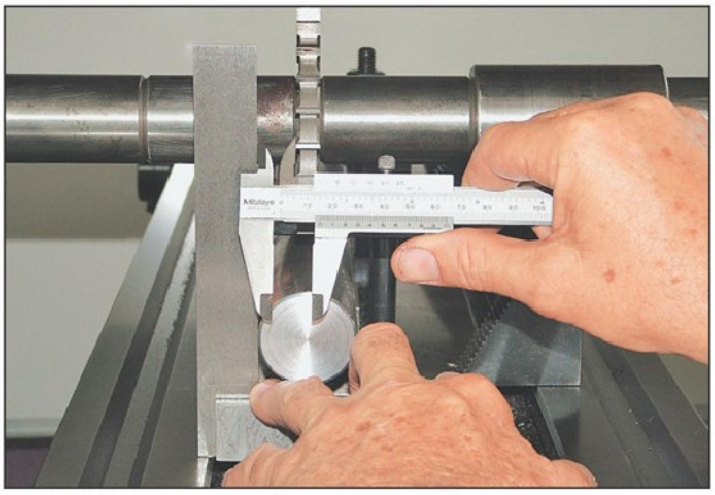


Photo 4. Setting a cutter by measurement.

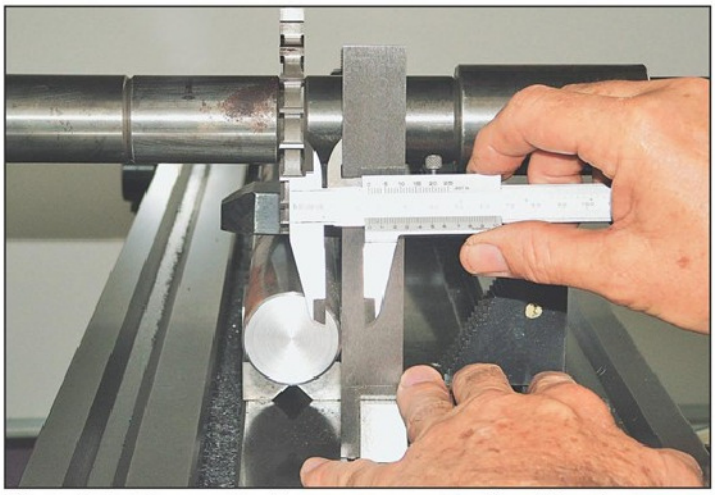


Photo 5. Setting a cutter by measurement, other side of cutter.

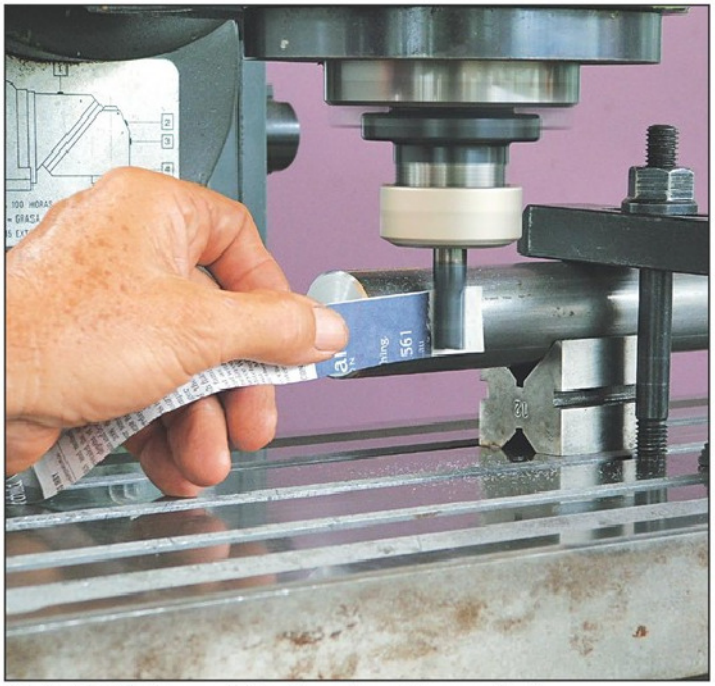


Photo 6. "Picking up" the diameter with a vertical cutter using thin paper.

Photo 7. Setting cutter to the top of work diameter using thin paper.

At this point lower the machine knee and move the cross feed a distance equal to half the width of the cutter, plus half the diameter of the work plus the paper thickness. For this example 19.99 + 4.75 + 0.072 = 24.812 mm gives the correct position. Using a plunger dial indicator rather than the handwheel graduations will increase the accuracy.

Now the cutter is over the diameter of the shafting, pick up the top work surface using the same paper technique. Zero the knee height graduated collar.

The cutter has been accurately positioned to commence machining, refer to **Photo 1.**

If a slot is required in a square or rectangular workpiece the reference edge of the work can be found using the same technique. The difference being that the full width of the cutter is added to the distance the slot is positioned from the reference edge.

If the machining movement has a defined length i.e. the length of a key seat, utilise the machine table stops to help achieve the slot end position for repeated cuts.

If you have never tried using thin paper to "pick up" an edge or diameter may I suggest that you practice it and you will be surprised by the results. A warning though; use long pieces of paper to keep your fingers away from revolving cutters.

An alternative method of cutter positioning when machining round stock is to approximately set the cutter by eye over the shaft and then measure the position of the cutter relative to the work diameter using measuring tools appropriate for the accuracy required.

To set a cutter using this method, try the following steps;

- Setup the machine as required.
- Position the cutter visually in the approximate position.
- Using an engineer's square off the table and with the blade against the work, measure between the square's blade and the side of the cutter on one side and record the measurement, **photo 4.**
- Measure the other side of the work using the same method, **photo 5** and compare both measurements. Adjust the machine cross slide by moving the cross slide half the difference between the two measurements. Check both sides after any table movement and adjust as required. When the cutter is centralised, lock the appropriate table clamps.

Ensure that you measure from the same point on each side of the tooth to improve accuracy. Depending on the measuring equipment used and some practice, this method of cutter positioning will be sufficient for many milling applications, however, my preference is by using the thin paper method.

Vertical machining of slots and grooves

When setting vertically positioned cutters to a workpiece, the steps for either method above can be used with equally accurate results, see **photos 6 and 7.**

Should you decide to measure the distances from an end mill or slot drill and engineers square and the work ensure that you measure from the square to the parallel shank of the cutter and not the cutting edges. I would suggest that you use a short length of suitable diameter silver steel or use a cut off parallel drill shank in the collet chuck rather than a cutter. You will still be positioning the cutter on the centre of the shaft. To be continued...

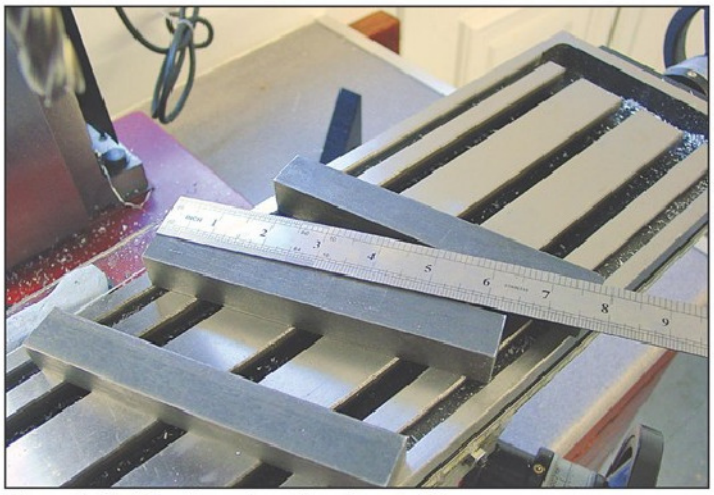


Photo 1. Cut the three lengths of material.

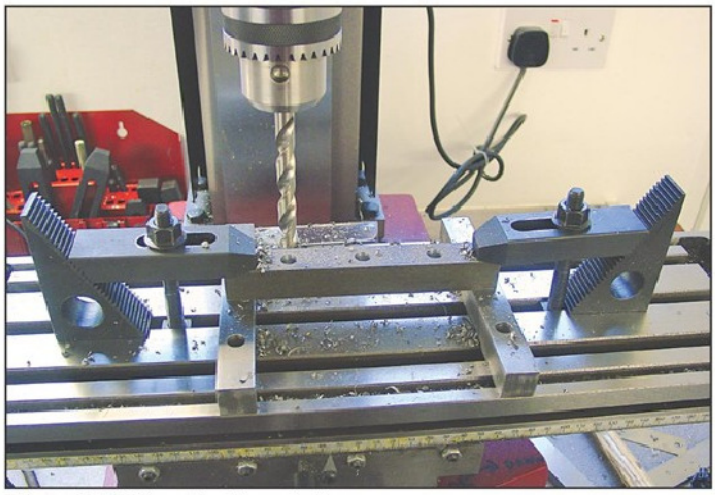


Photo 2. Drilling the three holes.

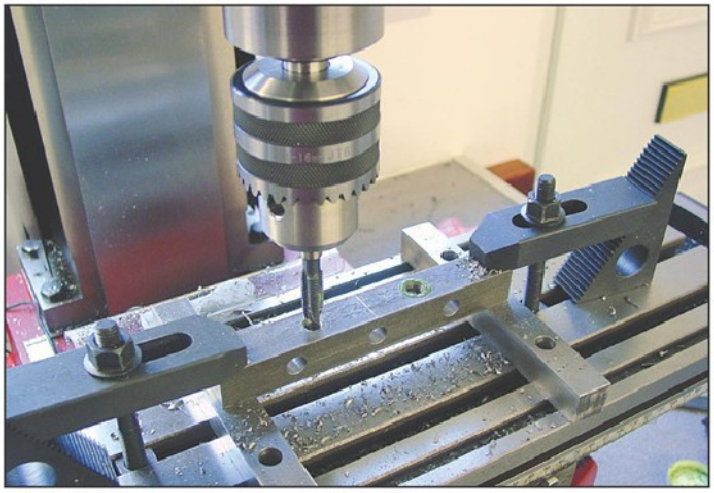


Photo 3. Tapping two holes in the mill.

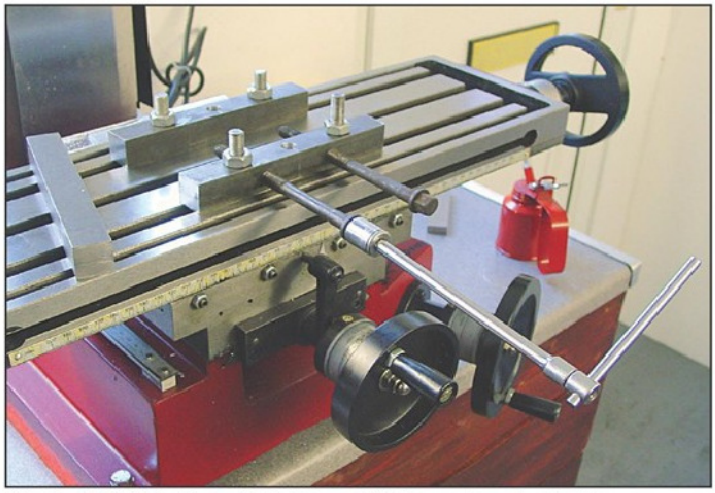


Photo 4. Bolt to the mill table and fit two clamping bolts.

A simple homemade vice

Richard K. Wightman makes a simple milling machine accessory.

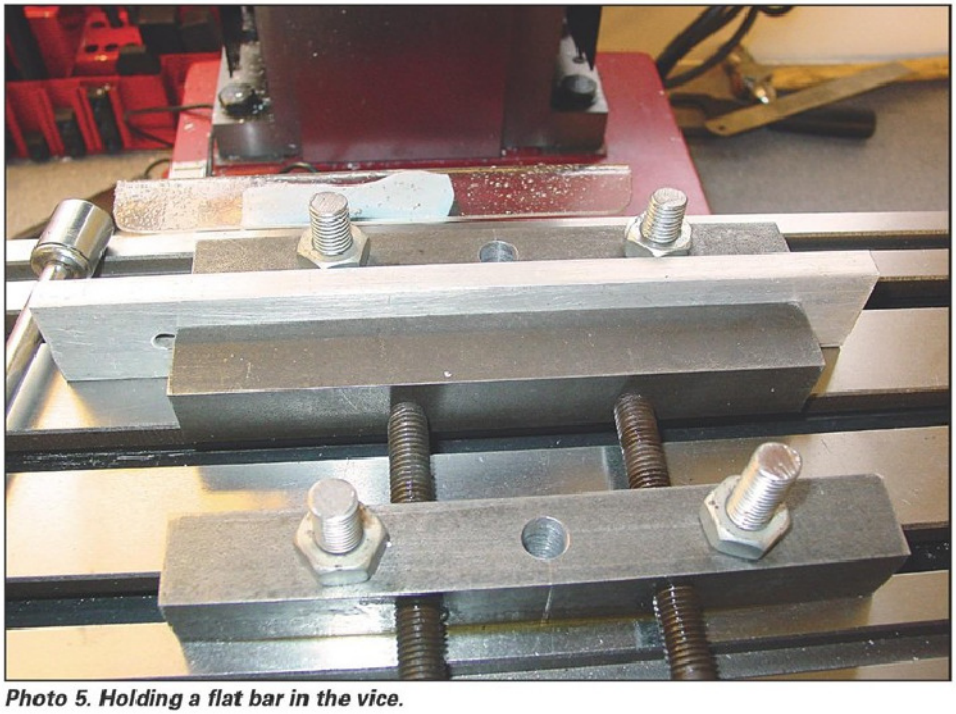


Photo 5. Holding a flat bar in the vice.

I'm sure you will agree that a vice for the milling machine is a must have piece of kit and is probably the first accessory you will need to carry out any sort of work. A vice is probably the easiest way to hold a work piece for carrying out the various machining operations. However, holding some parts can be tricky especially if they are long and narrow. Vices are limited by the width of the jaws and how far they will open. Clamping the workpiece directly to the milling machine table is one answer but clamps can often get in the way. What I needed was a low profile vice that would allow me to set the workpiece directly onto the milling machine table while at the same time holding it securely.

After due consideration and playing about with bits of metal this is what I came up with. It took me a little over an hour to make it and it is designed to fit my X3 milling machine but would be easily adaptable to almost any make and size of machine. The first job was to cut three lengths of ⅞in. square steel to 6 ⅜in. long, (6⅜ inch being the width of the table on an X3 milling machine). Then drill three 10mm holes in what will become the fixed jaw, spaced the

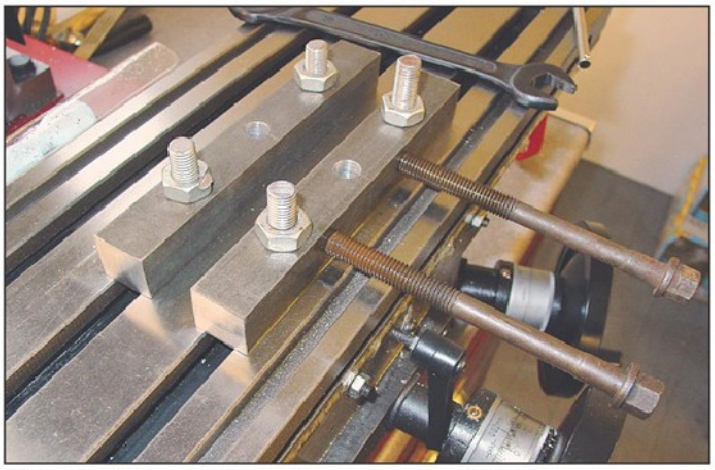


Photo 6. You can fit the main components into adjacent Tee slots and use the bolts as clamps.

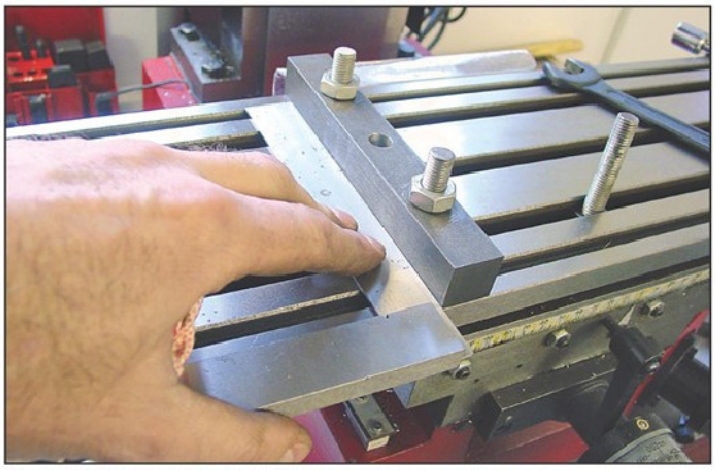


Photo 7. Setting the fixed jaw at 90deg. to the table.

Photo 8. How long do you want your vice?

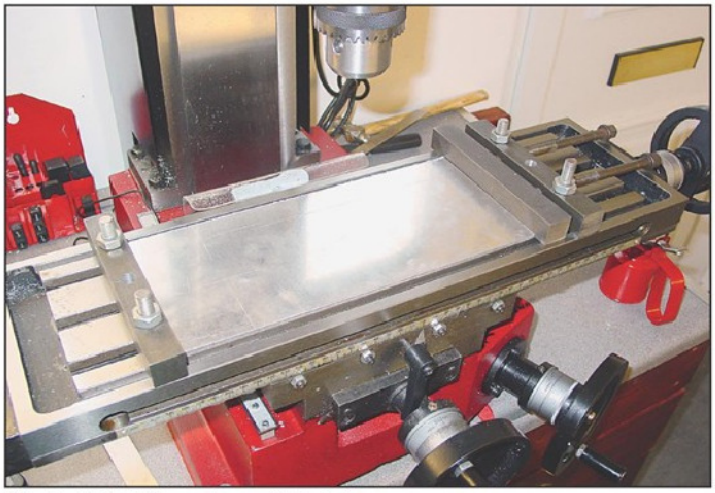


Photo 9. Holding a large flat plate.

same as the three Tee slots in the table. Drill the same three 10mm holes in the other fixed jaw and then turn it through 90 degrees and drill two 8.5mm holes. The two 8.5mm holes can then be tapped out to 10mm X 1.5mm pitch. Two long 10mm bolts will be needed for the vice. I used Ford escort cylinder head bolts (yes I'm in the motor trade). They are high tensile bolts and have a nice small 13mm head. The third length of steel is left plain and is used as a moveable jaw. In use the vice is extremely quick to set up and very versatile. The two fixed jaws can be bolted to the table in an infinite number of positions, either across the table or along its length and positioned so it will overhang the table where the bolt hole in the overhang can be used to mount additional clamps or jigs. The vice can be used in conjunction with clamps which can be fitted with the stud going through the spare hole in the vice and into a 'T' nut in the table. By using longer studs to clamp the vice to the table they can then be used to hold additional clamps.

I have it in mind to drill and tap the two jaws M6 so that the studs and clamps from my X1 milling machine could also be used. The two fixed jaws can also be used as stops and also set up at 90 degrees to each other. This is very useful when carrying out repetitive or batch work. Because the third jaw is not fixed but is floating, odd and irregular shapes can be gripped with ease. Being made from mild steel, accidentally running the cutter into the vice will not damage the cutter; in fact in some circumstances the jaws could almost become sacrificial. Work can be mounted across the top of the vice jaws with clamps when drilling right through the workpiece. The photos are to show how versatile this vice can be.

In practice, additional clamps and/or stops may be necessary depending upon the machining operation in hand. As time goes by, improvements and mods will be made I'm sure but the main thing is the cost, which was next to nothing. The vice has been in almost permanent use since its conception. To someone who has just made the purchase of a milling machine and has limited funds available, this vice could fit the bill and would make an ideal first project. A similar idea could be used on the drill press and once set up would be ideal for batch work. The floating jaw could be replaced with a shaped jaw used for holding circular work pieces. ■

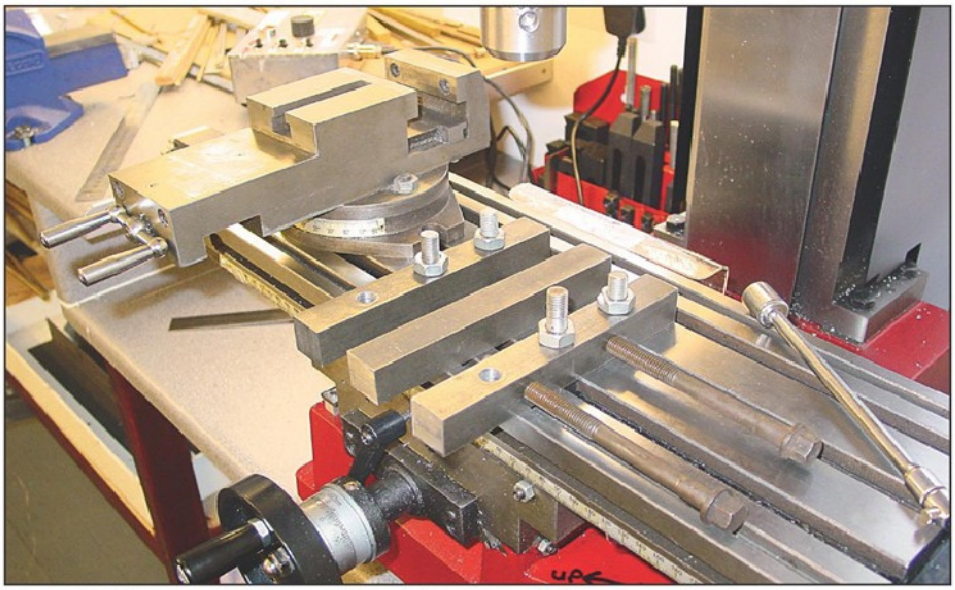


Photo 10. The new vice is much lower than the old vice.

MAKING A WELDING TROLLEY

Jayne Reeve makes another simple welding project

Following on from the bandsaw stand, this is another fairly simple project that will give your fledgling welding skills some more practice.

Weather permitting I prefer to do my arc welding outside as fumes dissipate easily and the abrasive dust created using the angle grinder doesn't end up covering the contents of the garage. To save me having to carry the welder outside, a welding trolley was deemed necessary. The ability to neatly store the welder and associated accessories when not in use would also be a bonus. The finished trolley is shown in **photo 1**. For storage, the welding unit, chipping hammer and wire brush sit nicely on the bottom shelf, with the welding helmet and gloves (in the box) on the top shelf. During use the welder is lifted to the top shelf to give easy access to the current control and main on/off switch as shown in **photo 2**.

To keep the design as simple as possible steel angle is used throughout and most of the welds are simple butt joints. A steel thickness of 2.5mm has been used to make it easy for arc welding by novice welders and all the lengths are cut with square ends. As drawn the trolley can be made from 4m of material, leaving a little left over for welding practice. Dimensions can be adjusted to suit individual applications.

Material cutting list

All 25mm mild steel equal angle, 2.5mm thick

- 4 off 300mm
- 4 off 200mm
- 2 off 375mm
- 2 off 400mm
- 2 off 40mm

Shelves

- 2 off 245 x 345mm approx.

Shelf material is largely personal choice and depends on the intended use of the trolley (and what you have available). Currently I've used 3mm thick rigid PVC sheet just because I happened to have some suitable off-cuts. It actually works quite well as the shelf is small and well supported and my welder is not too heavy. PVC is also self-extinguishing so that could be useful when hit by sparks and spatter during welding! A better more robust choice would be steel or aluminium. For ease of cutting when a hand saw is all that is available, shelves could be made from plywood etc.

Handle

The handle used here was bent from 6mm diameter aluminium bar using the temporary jig pictured in **photos 3, 4 and 5**. The 'formers' used are around 20mm diameter. The remaining parts are from a universal clamping kit. The two formers are positioned so that the bar is held securely and then the bar is bent to the required angle using muscle power, trial and error, and measuring by eye then repositioning the bar as required until the handle shape is formed. Although not perfectly symmetrical, the handle produced does the job. Again the material chosen will depend on personal preference and availability. It could equally be made from other materials such as steel, brass etc. For the dimensions shown in **Fig. 1** a bar length of at least 400mm would be required.

Wheels

The wheels chosen were 80mm diameter rubber tyre versions with a 12mm bore. I favour these wheels as they roll much easier over uneven surface than smaller diameter wheels. These are available not too expensively from RS components. The axles are 12mm bolts. If you have access to a lathe then suitable wheels could be turned from nylon, acetal etc. Makeshift rubber tyres can be made from short lengths of motorcycle tyre inner tube stretched over the turned wheels. The axle bolt is passed through the 12mm hole in the upright from the inside and the head welded onto the inside of the framework. A double nut arrangement is then used to prevent the nut undoing as the trolley is wheeled around. The nuts are adjusted to allow the wheels to move freely but with a minimum of sideways play. If different diameter wheels are used then adjustments will need to be made to the design to accommodate.

Construction

Drill the holes for the wheel axles into the two 375mm uprights. Then starting with one of the larger sides of the trolley,

Photo 1. Trolley stacked with welding equipment ready for storage.

Photo 2. Welding unit moved to top shelf ready for action.

a 400mm and 375mm upright and two 300mm cross members, arrange and clamp them ready for tack welding. See **photo 6**. Take time to ensure that the frame is flat and square as it will be used to help assemble the second side. If you're a good competent welder then it should be possible to fully weld material 2.5mm thick from one side. However for the less competent it is probably desirable to weld both sides of the joint and this does also help to even out the distortion caused by welding. Finish weld the joints of this first frame side and then grind flat the outside welds as shown in **photo 7**. The component members of the second side

Photo 3. The handle.

Photo 4. Makeshift bending rig for forming handle.

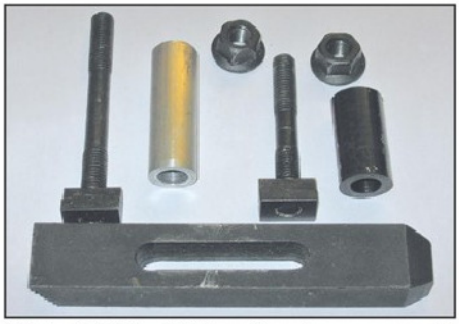


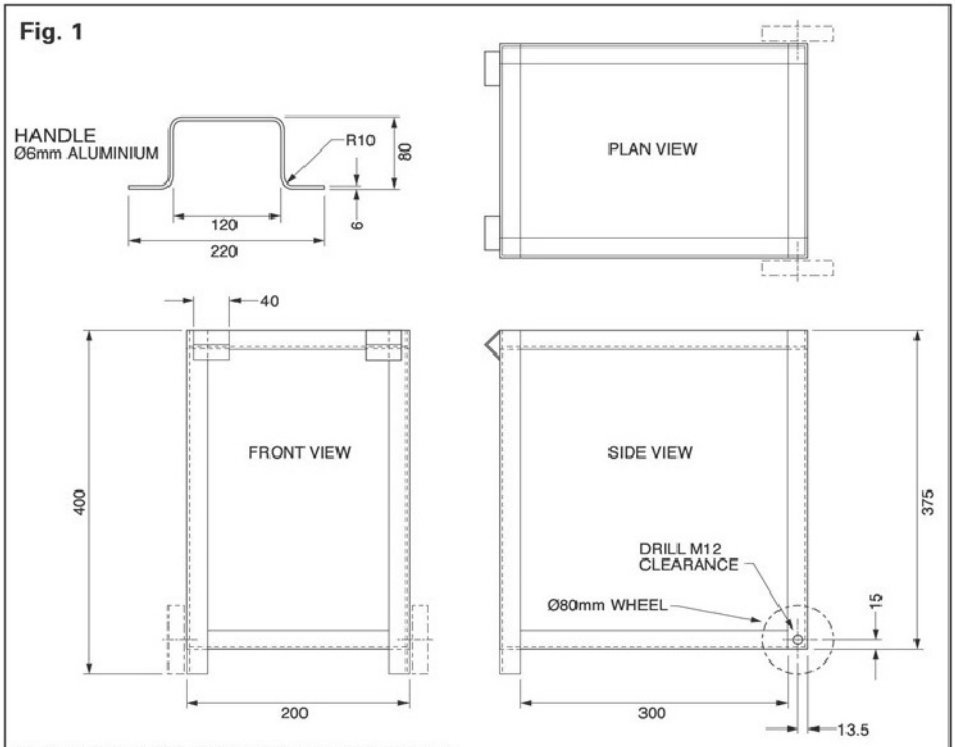
Photo 5. Makeshift bending rig components.

Photo 6. First frame side clamped ready for tack welding.

Photo 7. Frame welded both sides, outside welds ground flush.

Photo 8. Second frame side members clamped to first for tack welding.

Fig. 1



WELDING TROLLEY (SHELVES NOT SHOWN)
MATERIAL: 25mm EQUAL ANGLE, 2.5mm THICK MILD STEEL

can then be clamped to this ready for tack welding. See **photo 8**. This hopefully should mean that both frame sides are as near identical as possible. Make sure that your tack weld penetration is not so good that you weld through to the first frame! Once tacked, unclamp the two sides and finish welding the second side.

The final job on the basic frame is to weld the four 200mm side members in. The already completed sides are held vertically and a suitable piece of scrap material and two G clamps can be used to hold the top edges the correct distance apart, **photo 9**. The bottom edges and the first two 200mm members are clamped in place and once everything is checked and square in all dimensions these can be tack welded together. The scrap material and G clamps can then be replaced with the remaining 200mm members, which will need to be clamped in place ready for tack welding. Again make sure the frame is square before tacking. The basic frame is complete and after one final check to ensure that everything is square and level as required the welds can be finished, **photo 10**.

Two 40mm lengths of angle iron are used to form brackets to hold the handle in place. These are positioned approximately 10mm in from the edge of the trolley with the top edge of both trolley and handle brackets in line with each other. Tack one bracket in place, fit the handle and then position and tack the other bracket. The brackets can then be fully welded along the top edge and partially welded along the bottom edge where they contact the trolley uprights.

Fit the axle bolts and weld the heads in place. You may wish to turn down the bolt heads to reduce their thickness to around 2.5 to 3mm thick. This makes them easier

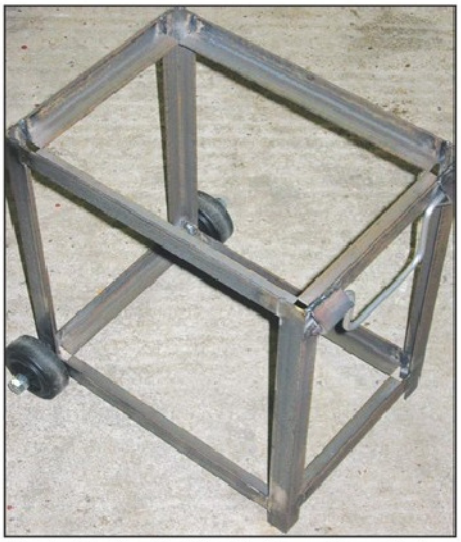


Photo 10. The finished trolley minus shelves.

Photo 9. Clamping frame sides for welding in 200mm side members.

to weld to the 2.5mm thick frame material and will also reduce the amount of fettling required to get the shelves to fit around the bolt heads. The wheels can now be fitted, **photo 11**.

Shelf dimensions are nominally 245 x 345mm but will possibly need to be adjusted to fit the finished frame. Some fettling maybe needed at the corners to fit around welds and bolt heads as required. If using sheet steel for the shelves these could be welded in place with a series of tack welds. Otherwise depending on your preference and the material used, the shelves can be loose fitted or bolted/screwed in place. ■

Photo 11. Trolley with shelves fitted.

A MYFORD SUPER SEVEN TOPSLIDE WITH DIGITAL READOUT

Ken Willson utilises a miniature readout scale.

In MEW issue 144, our editor commented after the 2008 Model Engineer Exhibition "it's hard to believe that there's a DRO hidden inside" so let's see what I can do to convince you.

Visitors to the previous 2007 Model Engineer Exhibition at Ascot may well have seen the original working experimental version of the above. In addition, photographs and a write up appeared in the Model Engineer Exhibition reports in both ME and MEW magazines following the Show.

It had always been the intention to progress the idea to a more practical stage, with the aim of producing an "exact replica" of the original Myford product but with the DRO fully integrated within the slide, leaving the only disadvantage of a connecting cable.

At the 2008 Model Engineer Exhibition the final version was put on show, together with the concept wooden mock-up and the first machined base together with the 2007 exhibit, **photo 1**. This article is intended to show how the parts involved were made and assembled together with the constraints on the process brought about by the physical sizes of individual parts. Of necessity, to deviate as little as possible from the "Myford pattern", certain Myford spare parts were utilised, some of which were modified to provide a better basis for this design.

Using G17 continuous cast iron block, the top slide base was machined from the solid on a Myford S7, with the mounting spigot diameter matching the standard cross slide. However, the taper angle was reduced to gain valuable space within the spigot. This necessitated a production jig for revised pads. Some consider that a roughly filed soft circular pad will do the trick, but unless the contact face corresponds closely to the taper angle and follows the curve, you will stand a good chance of spreading the end to such an extent that it may be difficult to ever remove the pads or top slide base. It should be noted that they are a pair, i.e. handed, **photo 2**.

A larger calibrated circular base was incorporated, **photo 3** giving slightly better support making the 1 degree steps around 1/32" intervals apart. The Myford dividing head was fixed to the rear of the mandrel giving a direct drive through the headstock. I scribed the degree marks with a HSS "V" tool set on its side. The height of the mark was determined using "sized" spacers, which were used on the tailstock-constrained carriage; the small diameter rod shown in **photo 4** is attached to the stud normally used to attach the threading dial to the carriage. Following setting out of the leadscrew nut and DRO scale positions, the dovetail was machined on the upper face following normal practices, for convenience, a standard cross slide was used as a "jig" to hold the base on the milling machine table during this process, **photo 5**.

At this stage the recess to hold the DRO Head electronics needed to be cut. Various cross section drawings had been prepared so as to ensure that it would fit, be in the correct position and of equal importance, that there was sufficient metal all around it. All of these requirements have to be satisfied at the same time and was an exercise in 3D imagination without the aid of CAD, **photo 6**.

The top slide was again machined from solid G17 continuously cast iron, and following machining of the matching dovetail, the oversized gib strip was held against the relevant face by a round brass rod, held by tool maker's clamps, which allowed the edges to be machined at the correct angle. A small spacer strip (cut from an aluminium beer can) was used during the final pass to ensure that the gib had some vertical clearance. Having set the top slide in the milling vice, the gib screw tapping holes and a plain reamed hole was provided for the lateral gib location pin. The screw holes were all drilled into the gib strip to a controlled depth, to accept the tips of

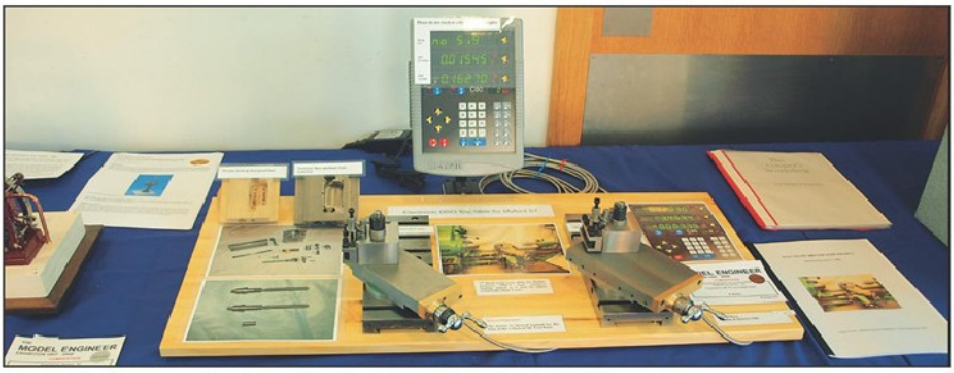


Photo 1. The entry in the 2008 Model Engineering Exhibition.

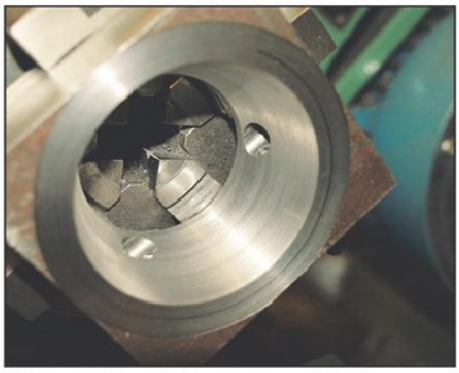


Photo 2. Machining the top slide base.

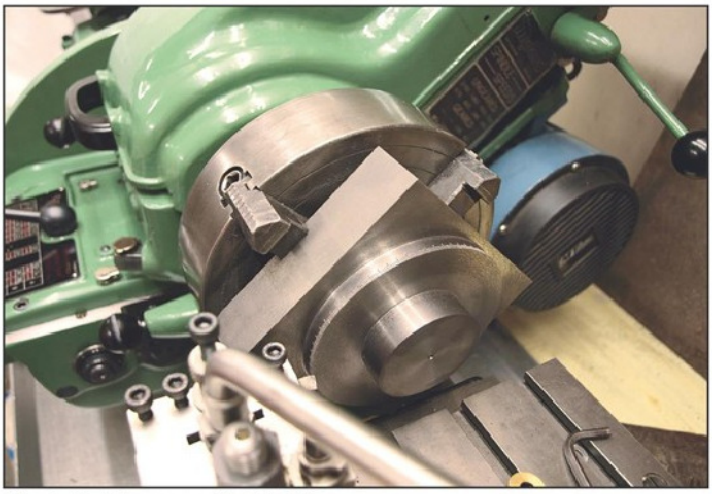


Photo 3. A larger calibrated base.

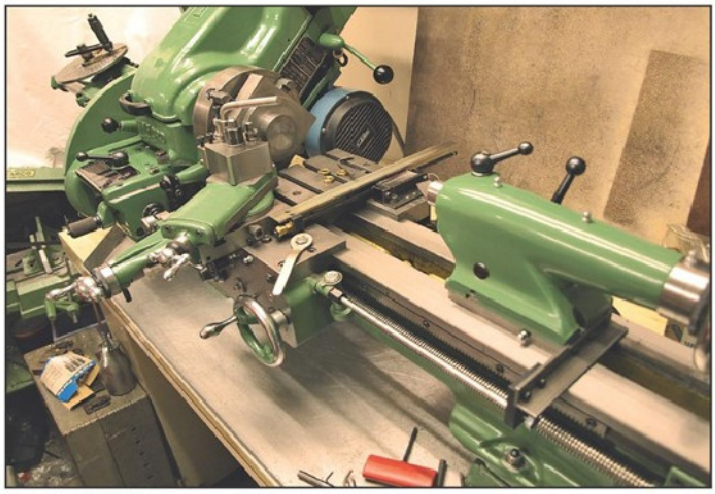


Photo 4. Calibrating the base.

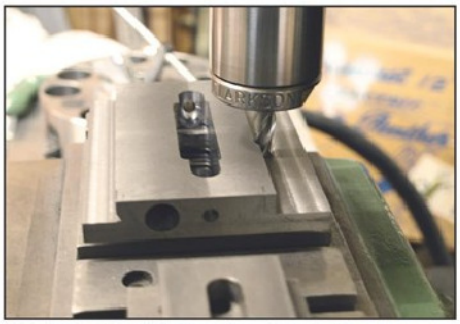


Photo 5. Machining the dovetail.

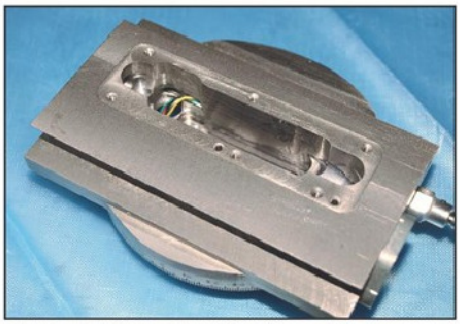


Photo 6. The cutout for the scale.

Photo 7. The two feedscrews.

Photo 8. All the small pieces.

Photo 9. Homemade connector parts.

the gib screws. In this way all holes were properly aligned through both parts. All drilling was done on the vertical mill using DRO coordinates without marking out.

The top slide was then married with the Base and firmly locked together by the setscrews. Final machining to size using an end mill now took place for both Top and Base.

Unlike the original top slide, which had plain bearings with a steel feed screw shaft running in a cast alloy end plate, this new design uses a pressed in, full complement needle roller, together with needle thrust bearings. This required changes to the end plate sizes and design as well as a new style adjusting collar. Because of the longer bearing assembly, changes were required to the normal feed screw sizes to accommodate this greater length. **Photo 7** shows two feed screws, with the normal and new version bearing. Yes the top screw is metric being the only spare one to hand.

The feed screw was set up in a four-jaw chuck, with a soft aluminium protection strip between the jaws and the shaft, the end being supported by a hollow cone tailstock centre. TIR of 0.0004 was achieved and the surplus material removed to accommodate the new sleeve bearing shaft. At 0.002in. to go, the old sleeve came away, it was not solid after all and I now had a clean surface, concentric with the acme thread as it was originally manufactured. Using a short length of ground silver steel of the appropriate size, a replacement sleeve had to be made, held at all times within the mandrel end using a Myford MT2 Collet, drilled and then bored, thus ensuring the best possible concentricity without resorting to grinding practices. The small pieces "kit" was now complete, **photo 8.**

The original experimental version had a split anti-backlash feed nut arrangement but time prevented this being fitted to the final version in time for the Exhibition. This is not in itself a showstopper since with the DRO in place, the exact position of the top slide is known with good accuracy.

An advantage that came without being first thought about was that with the conventional topslide, the feed screw is centrally placed and under some circumstances, the handle clashes with the tailstock. Being off-set to the left in this version because of the necessity to have the read head in the centre, this is less inclined to happen.

All that now remained was to fit the tool post stud. The top slide was inverted and both the through hole and the step counter bore were machined at the same setting with the table locked in both X and Y axes.

One last problem needed to be solved; a suitable 7-way miniature connector could not be found with the required diameter of less than ⅜in. so I resorted to making a suitable substitute using PTFE rod, with two concentric rings of stepped holes, the smaller diameter to just clear the 0.6mm stranded wire and the larger to just clear the insulation. A quick soldering job with a very small bit and all was connected, **photo 9.**

The final assembly detail was to screw in place the cover over the read head and to seal the 7-way connector with silicon sealant.

The object of this article is not necessarily to provide a project for others to emulate but to demonstrate that with a degree of skill, it is possible to provide oneself with a tool that is not commercially available. I tend to screwcut all threads and only rely upon a die to "chase" the final item, although this takes a little longer, it does result in clean regular threads without any "drunken" throwaways. The use of the inbuilt DRO enables me to precisely set the in feed and also, when using a "summing facility", maintain accuracy with known X and Y readings, even when the topslide has been used (at a known angle). The finished top slide is shown in **photo 10.** ■

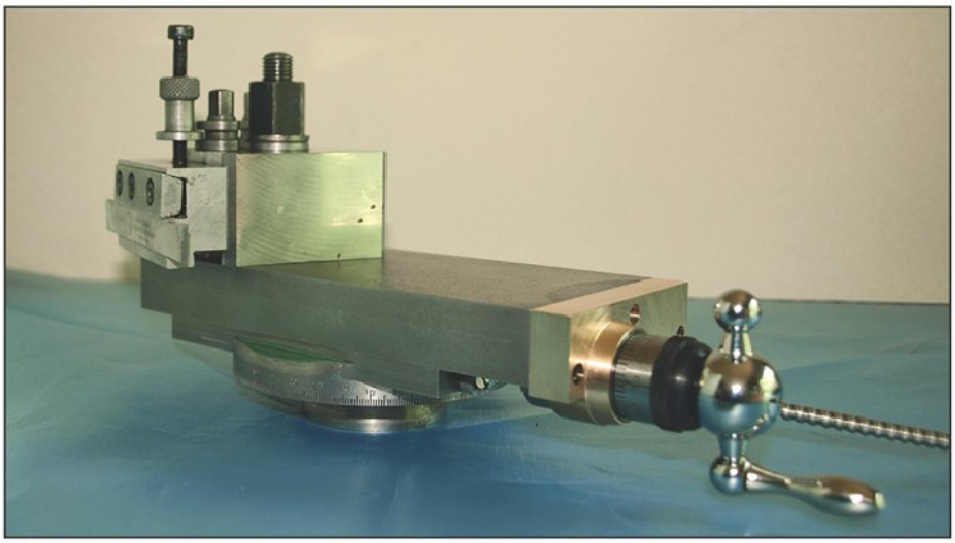


Photo 10. The finished top slide.

A SMALL COMPRESSOR

Richard K. Wightman gets the pressure on.

I've spent the last few years getting myself kitted out (and building a new workshop) so that I can have a serious go at model engineering. Each new bit of kit enables me to make another bit of must have kit and so it rolls on. Great fun isn't it. There is still quite a lot on the wish list but the time has come (prompted by my wife saying when are you actually going to make something useful) to have a go at building my first model steam engine. I have decided roughly what I want to build and started jotting down ideas.

The inspiration comes from my favourite magazines; it's a steep learning curve but I'm hooked now, no turning back I'm afraid. However it appears there is another piece of must have kit, a compressor for testing said engine. I'm in the motor trade so I have some knowledge and experience with compressors. Brand new ones are available for under a hundred quid and there are plenty of second hand ones around but all of them from my experience do tend to be a bit on the noisy side; not what I want in my workshop. From what I understand, model steam engines will run on as little as 5-15 psi so I decided to have a go at making my own compressor. The requirements would be small and light enough to shove under the bench when not needed, quiet and capable of 50 psi. A bit of compressed air in the workshop will be handy for blowing out jets and crevices and hopefully it will be good enough to run a small air brush. The compressor, as can be seen from the photos is made from an old fridge pump with a fire extinguisher as a tank. I'm not going to provide any detailed drawings as it is unlikely you would be able to scrounge the exact same parts as me but the photos should give a clear enough idea of how it all goes together. Acquire a pump from an old fridge; your local recycling plant will usually let you have one but if you put the word round you will soon find someone who will be only too glad to get rid of their old fridge. The same goes for a fire extinguisher.

Photo 1. The raw materials, an old fridge compressor and a fire extinguisher.

Photo 2. The extinguisher with the guts removed.

So having acquired the two main components (the pump and the fire extinguisher) the first job is to rewire the pump so that it runs permanently when switched. In the fridge it would only cut in when the temperature was high enough and cut out again when the temperature was low enough. This involves disconnecting the wire from the thermostat and rewiring the power connection to include the thermal cut out (in case the pump over heats). It's a fairly simple job but I can't show how it's done as all makes of pump will be slightly different. Just ask a good sparky to do it for you if you're not sure. It's best to make sure the pump runs OK before proceeding with the rest of the project.

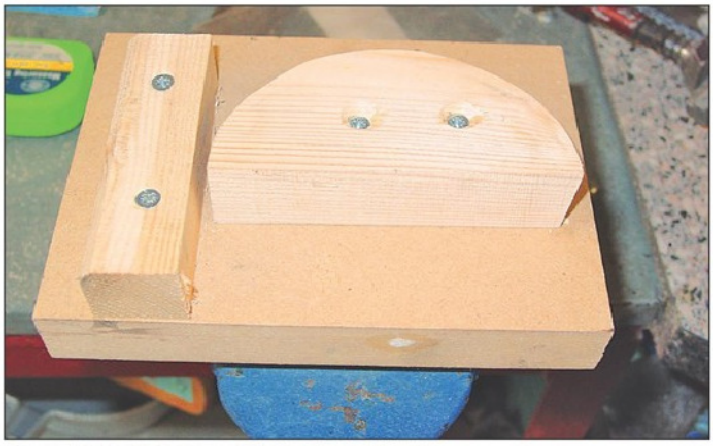


Photo 3. The bending jig.

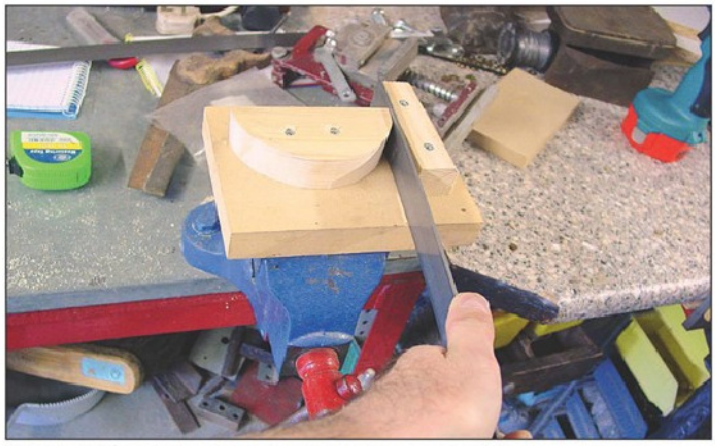


Photo 4. Bending one of the mounting brackets.

Photo 5. Bending the end of the mounting bracket.

Photo 6. The circular part of the mounting brackets.

Photo 7. The wooden tank supports.

Photo 8. Bending the square part of the brackets.

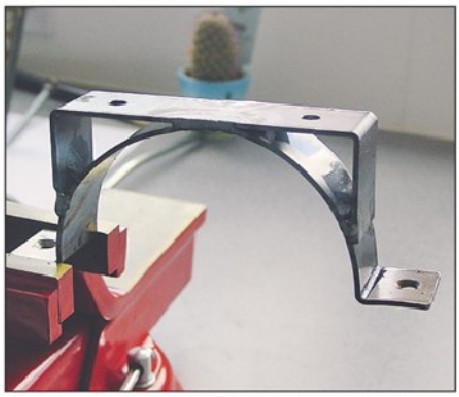


Photo 9. A finished mounting bracket.

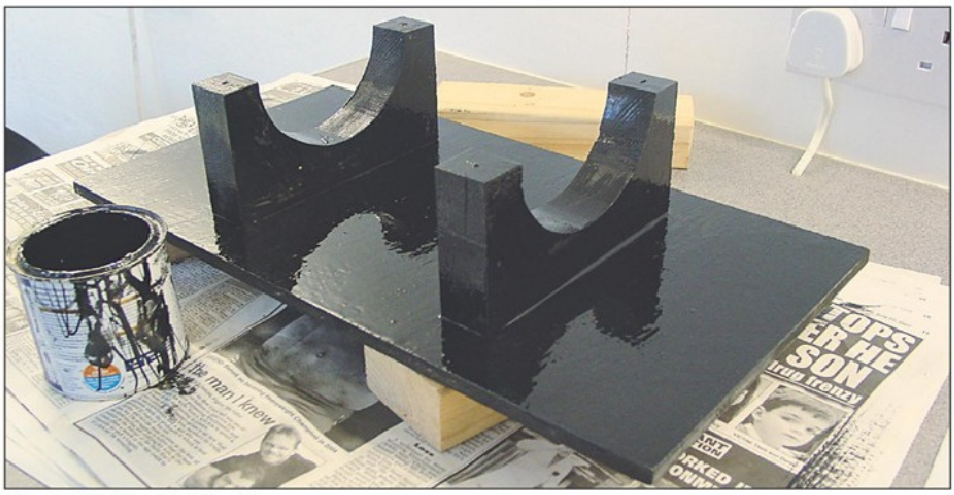


Photo 10. The finished base.

If all is well then you can proceed with the tank. The tank is made from an old fire extinguisher. As can be seen from the markings, the tank has a capacity of 2 litres, a working pressure of 18 bar and a test pressure of 27 bar, well above the 3-4 bar (40-50 psi) that I intend to run it at.

Make sure the fire extinguisher is completely discharged and unscrew the trigger etc from the top. Remove the little gauge, the handle, the tube and the nozzle. The threads turned out to be 1/4 bsp so it was fairly easy to make up the necessary connections with Tee pieces and odd bits from the scrap box. First of all find a bit of board of suitable size. The two cradles for the tank were made by firstly measuring the diameter of the tank and then cutting a hole the same size in a piece of wood and then cutting the wood in half, these were then screwed to the baseboard from underneath. Four rubber feet were fixed to the bottom of the baseboard. The offcut circle of wood was then cut in half and used to make a jig to bend the metal brackets. These were then drilled and countersunk to take screws. The metal brackets to mount the tank were then made and welded to the tank mountings, although they could just as easily be drilled and bolted together. The baseboard, brackets and pump now were painted with black Hammerite to clean things up a bit. With the tank and pump mounted on the baseboard the motor can be mounted on top using its original rubber mountings and bolts. Now it's a straightforward job to connect the two together with various connectors and bits of pipe. Here the photos should be clear enough to show how I did it. Note that I coiled the main pipe to give it a bit of flexibility. The pressure gauge was bought from Machine Mart (usual disclaimer) for £4.69 along with a standard air line connector.

I made a simple one way valve, which is fitted at the air entry point. It is made so that it is a press fit into one of the brass adapters. It's a simple bit of brass turning with a ball and a spring made from bronze wire, the spring wire being wound round the shank of a twist drill.

A pressure relief valve is also a simple bit of turning and made to fit inside one of the brass adapters, an 'O' ring forming the seal. I had to mess about with various springs until I found one that would blow off at the required 50 psi. All the bits such as one way valves, pressure relief valves etc are all available from Machine mart if you don't fancy making them yourself. In operation it is so quiet that I had to put my hand on it to feel if it was running. It takes less than 1 minute to build up to 50 psi from an empty tank at which point the pressure relief valve gives a little hiss and maintains the pressure at 50 psi. Automatic cut off and starts are also available from Machine Mart but as I will only switch mine on when I need to use it I think that would be an unnecessary expense. At some point I shall have to fit a pressure regulator to the outlet so that I can control the pressure.

A few accessories have been made which include a blow gun and a simple tyre inflator with parts scavenged from an old foot pump. It will inflate a tyre, albeit slowly, but a lot easier than the foot pump method. I also have all the little adapters that are used to inflate air beds and the like. Well that's about it, a very useful bit of kit, quiet and above all for next to nowt. A bigger tank (fire extinguisher) will hold more of a reserve of compressed air but will obviously take longer to fill and take up more room. ■

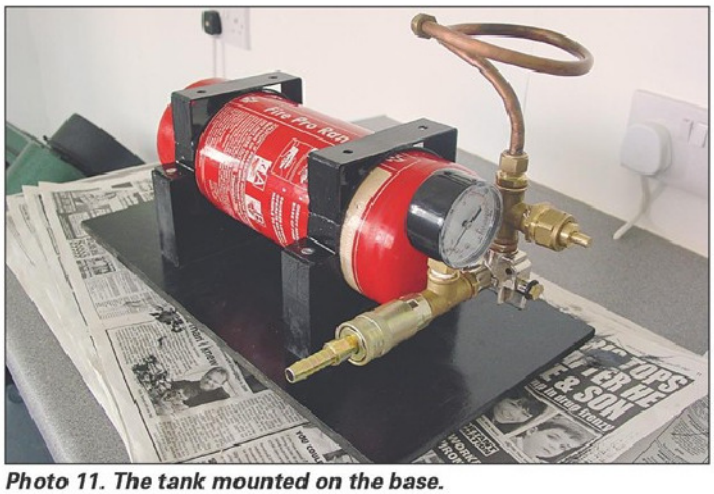


Photo 11. The tank mounted on the base.

Photo 12. The complete compressor, assembled and ready to run.

INTRODUCING COLLETS AND COLLET CHUCKS

Dave Fenner gets a grip on his work

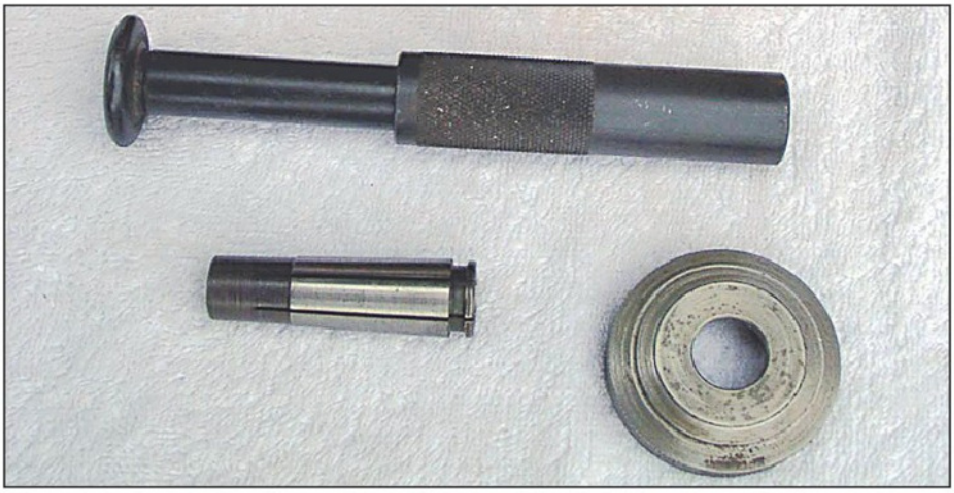


Photo 1. Collet, closing ring, and installation tool for Myford patent collet.

What is a collet?

For the benefit of those new to the hobby, we will start by trying to define a collet. In this context, it is basically a device for gripping either the work or the tool, which is often of circular cross section, (but may also be hexagonal or square). So why not use a conventional three or four-jaw chuck? Collets can give a number of advantages depending on the circumstances, but usually relate to the tight tolerance on concentricity, and the even pressure exerted around the work, which avoids marking and allows firm support of thin walled work. For quantity production, some collet chucks allow the material to be released and fed forwards without stopping the spindle, thus giving an improvement in cycle time.

So how is the collet made to grip? The simplest forms are bored on the inside, turned with a taper on the outside, and given a number of slots along the axis. If this is then pushed into a bored housing having a matching taper, then the slots close up and the inside bore decreases. If a correctly sized bar is placed in the bore then it will be gripped. The next point to note is that if we assume the half angle taper to be say 1 in 20, then if the diameter of the material being gripped varies by 10 thous (about 0.25mm) then the axial position of the collet will change by 100 thou (about 2.5mm). In a production situation this would probably not be acceptable, as it would require an additional facing cut to achieve an acceptable tolerance on component length. Let us first consider collets as they are applied to holding work in a lathe, and start with those used on Myford machines. Mention will also be made of tool holding applications in connection with milling, where the all round support to the tool shank gives superior results to say trying to work with a three jaw or drill chuck.

Photo 2. Double diameter component noted in text.

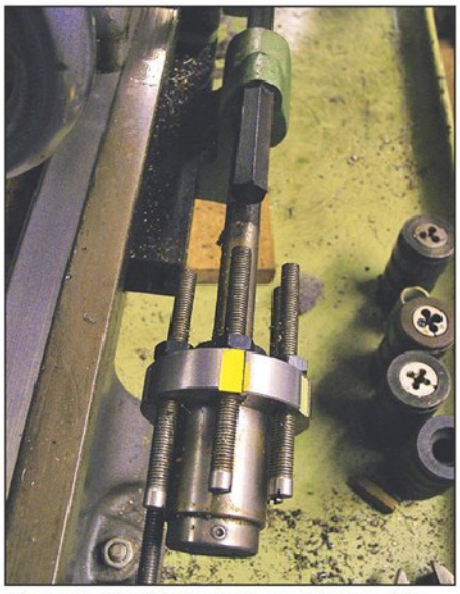
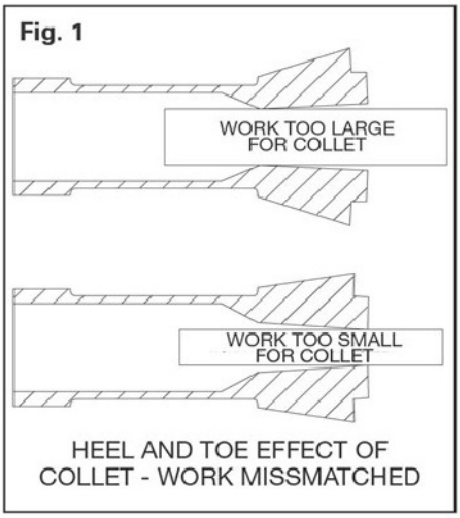


Photo 3. The Myford six position saddle stop is fitted at the rear of the bed.

Myford collets

Many readers will be aware of the Myford Patent Morse taper collet kit which is available as an accessory for the ML7 and Super 7 lathes. **Photo 1** shows one of these together with the device for manually compressing the collet to fit the closing ring to the groove. Once fitted, the collet may be inserted into the Morse taper in the spindle, and the closing ring tightened, gripping the work. When the ring is unscrewed, its engagement in the groove pulls the collet out of the taper, releasing the work. We should note two points, the first, as outlined above is that a small change in work diameter will result in a magnified change of axial position. So taking the part shown in **photo 2** as an example, if we want to mount the part in the collet hard against the collet nose, to face the head down to a thickness, then we need to measure out from the collet nose for each component. Secondly, these collets are each made to grip a particular size of bar. If material of larger or smaller than nominal is gripped then the collet can be distorted leading to incorrect grip by heeling or toeing. This incorrect gripping is depicted in **Fig 1** which shows a general collet shape, and it will be seen that pressure is applied around a ring, so that the component is then easily deflected from its true axial position by cutting forces.



The beauty of these deceptively simple collets, is that by being mounted directly in the spindle, the overhang is reduced, and the concentricity will be potentially the best obtainable. In addition, because the pressure is applied all round, and not just at three lines, it becomes possible to grip thin walled cylindrical parts which could otherwise be deformed or crushed. (It may also be noted that the internal gripping length is higher than some other patterns, leading to better stability.)

One technique to get around the "non dead length" aspect for repetitive work is to first set up the multi position stop, **photo 3** to give positions for the material feed point and the various features. The top slide is then moved to bring the first (facing) tool into contact with the end face and then proceed with the various operations, without moving the topslide. The final operation is to part off ensuring that excess material is allowed. A second operation is then needed to face to length.

As many model engineering tasks involve either one or just a few identical parts, it is easy to accept this minor inconvenience.

A second type of collet chuck supplied for the Myford machines is the lever operated style. The availability of the (MA99E pattern) collets which fit this chuck has become more restricted in recent years, so be prepared to search for good secondhand examples. This chuck/collet combination falls into what is known as the "dead length" classification. The mechanism is more complex than the simple taper, in that the collet, its position having been set by the closing ring, remains essentially still, and the gripping is effected by forcing a tapered sleeve along the outside of the collet, from the rear. **Photo 4** shows this type of chuck partly dismantled. The nose ring has been removed and it is standing on its front face; the closing sleeve has been shifted forwards to expose the ball bearings. Moving the lever shifts an outer tapered sleeve which moves the ball bearings radially inwards. Their movement into a groove, forces the inner tapered sleeve towards the tailstock, compressing the collet. Clearly with several moving parts, such chucks must be accurately manufactured.

If a batch of parts is to be made, then the advantages are:

The machine may be kept running while the bar is fed forwards.

Even if the spindle is halted, it is much faster to release and grip by pushing the lever than by unscrewing and retightening a cap or chuck, with or without a key.

If the material is fed up to a stop, then the "dead length" characteristic means that the position will be repeatable.

Photo 5 shows this chuck mounted on the Super 7 and here, if we wish to locate the component shown earlier in **photo 2**, its position will be repeatable, and hence if a number of parts are to be faced, then the saddle may be fixed at one setting. Similarly, if for multiple components, the bar material is fed up to a stop, then the position after gripping will also be repeatable, so if the multi stop is employed, then the topslide may be left unmoved.

In terms of concentricity, these collets are in my experience very good, but are unlikely to achieve the levels of the MT2 series.

It was noted that these collets are not so readily available nowadays. My understanding is that there is just one supplier - Crawford Collets. Within the range of collets shown in the Crawford catalogue, this general shape of collet is shown as CDL1, particular designs being defined by the dimensions shown in **Fig 2**. I have not been able to find details for the MA99E, in my old Crawford catalogue, but the details I have measured are A = 24mm B = 58.5mm C = 29mm Q =14.5deg

I would sound a note of caution regarding these figures, particularly diameter C which ideally should be measured with the collet compressed to correct nominal bore size, and the angle which was measured by eye using a protractor against the chuck bore. If other readers have more accurate information, then they might care to pass this on to the editor for future publication. A further dimension worth noting is the depth available from the chuck taper face back to the Myford spindle nose, which on mine is 56mm. This places a limit on the length of collet which may be accommodated when alternatives are examined.

A Close Approximation

Many years ago my employer at the time, scrapped off an old lathe, and with it a number of collets. These were duly rescued from the skip and kept for considerably more than the proverbial seven years. The dimensions of these lead me to believe that they conform to Crawford catalogue number 233, where A=22mm, B= 55mm and Q= 15degrees. It appeared that with the addition of a thin cylinder 24mm OD and 22mm ID, to support the rear end, these collets might be used in the Myford style chuck.

The result, **photo 6** is not perfect, as the position of the closing ring and ring lock nut move somewhat, and the angle appears slightly incorrect, but the result is eminently usable for the occasional job. On the question of angle, examination of the witness marks on several of the 233 collets shows bedding part way along the taper, suggesting that the original housing was slightly bell mouthed.

These collets are cross referenced in the catalogue against a number of machines, so may be more easily obtained than the correct MA99E.

Photo 4. Dead length collet chuck for Myford, shown nose down, with the actuating balls visible.

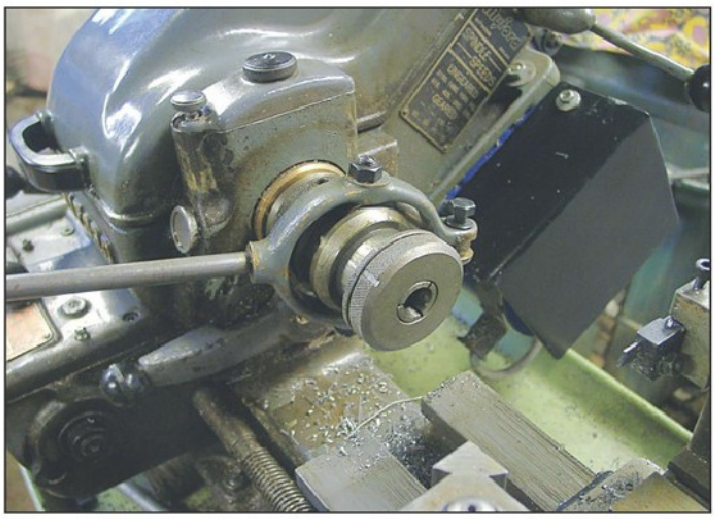
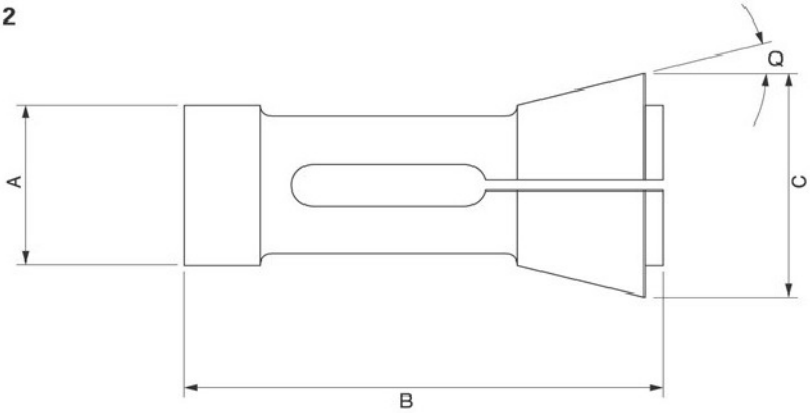


Photo 5. Dead length chuck in position on the lathe. The handle is linked back through a tapped mount to the headstock.

Fig. 2



TYPICAL CDL1 STYLE COLLET

Photo 6. Correct MA99E collet (left) and modified 233 (right).

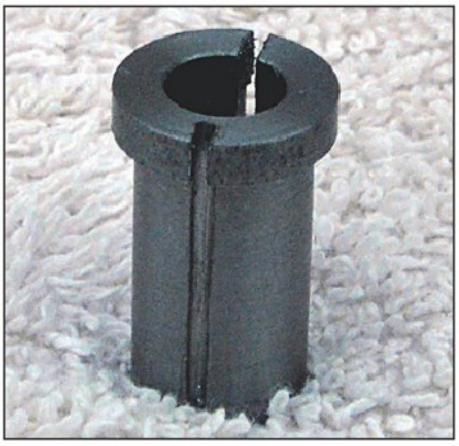


Photo 7. Homemade adapter caters for alternative sizes.

Photo 8. The elements of an adapter to handle 3mm material in a half inch collet. Bottom - slotted adapter, middle - guide tube, top - pusher bar.

Bending the rules

Collets are not cheap items, (MA99E types are currently advertised second hand at around £20-00 each) so any means which extends the usefulness of a limited stock is worth exploring. Multibore (collets see later) were costing about £50 each in the early 1990's and will, in all likelihood, have risen considerably since then.

We are probably all familiar with the technique of wrapping a strip of aluminium or brass around a workpiece to avoid marking the surface by the hardened corners of the chuck jaws. We can extend this line of thinking to collets. Suppose we have only a ⅜in. (9.5mm) collet but wish to gip a ¼in. (6.35mm) workpiece. If a short length of steel is drilled ¼in. turned to ⅜in. OD, and then given an axial saw cut, it may be placed inside the collet and used to grip the smaller rod. Obviously, to preserve accuracy, the dimensions and concentricity must be closely controlled.

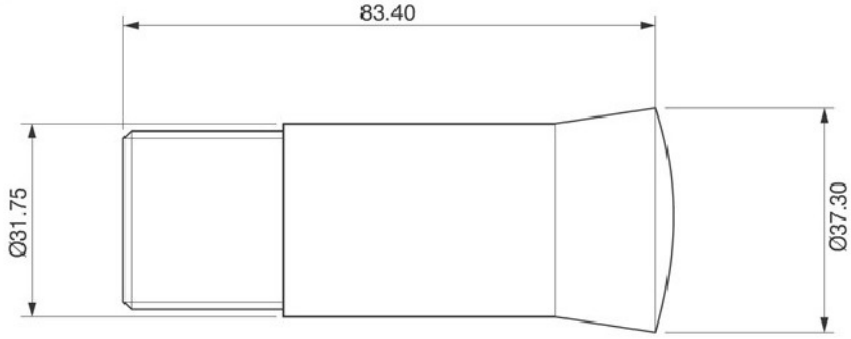
Depending on the type of collet, further embellishment may be added. Using the part shown in **photo 2** as a basis, an outer shoulder, **photo 7** will stop the adapter disappearing into the collet. An inner shoulder coupled with an outer groove and circlip would hold the adapter in place allowing material to be fed through the chuck.

A good number of years ago, much of the volume turning in my shop was handled by two automatic capstan lathes, a Herbert No 4 Dialset (two inch or 50mm bar capacity) and an EMI Mec Herbert 2D (1⅝in or 41mm bar capacity). By model engineering standards, these were pretty heavyweight machines. One job which came my way involved cutting and chamfering 3mm material to short lengths. The four bits and bobs shown in **photo 8** were cooked up, comprising pusher bar, spindle adapter, guide tube and slotted collet adapter. The guide tube is just a length of copper water pipe locked on to an aluminium component which could be clamped by screws in the rear of the spindle. This Heath Robinson set up allowed the use of a standard half inch collet, and the normal bar feed arrangement with the load set to minimum. The programmed cycle probably followed the sequence:

- Turret forward with stop
- Open chuck and feed to stop
- Turret back, feed Vee tool on cross slide to chamfer and part off
- Repeat.

It may seem a little like a sledge hammer to crack a walnut, but it produced several thousand components repeatably and unsupervised. Something that earns money and does not demand wages is a great asset for the self employed.

Fig. 3



EXTERNAL THREAD (IMPERIAL) 1.24 - 20
INTERNAL THREAD (IMPERIAL) 1.041 - 24

LEADING DIMENSIONS FOR 5C COLLET

Other fixed size (solid) collets

As has been mentioned the collet systems considered so far, are designed on the basis that each collet should be used to grip a specific bar size. There are many other systems which also fit this category. A few which may be of interest to amateur engineers are as follows

Morse taper

Giving several of the advantages of the Myford system, a range of collets is available to fit MT1, MT2, and MT3 sockets. These may be fitted directly to the spindle of an appropriate lathe or mill. However, unlike the Myford pattern, these are closed by means of a draw bar, which thus precludes the use of long material (unless a draw tube is constructed). Such equipment may though be used on a milling machine with a MT quill to hold end mills etc. of appropriate size

5C

This a style regularly seen on quality industrial lathes such as Hardinge, the form of the collet is sketched in **Fig. 3**. Typical means of closure include either a key operated mechanism contained within the chuck, or a draw tube arrangement passing back through the headstock employing lever or power actuation. In either case, the pull is applied via the external thread at the rear of the collet. **Photo 9** shows a typical 5C together with a rapid action rotary table which takes these collets and gives up to 24 divisions. The 5C pattern has become more popular in recent years, and will accommodate up to 1.125in. (28mm) diameter material. In addition to round, they are also available for square and hex shapes. A range of accessories is also available, such as the Spin Indexer, as well as sensibly priced, key operated chucks.

In addition to the emergency collets mentioned later, 5C types are also available with oversize front ends. These may be machined to give collets suitable for gripping items such as washers or thin gears.

Photo 9. Foreground, a typical 5C collet, to the rear, a rapid action rotary table which accepts these collets.

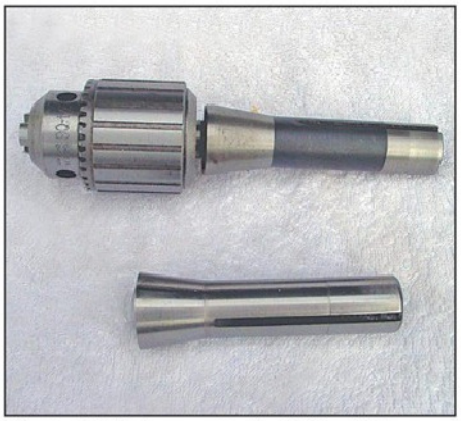
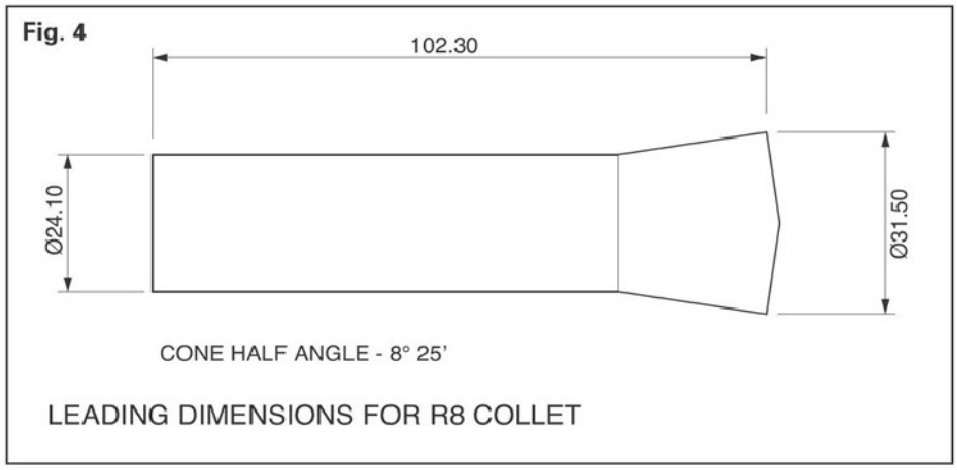


Photo 10. Below - a typical R8 collet, above a drill chuck with solid R8 shank.



R8

I believe that this form, **Fig 4** was popularised by its adoption on the Bridgeport turret mill where it was used to accept tooling having a solid shank to match. It is then a natural development, as with the Morse taper series discussed above, to produce collets to fit the same housing. As with the tooling, they are clamped by means of a draw bar, and have probably found much wider acceptance in mill tool holding than lathe work holding. **Photo 10** shows an R8 collet alongside a drill chuck with R8 shank. Like the MT collets the R8 is normally mounted directly in the machine spindle leading to high accuracy and rigidity.

It is perhaps worth noting that both the 5C and the R8 collets feature keyways, which ensure that when tightened, they do not simply spin in the housing.

Clarkson

These collets have a very specific application, to hold the threaded shanks of Clarkson type milling tooling, usually end mills, and are invariably employed with the appropriate chuck. As may be seen in **photo 11** the collet has a couple of driving dogs, which match the closing ring. Other features not so visible may be deduced by examining a Clarkson style end mill which is centred at the threaded end. A male centre is included in the rear of the chuck which engages with the female of the end mill. When assembled, the closing ring is screwed in lightly to contact the body. The tool then screws into the collet, until it contacts the centre. Finally the closing ring

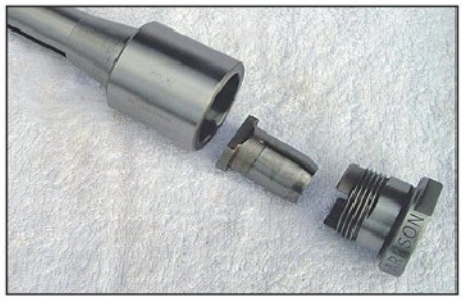


Photo 11. Left to right, body, collet and closing ring for Clarkson system.

is tightened with the spanner provided. The end mill is now supported at its end by the centre and by the collet further forwards. In operation, the tendency is for the tool to screw in tighter, thus the problem of it "walking out" which can occur with a plain collet is avoided.

The thread on all sizes is 20 tpi, and so it is relatively straightforward to make up holders such as shown in **photo 12** to carry tools such as centre drills, FC3 cutters and fly cutters, where their use might be more convenient than changing chuck and head height.

Emergency collets

For those occasions where some peculiar size is needed or non stock size must be found yesterday, the "Emergency" type may be considered. Probably best known in the 5C configuration, they are typically supplied with a 1/16in. (1.5mm) pilot hole, and three pegs to prevent collapse. Being supplied in a machineable condition, the collet can be drawn home into its lathe chuck, bored to the required size, then released and unpegged for use.

Wide Range Collets

So far we have dealt with types of collets where one size fits - one size, leading to the criticism that, to cover a range of sizes, a large and expensive set of collets is needed. To counter this, for industrial scale equipment, Crawford introduced their Multibore system, and Pratt Burnerd the Multisize. In both cases, a single collet has a gripping range of about 0.125in. (3mm).

Crawford Multibore

In the Crawford system, the collet is typically composed of eight (for round material) or six (for hex) segments. The tapered assembly has a half angle of about 15 degrees and is held together by a couple of split rings. Between each pair of segments is a spring arrangement (metal or rubber) causing expansion. When fitted to a machine such as the Herbert 2D, the chuck may be an adaptation of the dead length collet chuck fitted as standard, except that some internal parts are changed. The operation is by the original lever.

Pratt Burnerd Multisize

The Pratt Burnerd approach is quite different. Here the main body of the chuck is slotted to accept six hardened flat blades. Mounted in the tapered housing, the blades are pushed radially inwards to grip the work. Since there are six blades, round and hex material may be held in the same collet. Thus the boxed set shown in **photo 13** will

Photo 12. Three adapters made to fit Clarkson collets; left centre drill, middle FC3 holder, right fly cutter.

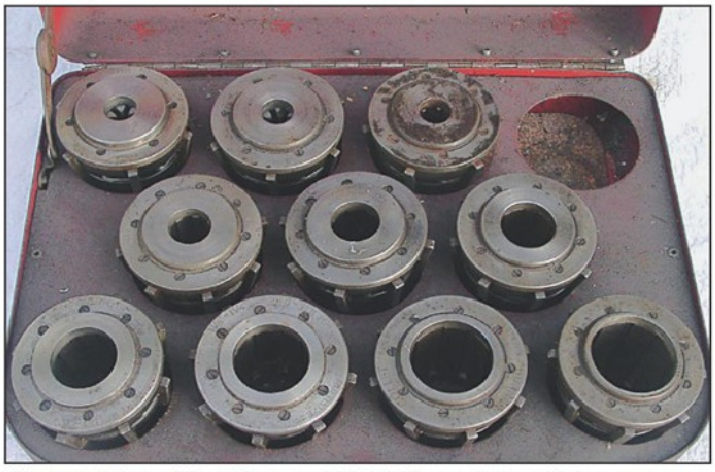


Photo 13. Set of Pratt Burnerd Multi Size collets which cover diameters from 0.062in. to 1.5in. (1.5mm to 38mm).

Photo 14. Detail of Multi Size collet shows the sliding blades. (In this pattern the blades project forwards flush with the face of the collet.

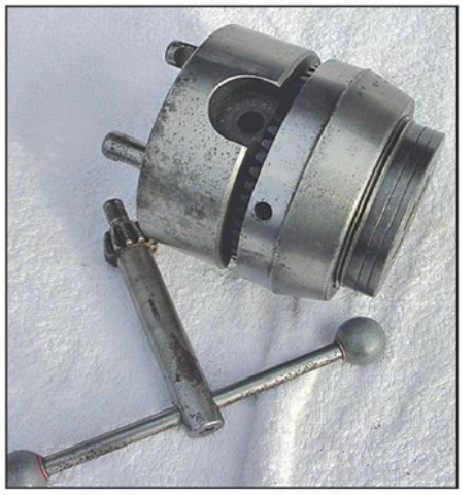


Photo 15. Key operated Multi Size chuck.

Photo 16. Eighteen ER32 collets cover diameters from 2mm to 20mm.

handle round material from 0.062in. to 1.5in. (1.5 to 38mm) diameter as well as a range of hex. My collets are distinctly secondhand, but the condition of the leading corners of some of the blades, does suggest that if worked hard at small diameters, then this area may suffer. Over time I have picked up a couple of PB collet chucks, one lever operated (and similar in concept to the dead length chuck discussed earlier), the other by key. The first of these uses a slightly different design of collet shown in **photo14** and came into its own when producing batches of a thousand parts on a Colchester Bantam. The bar (about 8mm diameter) had been sawn to length and deburred. It was then possible to load the running machine, turn the feature, and allow the work to drop out. Repeated stop - start would not have been feasible on a single phase machine. The key operated chuck is shown in **photo 15**.

One feature which should be appreciated regarding both of these collet styles is that if one tries to grip work over just a short length of the segments or blades, then the elements can swing out of line causing loss of grip (heel and toe). The recommended work around is to add a balancing piece having the same diameter as the work but positioned to the rear of the blade. Then when the gripping force is applied the blade or segment maintains its correct position.

As noted these are industrial size items, and are unlikely to be fitted to a lathe of less than five inch (125mm) centre height. For a wide range collet design suitable for smaller machines, we may choose to look long and hard at the different size groups within the ER system.

ER Series

In total there are seven size sets readily available within the ER series: ER11; ER16; ER20; ER25; ER32; ER40; and ER50

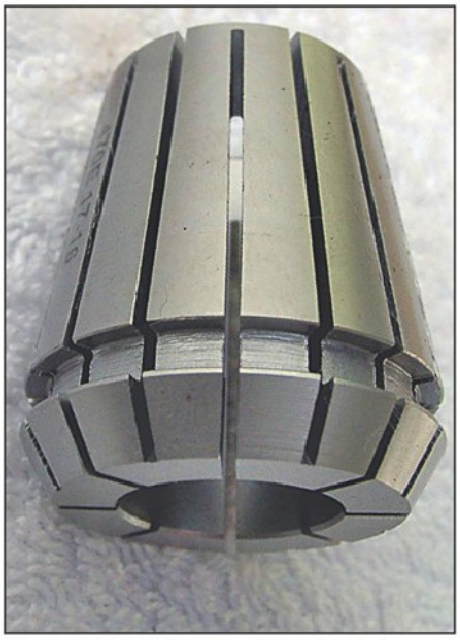


Photo 17. Detail view of ER32 collet shows the slots which run from alternate ends, permitting parallel collapse over 1mm range.

Photo 18. Typical ER32 chuck fitted to Mini Lathe.

The range covered and number of collets in each series is: -

Type	Range	Number
ER11	0.5 - 7mm	13
ER16	1 - 10mm	10
ER20	2 - 13mm	12
ER25	2 - 16mm	15
ER32	3 - 20mm	18
ER40	4 - 26mm	23
ER50	12 - 34mm	12
In addition, the Hardinge website makes reference to ER8 and ER12.		

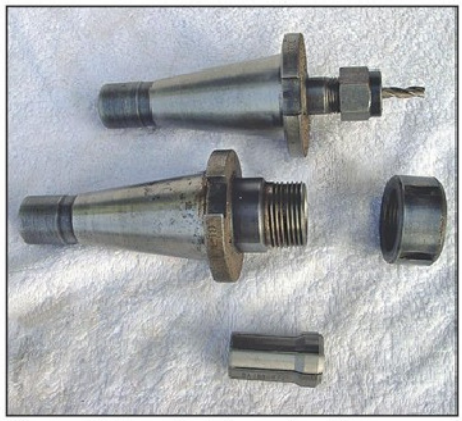


Photo 19. Two double angle collet chucks and a typical collet.

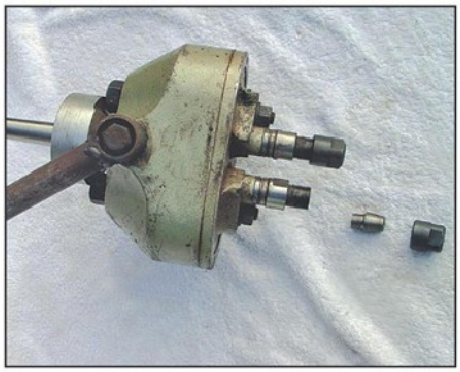


Photo 20. This production device allows simultaneous drilling of two holes using a single MT2 drive. Simple split collets were turned to hold the drills.

It may be deduced from the above that the gripping range varies from 0.5mm in the smaller sizes to 2mm in the largest.

A number of years ago, I was able to take advantage of an offer by WNT on the set of ER32 collets shown in **photo 16**. A single example is shown in more detail in **photo 17.** I later acquired one chuck from Warco, which has been fitted to the Myford, and a second from Arc Euro Trade, **photo 18** which fits the Mini-Lathe. For either machine, one set of eighteen collets covers all the round sizes from 2mm up to 20mm.

My knowledge of machine tool history is none too deep, but I seem to recall that the ER series was derived from an earlier similar pattern intended for lathe work rather than the interrupted cutting associated with milling. Today, the ER series seems to be accepted for both applications, chucks being readily available for both turning and milling.

To install an ER collet, it is first located in the closing nut, which carries an eccentric ring. The collet is pushed into the nut at an angle then rotated slightly so that the ring clicks into the collet groove. It is then loaded into the chuck and the nut screwed up to adjust. A very clear pictorial description of this procedure is given in the Arc Euro Trade catalogue and also on their web site.

I have heard the view expressed that the gripping length on some ER collets is shorter than some other patterns, which if correct might translate to lower rigidity. As I noted, mine were sourced from a supplier of high quality tooling to industry; the larger sizes grip over the full length and the smaller over a length of several diameters. Other readers who have experience of budget import sets may care to comment on this point.

Double angle collets

I originally came across these because the Matchmaker mill arrived with two chucks for this style of collet. Again, each collet has a specified gripping range, so it is thus possible to cover the common sizes of milling cutter with a fairly limited expenditure on collets. **Photo 19** shows one of these chucks with a double angle collet. Known as double angle, the collets actually appear to engage on three tapers, two in the housing, and one in the closing nut.

Other collets

Before concluding, I will make brief mention of a couple of other applications. The double drill attachment shown in **photo 20** requires a small collet to grip each drill. It came with none, so very simple taper collets were turned to get the kit into use.

The two Tapmatic's, **photo 21** allow high rate tapping when mounted in a drill or mill. At a preset depth, the drive disconnects, then as the quill is raised, it reverses 75% faster than the spindle speed, unscrewing the tap.

Here the correct collet is a Flex or Rubberflex which in a way is like a miniature version of the Multisize, having six blades, but here they are bonded by rubber. The collet is intended to centralise the tap, the drive being transmitted to the square end by either two metal jaws (large model) or a pair of grub screws in the smaller.

Again, these are not cheap, so rather than spend hard earned cash on collets for short production runs, simple split tapered alternatives or adapters, **photo 22** have proved perfectly satisfactory.

Depth stops

One of the accessories frequently constructed for hobby lathes is a depth stop so that parts may be loaded into the chuck to a repeatable position. This frequently takes the form of an expanding section fitted to the rear of the spindle, with an adjustable length rod to set the depth. Some of the industrial type collets include features so that a stop may be fitted directly to the collet. Thus a collet may be dedicated to a specific job being permanently fitted with a stop, thus reducing set up time.

In addition to the external drawbar thread, 5C collets have an internal thread which might be used for locating a depth stop. Multi size collets are often fitted with a bell mouthed guide to ease the passage of bar material into the collet. This guide is held in place by radial grub screws. If the guide is removed, and a stop made to fit, then it may be retained in position by these same screws. It should be noted however that unless a dead length chuck is used, that the repeatability will not be as good as obtained with the spindle mounted version described above. ■

Photo 21. Tapmatic's come in different sizes and fittings.

Photo 22. Genuine collet (left), tapered adapter (right), cylindrical adapter (centre rear).

A Clarkson Tool and Cutter Grinder 3

Mike Haughton looks at wheels, cutting off and drill sharpening

In this part we make a start on describing how to use the Clarkson tool and cutter grinder on jobs likely to be found in the home workshop. Most of the description is applicable to other makes and designs of Universal Tool and Cutter Grinder.

1) Operator controls

Photo 18 shows a view of the Clarkson with the major operator controls identified so you can hopefully follow my descriptions of the grinding operations that follow. In their literature Clarkson and March were not very consistent in their naming of the machine parts! To provide a less cluttered view, the accessories have been removed from the table and rear tooth rest support area.

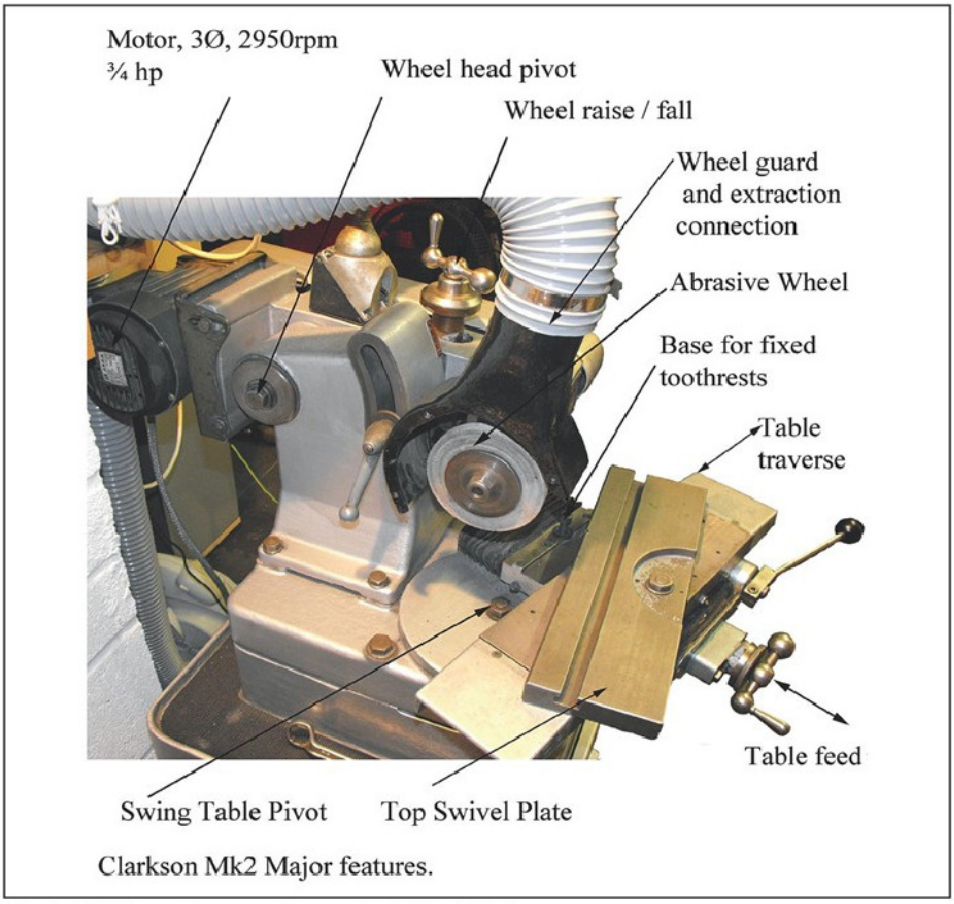


Photo 18 The major operator controls identified.

2) Wheels

New Clarkson machines came with just 2 grinding wheels. A plain wheel 5in. dia. X ¼in. thick and ½in. bore. The wheel Code was 38A60K5VBE.

A cup wheel 3¼in. dia. Tapering to 2in. dia. X 1¼in. wide with a ½in. bore. Wheel Code was 38A60K8VG.

I guarantee it won't be long before you have a much larger collection of wheels than these two! I think I had 20 at the last count.

Wheel shapes are defined by ISO 525:1999 and are summarised in the Black Book, **Ref. 20**. In practice you will probably only use around 6 shapes from the 30 standard ones. Part of the reason for so many wheels are the different wheel materials and diameters.

Wheel codes have been described in recent articles in MEW. **Ref. 21** so I won't go into much depth here. Taking the code for the Clarkson standard plain wheel, mentioned above we can split it into fields as in **table 1**.

Examining this table we get;- 38A is a white aluminium oxide abrasive, hard and brittle. Some manufacturers may use the Abrasive code WA to indicate White Alumina. Other abrasive types are C, Silicon Carbide and D, Diamond. There are many other abrasive codes, consult **Ref. 20**.

A grit size of 60 is medium and will cut quickly. The bigger the grit number, the finer the particles, all to do with sieve sizes. Grit size 80 is normally specified for a Quorn and will cut slower but give a superior surface finish. Remember the Quorn has less motor power available, ⅛H.P. compared to ¾H.P. on the Clarkson.

Grade indicates the strength of the bonding material holding the abrasive particles together and goes from very soft, grade D to very hard, grade W. Grade K is a soft to medium strength. If you are going to grind threads, where you want to retain the thread profile on the wheel for a long time, a much harder/ stronger grade would be required for a decent life between re-dressings.

Structure indicates the proportion of abrasive particles in the wheel. 5 indicates a 52% abrasive content. Frequently this field is omitted from wheel markings.

Bond type V is vitreous, i.e. ceramic, bonding the abrasive particles together. Vitreous bonds are very common for precision grinding because it's porous, has high strength, is rigid and is unaffected by oils, water or heat. It is not generally used for thin wheels for cutting off.

Diamond wheels are marked slightly differently. Most of those offered by the home workshop suppliers are aluminium alloy with a thin (often 3mm thick) layer of a resin containing synthetic friable diamond particles applied to the cutting surface(s) of the wheel. The resin is usually coded B for the bond type (resinoid, organic). Diamond and CBM (Cubic Boron Nitride) are often described as "super abrasives". Diamond wheels will be described in a later part as they require different methods of mounting, truing and dressing.

Table 1

38A	60	K	5	V	BE
Abrasive type	Grit size	Grade	Structure	Bond type	Mfr's symbol

3) Any old wheels

I recommend you view all used abrasive wheels with suspicion. New wheels are not that expensive and will do a considerable amount of work before they wear down. The problem I have found is locating sources of new white aluminium oxide wheels that are suitable for use on the Clarkson. The Clarkson spindle is ½in. diameter and many wheels are now metric and have much larger bores so some form of mounting is likely to be needed. I have been using some wheels I bought for the Quorn project and a number I inherited with the Clarkson. The larger Quorn wheels I have are also 1/2in. bore and work perfectly well on the Clarkson.

Grinding wheels should have their specification printed directly on them or on one of the paper blotters that should be attached on both sides of the wheel.

It's important to check that an unknown wheel is rated for a speed above that of your spindle and that it has no obvious defects. The last thing you want is a wheel to explode over you and the workshop. The usual test for a defective wheel is to suspend it on a screwdriver shaft through the central hole and tap it lightly with a plastic screwdriver handle. A ringing tone is OK, a dull thud and you should scrap the wheel; it may fracture when under power. The largest diameter wheel that a Quorn can use is 100mm and the Clarkson 125mm.

The two Clarkson standard wheels were chosen for general purpose re-sharpening of High Speed Steel tools. A model Engineers objectives are likely to be wider than just re-sharpening and include the manufacture of tools from hardened HSS blanks and possibly from Carbide blanks. I find that for faster rough shaping of HSS a coarser grit is desirable. I have been using 48 grit wheels for roughing out shapes in HSS e.g for the manufacture of D bits.

I avoid wheels that come with or are offered as replacements for 125mm 5in. offhand bench grinders. These are frequently dark blue or green, they are still aluminium oxide in composition but a lot less pure and less refined (cheap) general purpose grades. For high speed steel, hard white alumina wheels are best and worth paying a small premium for. They seem to cut HSS cooler and with less burning. These wheels are quite brittle and need careful storage and handling. I prefer to keep wheels flat, as a single layer in a drawer with a soft anti-slip lining under them.

4) Mounting the wheel

I checked the spindle of the MK2 for any end float in the bearings with the wheel and belt removed and then measured the run out of the spindle with a DTI, see **photo 19.** In this photograph the spindle extension piece had been screwed on, it's a left hand thread 0.5in. x 16tpi Whitworth form (BSF). The run out on the clamping face was negligible < 0.0005in. (<0.01mm).

The Clarkson should come with two pairs of steel wheel flanges ½in. bore and 1.5in. or 2.5in. dia. Mine came with several more sizes that somebody had added at some time. It's good practice to choose pairs of equal size flanges and always use paper blotters just bigger in diameter than the flanges being used. Don't make the mistake of over tightening the spindle wheel retaining nut, you could crack the wheel. The Clarkson uses a tommy bar and spanner. The Clarkson does not use the Quorn drawbar and wheel arbor system, so changing wheels and then dressing them takes a little longer.

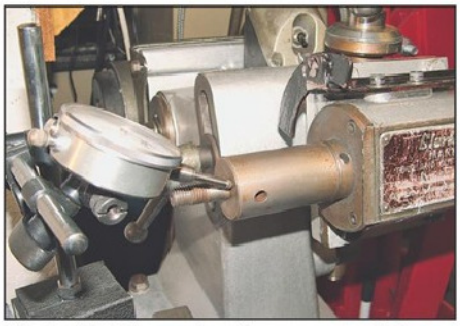


Photo 19. Measuring the run out of the spindle with a DTI.

5) Truing and dressing the wheel

Having mounted a new wheel on the machine it needs to be trued with a single point diamond on whichever parts of the wheel you are going to grind with. If you don't true the wheel, parts of the cutting surface will be pounded when you grind with it. The wheel will also be out of balance and this affects the quality of the ground surface. There is no provision for balancing wheels on the Clarkson, as one might find on a higher power and faster machine with bigger wheels. My machine

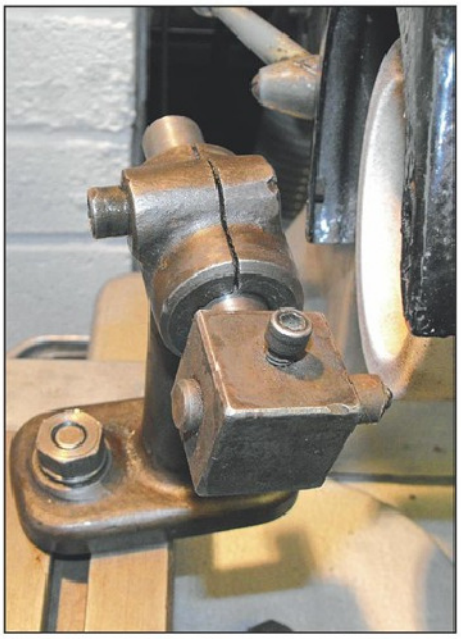


Photo 20. My machine came with a mounted diamond, not a Clarkson one.

came with a mounted diamond, **photo 20** that certainly didn't come from Clarkson! The Clarkson version is illustrated here, **photo 21. I** have been using a 0.35 carat diamond mounted in a short steel rod and then the rod is then held in a 2in. Three way vice, **photo 22.**

A wheel that has had some use will slowly stop cutting as freely and when looked at closely will look glazed. This is particularly obvious on white aluminium oxide wheels. This glazing is a result of the grinding debris blocking pores in the wheel. A well used wheel will also cut more slowly and produce more heat due to the abrasive particles becoming blunted; think of them as mini cutting tools. Wheel dressing will remove these blunt particles and their vitreous support to reveal the new sharp particles below. The only remedy is to use the single point diamond again with the very lightest of passes. The diamond dresser must be about the wheel centre height and is used in a dragging mode; it mustn't be able to dig into the wheel surface. If you do dig in, the wheel may give dressing lines, ridges on the work when you grind with it. On the side of the wheel you should dress from the centre outwards and the dressing diamond should always be moving.

Silicon carbide dressing sticks can also be used, by hand, to remove the glaze and re-profile the wheel should you need a corner radius for work on, say, flutes on taps and reamers. Silicon carbide is hard enough to blunt the aluminium oxide abrasive particles and a mounted diamond dresser is really the best choice in most situations. The dressing diamond may itself become dull with a lot of use and it's a good policy to occasionally rotate it if it's in a fixed holder. Personally I don't like, or use, star wheel dressers.

Both these operations must be carried out cautiously taking the minimum amount off the wheel. The quantity of abrasive debris produced, even with a good extraction system, makes it a necessity to cover the machine before use and clean it all down afterwards.

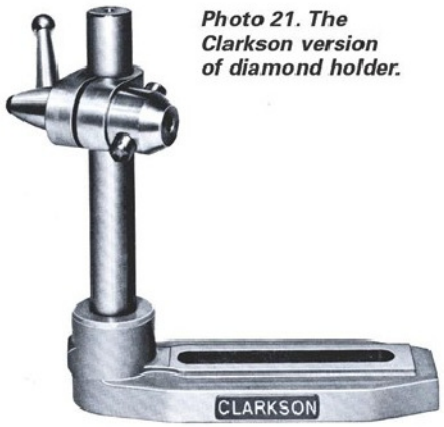


Photo 21. The Clarkson version of diamond holder.

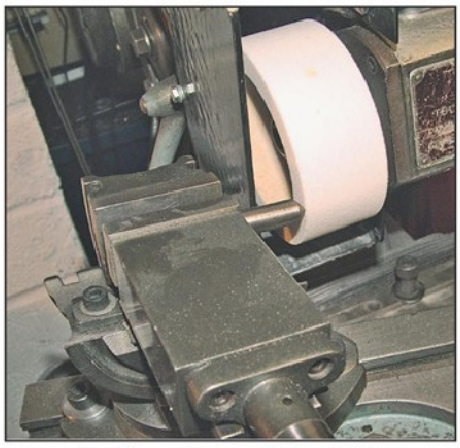


photo 22. I have been using a 0.35 carat diamond in a steel rod held in a three way vice to dress the wheel.

6) A three way 2in. vice

The use of this inexpensive vice is going to appear several times in my grinding operation descriptions so it's probably appropriate that I describe it now, see **photo 23.**

This vice came from Warco, **Ref. 22** at one of the ME shows and is very nicely made. After some use, I have found some operations where this design causes problems and something more like the Clarkson design, **photo 24** would be a

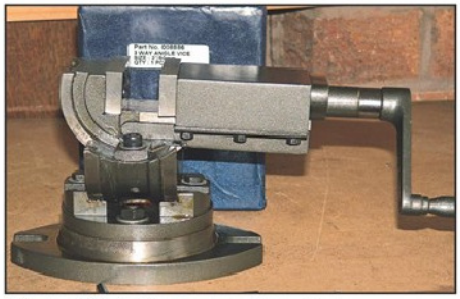


Photo 23. A three way 2in. vice.

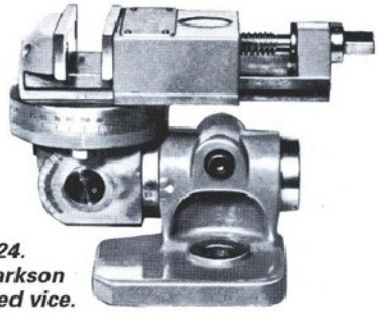


Photo 24. The Clarkson designed vice.

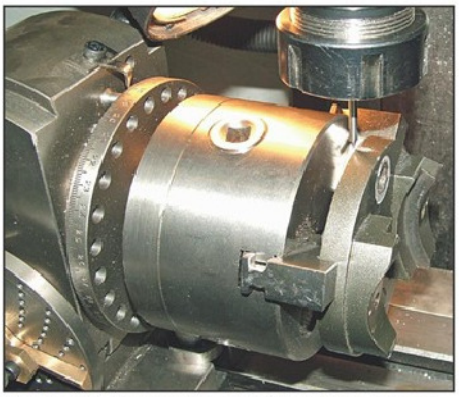


Photo 25. Engraving additional marks on the base at 90deg. to each other.

better choice; you live and learn! This Warco three way vice isn't truly universal. The base rotates through 360 but is only calibrated ±90deg. so I engraved three additional marks on the base at 90deg. to each other using the mill and a very small centre drill as **photo 25**. The next axis up from the base rotates ±45deg. but is only calibrated 0 to +45deg. The top axis rotates through 90deg. and is calibrated 0 to 90deg. only. Be careful to check what you are actually getting before you purchase one of these. Several of our suppliers offer similar imports from India and China.

7) Cutting off HSS tool bits

A number of thin Norton, **Ref. 20** cutting off disks came with the Clarkson marked 57A 60 P B25.These disks are not white but a dull drown. 57A is a semi friable aluminium oxide, 60 is the grit size, P indicates a hard bond and B a resin bond. These disks measure just over 1mm thick and must only be used to grind on the thin edge.

You will probably have in your collection HSS tool bits that have been nibbled away on an offhand grinder then snapped in a vice. The sort of effect is shown in **photo 26** and is just a waste of HSS and the corner of the grinding wheel. And a bit dangerous when you fracture the end off.

I find the ability to cut off HSS tool bits very useful either to remove an unwanted tool shape (somebody else's mess!) or to make a short tool for a boring bar. These wheels are shape 41, i.e. flat. They can be purchased from MSC/J&L Industrial, **Ref. 20**.

In **photo 27** you can see this cut off operation in progress using the 2in. three way vice again. Note where the sparks are going, despite the extractor being switched on during cutting.

Photo 26. Cutting up HSS tool bits.

Table 2

Operation - Cutting Off.	
ABRASIVE WHEEL	1mm wide flat cutting off disk. 57A 60 P B25
WHEEL HEAD	Raise wheel head to pass over vice support
Spindle length	Use spindle extension piece.
Swing Table Pivot	Set at 90° to wheel head spindle
Top swivel plate	Set to 0°
3 way vice	Set jaws horizontal and 90° to wheel
Feed	Use rack and pinion smoothly with a pecking action.

In an attempt to shorten descriptions of setting up the various grinding operations that follow, I have adopted an approach used by Prof. Chaddock in his book on the Quorn and summarise the set up in **table 2**.

I have found that these cut off wheels have to be mounted between absolutely perfect flanges so there is no run out at the periphery of the wheel. It's advisable to actually measure this with a DTI before you commence cutting. Should a run out be detected suspect and check the wheel flanges because even a small run out will dramatically shorten the life of these thin wheels. Don't use cheap stamped wheel flanges, they probably won't run true. The authentic March/Clarkson ones have been turned from solid then ground.

The wheel must be exactly at right angles to the work piece. It's important to set the swivel table at 90deg. to the wheel head spindle with a square and then put a square in the vice jaws and align it with the side of the cut off wheel as in **photo 28**.

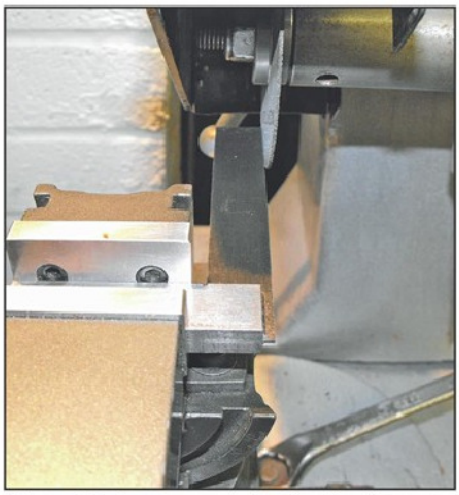


Photo 28. Put a square in the vice jaws to align the side of the cut off wheel.

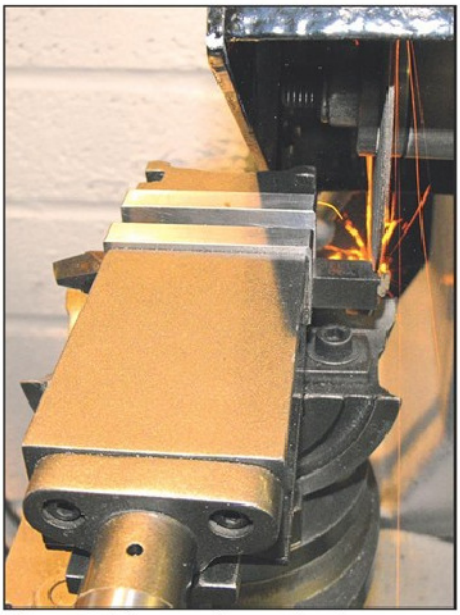


Photo 27. The cut off operation in progress.

If you feed the work on to a cut off wheel with a significant run out you will get rapid wheel wear and a fairy disgusting phenolic odour from the resin binding the wheel together as it overheats and decomposes.

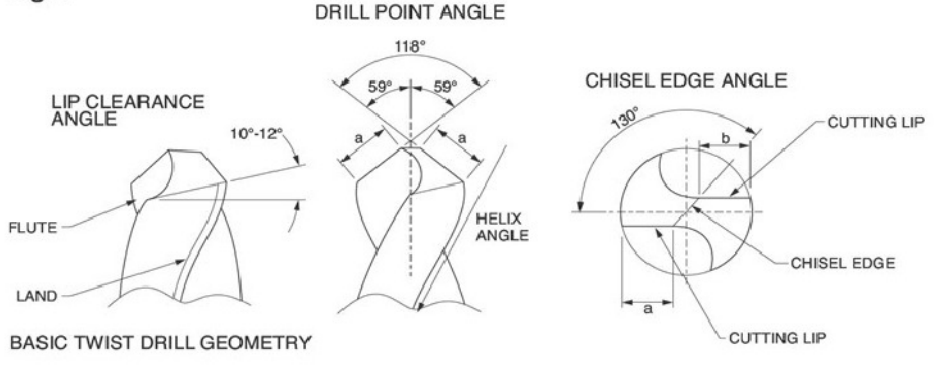
These cut off wheels seem to work best if you peck gently at the work and don't try to cut it off in one go. You will get a lot of grinding dust. I usually have to remove the side cover from the wheel to accommodate the vice.

The cut off surface is extremely smooth and uniform.

8) Twist drill sharpening

I'm sure that to some, the use of a tool and cutter grinder to sharpen drills is a total over kill. I used to think that way but I've been converted, for precise drilling at least. Due to the need to carefully study drill bit forms and damage before commencing re-grinding, I have become much more aware of different drill

Fig. 1



formats. (And I'm still learning!) Twist Drills are deceptively complex.

There is a lot to be said for maintaining two sets of drills in your workshop: an everyday set for rough work where the final hole diameter isn't critical and a precision set or sets for tapping, precision drilling, deep drilling and drills modified to deal with difficult materials.

Get an eyeglass (watchmaker's loupe) and critically examine the drill to be re-sharpened. Can you see evidence of wear, point thinning and multi facet sharpening? Has somebody re-sharpened it before? See **Fig. 1** for some terms.

The close up, **photo 29** shows the sort of horror story that you might encounter. This example came from severe industrial use, but was successfully re-sharpened on the Clarkson. The cutting edges are chipped and worn and the centre chisel almost destroyed.

It's important to decide what type of drill you are about to re-sharpen. What was it made for in the first place? Close up **photos 30 and 31** show different drill point styles. The lip clearance in **photo 29** is conical, in **photo 30** there are 2 facets and 6 facets in **photo 31**. Manufacturers use all sorts of in house codes for drill sharpening styles. The generic names Split Point and Modified Split Point are common in quality drills as in **photos 30 and 31**.

Table 3 might help you decide what you are attempting to re-sharpen, but it certainly isn't definitive. Note that there are at least **3** helix angles in commercial use. Every drill manufacturer will have their own solution to a drilling problem and you will see a large variation in the web shape and thickness when viewed from the cutting end. This has a big effect on drill point styles.

Measure the drill point angle of the drill you are going to re-sharpen. I usually use a gauge, **photo 32** provided with the J&L Black Book. There are many useful and not too deep references you could follow up if needed, **Ref. 24.**

Ref. 25 is Graham Howe's very interesting web page on home shop drill sharpening by several methods and jigs. You may have to look up manufacturers' websites for variations in drill profiles.

Photo 33 shows a "reliance" style drill sharpener mounted on the Clarkson. This is actually a new purchase from Axminster, **Ref. 22** simply because I seldom got good results from this style of sharpener when used on the side of a bench grinder. These are pretty cheap and I decided on a fresh start. **Table 4** gives the method.

This style of sharpener produces a conical point relief and easily achieves two cutting edges of equal length and angle; very important for good drilling performance. Experimentation is the order of the day, with test drilling into a scrap block of low carbon steel to see how things are going. You should see two equal width ribbons of swarf emerging from the drill cutting edges and end up with a hole close to the drill diameter.

Adjustment of the setting finger and the degree of drill point overhang were the biggest problem variables in my setup. Once you have got your technique sorted out you can rapidly sharpen a lot of drills in a short time. The drill overhang in relation to its diameter influences the lip clearance angle you end up with after sharpening.

Photo 29. This drill has suffered from severe industrial use.

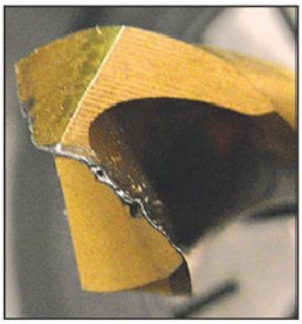


Photo 30. Four facet sharpening.

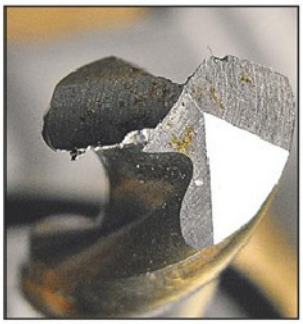


Photo 31. Six facet sharpening.

Table 3

Drill Point Angle	Lip Clearance Angle	Helix Angle	Work Piece
118°	10-12°	35-40°	Mild Steel: General purpose jobbers drills.
118°	9°	45-50°	Extra long drills. (Crankshaft Drills)
118°	15°	22.5°	Aluminium, Brass & Soft Bronze
135-140°	7-9°	22.5°	Tough steels: High Tensile Steels.
130-135°	7-9°	22.5°	Stainless Steels:
100°	12°	22.5°	Copper and some Copper Alloys
118°	17°	22.5°	Bakelite, Plastics, Moulded Materials
60°	12°	22.5°	Wood, Hard Rubber & Fibre

Photo 32. A gauge provided with the J&L Black Book.

Photo 33 A Reliance style drill sharpener.

With care, drills from about 3mm to 19mm diameter can be sharpened. The jig can't handle long drills, over about 180mm in my case, which is very limiting if you want to sharpen Morse taper shank drills and long series drills. Larger versions of this jig are said to be available to deal with longer and bigger diameter drills.

I have found that the results I get depend a lot on the type of web shape and helix angle formed on the drill when it was manufactured. When re-sharpened the two cutting edges should be straight but if you re-sharpen at a different point angle from the original, a curved cutting edge can result. This seems to be mostly a problem with "modern" high production drills sourced from a local factory using CNC machining centres. Many of these drills by manufacturers like Guhring, Dormer, and Titex that I have "acquired" have drill point angles of 135 to 140deg. and thick strong webs and are intended for drilling tough materials like stainless steels.

I think the failure to deal with small size drills stems from the inaccuracy of the indexing finger and the clamping device. Also you need magnification and good lighting.

I find that some cheap HSS imported drills actually improve in performance if you sharpen them straight out of the box.

Table 4

Operation - Drill Sharpening, Reliance Jig	
ABRASIVE WHEEL	WA80 -JV1 Straight Cup
WHEELHEAD	Adjust height so drill bit is approximately at centre height
Table	Set at 90° to wheel head spindle
Top swivel plate	Set to 0°
Drill grinding fixture	Mount at 90° to wheel face. Set drill point angle. Set drill overhang to 1 drill diameter, set finger so the drill cutting edge to be ground is vertical.
Feed	Lock the rack and pinion. Use cross slide feed. Swing drill point from centre of wheel outward. Return at same setting. Rotate drill and repeat on second lip.
Notes	Resist the temptation to take too big a cut with the cross slide feed. <0.25mm (0.01") is an absolute maximum for a 10mm drill. Smaller drills need smaller cuts.

OK, so this removes the TiN gold coloured coating, but this is so badly applied in some cases I doubt its presence is much more than cosmetic. You have only got to compare the appearance and feel of a cheap import against a quality drill. The cheap stuff is rough on the flutes and has very dull coatings. I know that some will maintain that it's not worth re-sharpening drills, especially small sizes and cheap imports. It's your choice!

10) Thinning the drill web and the drill point

It is said that twist drill webs get thicker towards the shank so if you shorten a drill the web thickness will increase, leading to a longer chisel edge. The longer the chisel edge the higher the drilling force.

Occasionally you will come across an old drill that has been repeatedly used for shallow holes and this leads to wear of the drill land close to the point. When you attempt to drill a deeper hole the drill has a tendency to dangerously jam in the hole. The only remedy is to scrap the drill or grind away the tapered bit at the end and then re-sharpen.

If you drill from a lathe tailstock with a long slender drill you can often see the drill flute "unwind" as the hole gets deeper and the torque increases. Longer "crankshaft drills" (intended for boring oil ways) are extremely useful in the lathe tailstock and are usually made with thicker webs to withstand this winding action. Similarly, some drills made for tough materials have thickened webs by design. Many of the import drills have very thin webs, perhaps to save on material and to avoid point thinning when sharpening. (Or maybe they just copy from each other!)

The chisel edge at the centre of twist drills has a negative cutting angle and it needs a lot of force to push the chisel edge into the work. In some workpieces work hardening can occur and friction heating follows. Because the chisel edge is flat it provides very little self centering action. We often drill a small pilot hole and then open it up with a succession of larger twist drills because the follow-up drills are not cutting with their chisel edges. Once a pilot hole has been drilled the chisel diameter of the next drill isn't cutting and drilling forces tend to be less. This is particularly noticeable when drilling from the tailstock on a lathe. Examination of the drills described above show that many have thinned points, see **Photos 30 and 31**. To be continued...

References

Ref. 20 Engineers Black Book ISBN 0-9580571-1-1-7 and Norton grinding wheels are available in the UK from www.mscjlindustrial.co.uk/cgi/insrhm
Ref. 21 MEW 139, 140 by M.Christiaens
Ref. 22 Warco http://www.warco.co.uk/index.aspx
Ref. 23 Axminster http://www.axminster.co.uk/
Ref. 24 Drill references: Tubal Cain "The Model Engineer's Handbook" ISBN 978-1-85486-134-4. Also by Tubal Cain (T.D.Walshaw) "Drills, Taps and Dies" ISBN 0-85242-866-9 Workshop Practice Series No12. Also Harold Hall's "Tool and Cutter Sharpening" ISBN 1-85486-241-3 Workshop Practice Series No 38. These books are all available from www.myhobbystore.com
Ref. 25 www.homepages.mcb.net/howe/Newssmalldrill.htm

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The new Dremel Driver offers precision, control and power - simultaneously. Targeted at anyone doing drill/ driving work in a variety of detailed applications, including medium and light duty DIY, it measures just 12.5cm and has a T-handle design and precision variable speed trigger. It's ideal for DIY tasks such as mounting pictures on a wall, installing a lock set, mounting cabinet hardware, installing lighting fixtures, putting lights on a deck and assembling flat-pack furniture - there are even two IKEA bits included in the kit! It's just as useful if you are working on the car.

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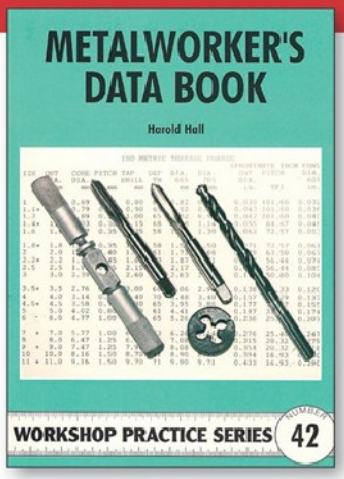
The Metalworkers Data Book by Harold Hall



This is book No. 42 in the Workshop Practice Series. It has long been awaited but has it been worth the wait? On occasions I have been asked if I would republish the Data Book charts. For readers' who are not familiar with the Data Book, It was a reference manual supplied in many parts in early issues of Model Engineers' Workshop. There were even special A5 binders available. (I believe two binders were required.) The original was printed on thin card and the whole thing was compiled by Harold.

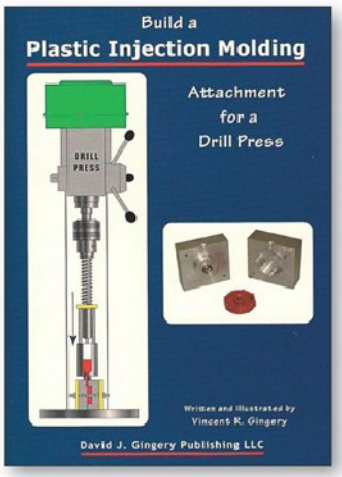
I spoke to Harold about reprinting the charts and he mentioned he was considering having them reprinted in book form so I stepped back and let him continue. Unfortunately, getting a book into print can take a year or more, probably in this case because of the sheer amount of information and the very large amount of proof reading to be done I think it has taken about 18 months.

The text, tables and diagrams are very clear and easily readable. The book is full of very useful information and includes conversion tables and screw head (hardware) dimensions amongst others.

The book is not a slavish copy of the original Data Book, it is a revised and greatly expanded edition with 217 pages between the covers. I think I can safely say that it is the thickest Workshop Practice book yet available. Although the thickest book available, the price is still £6.95. In this day and age it is remarkable value for money.

So, back to the original question, was it worth the wait? Yes, it belongs in every engineer's workshop. If you do any design work, I would buy two copies, one for the workshop and one to put next to the drawing board or computer. It deserves to sit alongside Tubal Cain's Model Engineer's Handbook, not instead of but as well as because the data in the main is different.

It is available from www.myhobbystore.com or by phone, Tel: 08448 488822 between 10am and 2pm Monday to Friday, price £6.95 + P&P. Alternatively, on the page opposite is a subscription offer for Model Engineers' Workshop where you can get the book for free. (Sorry, UK subscribers only.) Use the direct debit facility offered and you will get 13 issues in a year, one more than the 12 issues you would expect and also receive the Metalworker's Data Book totally free.



Build A Plastic Injection Molding Attachment For A Drill Press by Vincent R. Gingery

This little book has 48 pages and is well illustrated with black and white photos and line drawings. The machine itself is designed to be used by the simple use of a drill press to provide the injection force.

You will need a floor standing drill press rather than a bench drill press as the machine measures 12in. long and you have to add on the thickness of the mould. The heating elements are two tiny cartridge heaters that are readily available in voltages to suit the UK or overseas builder. The barrel temperature is controlled by a digital temperature controller and thermocouple. The finished machine will inject slightly more than ½ ounce of plastic, this is equivalent to about 1 cubic inch of plastic, more than enough for small projects in the home workshop.

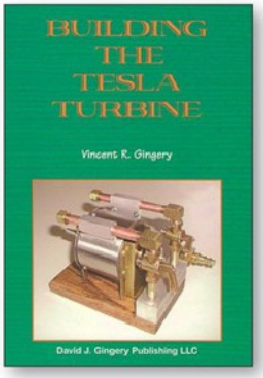
Full construction drawings for making the moulding attachment are given and apart from the compression spring are readily available in the UK. The spring is available from a US company but I am sure there will be an equivalent supplier here in the UK.

Full wiring details are given and the simple circuit diagram should be well within the capabilities of even the novice in electrical wiring. There is a drawing of a test mould given; this is just a straightforward mould to make two slugs of plastic but it will give you the basics of mould design and enable you to move forward to more advanced moulds.

The book concludes with a plastic identification chart so you can use recycled plastic in your machine and also includes the correct temperature settings for injecting the plastic. Even if you don't want to build the machine shown in the book, the information included within its pages will enable you to build a purpose made injection moulder from scratch.

The book is available from Camden Miniature Steam Services, Freepost (BA 1502), Rode, Frome, Somerset, BA11 6UB Tel: 01373 830151. The price (taken from the web site) is £11.75 + £1.30 P&P. www.camdenmin.co.uk

Building The Tesla Turbine by Vincent R. Gingery



The back cover of this book states that now you can build your very own model Tesla Turbine. I disagree with this statement; it is not a model but a real working turbine 3 1/2in. wide, 6in. long and 4in. high. Tesla also said that the turbine could give 10 horsepower of output for every pound the turbine weighs. The photo of the turbine on the cover looks very impressive but what can it do? For one, it can go in forward or reverse by simply changing over of two levers. It can also be used as a very powerful pump for both liquids and gases; it will even act as an air compressor. It can be driven by fluids, both in liquid or gas form.

The original patent is printed in the book as well as full drawings and instructions for making your own turbine. This is a simple project and could be built be the beginner with every chance of success.

This book is also available from Camden Miniature Steam Services. The price (taken from the web site) is £7.85 + £1.30 P&P.

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SCRIBE A LINE

An excellent article on soft jaws for chucks

I had an old set of hard jaws which were past their best so I thought I'd try annealing them.

I got them up to a red heat for a couple of minutes and let them cool. I was then able to hacksaw off the steps and face them on my mill. I then used the methods in the article to bore the insides and skim the outsides and then a light cut to true the faces. This left them 0.150in. proud of the chuck body. I then marked and drilled 3 blind holes in the faces for M6 screws so that I could fit a variety of attachments in different places.

I made up a set of wide cheese wedge jaws for holding diameters over 2.5in. on the insides. They could come in handy for making the occasional gold or silver bangle as I am a goldsmith. The first job though will be to hold a set of brass expanding chucks for slitting. I started these a while ago with the intention of holding wedding rings on my 8mm watchmakers lathe for truing up the edges or marking divisions for holes to be drilled to set diamonds evenly spaced as in eternity rings.

With the soft jaws, I now have an accurate way to hold the brass chucks at a fixed depth. Now to mount a Myford vertical slide to my Smart and Brown lathe's tool bed and start slitting.

Carry on with the current format, the standard is superb and you have a good mix of articles ranging from basic to advanced.

Mark Rose, by email.

Depth of information

Mr Shaw's 'Scribe a Line' article in issue No. 146 regarding the depth of information required by readers for precision machining has prompted me to add my own experiences to further highlight the depth of what can be done with a little training and a lot of practice. Like Mr Shaw, my grandfather was an excellent machinist; his lathe had previously been used as an anvil before he got it, and required many hours of hand-scraping to bring it back to usable. Unfortunately he passed on before I became interested in learning the art for myself, but my father has regularly told me of how he could face off two pieces of bar, oil the faces, clamp one piece to the bench and support his weight holding onto the second bar, the surface tension of the oil being the only thing holding him up. During my formal years at school I studied manual arts, however our teacher had us exclusively work on sheet metal (my brother was able to do turning and milling at a much earlier age at the same school).

My first use of the lathe came during university, where we were required to devote one 2 hour session every week to learning such tasks as welding, milling, etc. We only spent 1 session on turning. A few years ago whilst working as a draftsperson I met one of the welders from the same company, who I learned was building a Supermarine Spitfire at the local military musuem. I went along one weekend, and was soon pressed into using the lathe to make several small pins for the seat frames on an old, poorly maintained Hercus 9c, which some readers will recognise as an Australian copy of the South Bend 9in. Using this machine for about 2 years I learned to deal with it's eccentricities as well as my own, producing good work in the process with no-one to show me what I was doing. All I had was a copy of L.H. Sparey's excellent book 'The Amateurs Lathe'.

By learning to grind my own tools and by listening to what the machine was telling me (reduce speed for chatter, etc.) I got the hang of it. Eventually the museum deemed the machine to be unsafe (because of a damaged chuck and broken bed clamp which it had had since before my time) and I moved on to a much larger Sheraton Defiance. Eventually I took possession of the Hercus and spent almost a year restoring it; pulling it apart to clean out some 46 years of oily swarf and replacing any worn parts like the brass cross feed nut. the final result being that I can now face off two pieces of bar and have trouble getting them apart if a film of water is applied first, and get a gas-tight sliding fit on any pistons/liners I've made with relative ease.

Given my 'training' and the machine I use, I'd figure that any good machinist should be able to do the same. I've also started work on a Bentley B.R.2 Rotary from L.K. Blackmore's book, which will be my first big project after the spitfire. Incidentally, the warrant officer who took over the running of our side of the museum said that the military give their machines a complete strip-down every 12 months. My suggestion therefore, for any newcomers to the hobby, is simply to get in and build up your experience through practice. Those in the know might disagree, but I would also advocate pulling at least the carriage and apron on your lathe apart and giving it a good clean and replacement of old felt wipers with neoprene ones; especially so for older machines, but the newer ones will also benefit from clean, tight gibs and to make sure everything seats nicely since leaving the factory.

It's amazing how much a bit of TLC can go towards improving ones quality of work, and hence enjoyment, of the hobby. You will also familiarise yourself with the intricacies of the machine, and thus better understand its operation. On an semi-related note, I was wondering if MEW could devote a future article to the tools which an amateur turner should possess; both the essentials, and those (such as taper attachments and ball cutters) which would be nice to have.

Nathan Stern, by email

Workshop heating

As a long time reader of your magazine and a "shed person", I would be grateful to hear how readers of MEW manage to heat their workshops in a reasonably cheap manner.

I have a wooden shed; it is 22ft x 12ft and was quite well insulated when built some 16 years ago. It has a rather large milling machine of Russian origin and a Colchester Chipmaster lathe. There is also a Myford lathe, metal cutting bandsaw, pillar drill and some other fairly heavy cast iron kit in there.

I have tried many ways in which to heat the place and have come to the conclusion that, unless I leave heaters on permanently, which is rather expensive, condensation is the end result and therefore I'm back to square one. Do readers' have any suggestions?

Robert Logan (RAB) by email.

The Editor replies: *I use dehumidifiers in both of my workshops and very little rust forms.*

I read recently that you only need to run the dehumidifier for a few hours a day using a time switch but have yet to try this. I have sprayed equipment with WD40 when not in use as well.

Sheet Plastics Bender

Anyone wishing to build a Sheet Plastics Bender, as suggested by Harold Hall in MEW 147, might find this site useful: http://wires.co.uk/

Here is the page on bare NiChrome wires: http://wires.co.uk/acatalog/nc_bare.html

Michael Gilligan, Cheshire.

Electric etching pens

In 'Scribe a Line' on page 50 of MEW 148 G Bird asks about electric etching pens. An article by L Tattersall was published in Model Engineer 3rd September 1993 pages 292 and 293 describing the manufacture of such a pen.

John Noakes and Chris Smith by email.

The Editor replies: *I have an article on the way about building an electric pen.*

Etching pens and Clarkson cutter grinders

To reply to two points in the recent excellent (as always) MEW issue number 148; Mr G Bird of Herts, Scribe A Line, Page 50 asks about 'etching pens' - in preference to the 'vibro etchers' as manufactured(?) and sold under the Burgess name. I think he is referring to the 'Markonus' etching pencil. These pencils(!) are supplied with the described wooden handle, have an inbuilt 'trembler' coil, and use a tungsten needle tip rather similar to a gramophone needle but definitely not interchangeable with 'His Masters Voice' items! The pencil handle alone costs around £60 and if purchased with the multi-tapped transformer, which allows 'very fine' through to 'heavy' etching by staged voltage outputs, sell for around twice that figure. These are

available from Cromwell Tools and appear on page 806 of their catalogue (lower left hand corner) suitably displayed below the Burgess item. The catalogue is viewable online at www.cromwelltools.co.uk and the item is listed under hand tools, sub list 'etching and marking tools' or go straight to page 806. I have no interest or connection with Cromwell Tools and would be delighted to hear of other suppliers offering this tool; Cromwell are the only ones to stock it as far as I know.

Despite the price of the Markonus pencil it is one of the most useful tools one can have - I find myself marking special 'tools' I have made as reminders of what they are used for! I know that sounds 'daft' but I have often in the past wondered what a piece of intricate metalwork was originated for (knowing full well that it must have been a valuable aid at some point in the past) proceeded to modify it, only to realise a week or so later what I had originally made it for and to curse having 'lost it'. It would certainly be a good investment for a club to make and then to 'Hire' it out at a nominal fee (good for club funds) and security marked items (such as name and postcode in a subtle position marked on a model or tool) can often deter the more unscrupulous members of society or even better, lead to their apprehension.

The second item I would like to reply to is the request by Mike Haughton, which appeared in his well written and informative article 'A Clarkson Tool and Cutter Grinder', for the background to the Clarkson Company. The origins of this company were not in the Sheffield area but actually closer to their Nuneaton base. Mr. Clarkson (I believe his first name was George, but memory is a little foggy here) was employed at Alfred Herberts Co. Ltd,. Machine Tool Manufacturers of Edgwick Road in Coventry (8 miles to the south of Nuneaton town centre). It is known that George(?) Clarkson was the head draughtsman in the 'Equipment A' Drawing Office at Herberts, he is believed to have developed his ideas for the compact and eponymous cutter grinder whilst at Herberts following a request for a design of cutter grinder which would be capable of being used by semi skilled labour (remember this was in the aftermath of the Second World War when skilled labour was in short supply throughout Europe). The Herbert T&C which emerged from about this time was more complicated and considered to be 'less able'. Clarkson left Herberts to form his own company and manufacture the grinder in his home town of Nuneaton (a dormitory town for the more affluent workers in the North side of Coventry). The Autolock and Dedlock chuck systems were similar developments of a design which had been frustrated by the powers that be within Alfred Herberts. The cutter business grew out of the need to supply a cutter for this system and the ubiquitous Clarkson T&C's were put to good use within the Nuneaton factory producing the cutters for the 'locking chuck system. I believe this is now referred to in marketing terms as a 'circular sales system' - to use the cutter you ideally need the cutter holder, and purchasing the cutter holder alone requires the eventual purchase of the cutter!

Alfred Herberts Ltd, were at the time reputed to be the largest Machine Tool manufacturers in the world, and had an enviable record of full employment even through the days of the early 1930's. I write this as an ex-apprentice of Alfred Herberts, and as one who 'finished' his time in the very same 'Equipment A' drawing office in the late 1960's. There were many of the senior draughtsmen who knew Clarkson and this is the basis of my knowledge of the above. As an aside 'Equipment A' designed special tooling and special applications machinery for customers; the 'Equipment B' drawing office never officially existed! It was just called the 'Works' D/O - it designed special tooling for 'in house' applications and was probably more akin to a Jig and Tool D/O.

Whilst on the subject of Tool and Cutter grinders I actually rate very highly the 'Boremasters of Kenilworth' (and yes, that is their name!) Tiplap grinder. This is a very versatile grinder that is self contained (commonly bench mounted in other words! - but originally early examples were supplied on a riveted aircraft grade aluminium cabinet - a sign of the times post WWII) and a delight to use. It has the advantage of being able to grind lathe tools with ease, as well as boring tools, and with accessories it is capable of tackling slot drills and end mills. It is very similar to the Alexander/Deckel SO grinders in size but is more adaptable and easier to set up and use. It is interesting to note that of all the T&C's I see in small 'jobbing shops' around the Midlands the Tiplap appears to be the T&C of choice!

More articles please on this theme would be much appreciated. I await a really good article on the use of T&C's (which is where I hope Mike Haughton's subsequent articles will lead). Also a plea for some examples of small bench shapers and their use would be much appreciated having recently rescued from a farm and restored an ex REME workshop South Bend 7b from 1942. It now cuts to an accuracy of 0.0002in. over a 3 x 3in. test piece. Mick Whittingham's article on machine tool renovation in the same issue (MEW 148) is an example of another interesting article.

Martin Smith, Warwickshire.

Tolerance

Peter Woods, et al. in MEW 148. Do we, as model engineers, actually need to supply tolerances? If we are designing for industry where components are made by the thousands, and where mating components may even be made in different factories in different countries, then yes they are required. But surely not for model engineers whose outputs are measured in tens at the most, and more likely in ones and twos. Indeed Tubal Cain in his book Workshop Drawing has quite a few things to say about tolerances (and allowances and the confusion between the two) along the lines of not being necessary for model engineers and does it really matter of the cylinder is 1.998in. instead of 2in. or the buffer beam is 1mm too long provided they do their required job and other components can be made to match?

Finally, I note that there are people using AutoCAD for their drawings. Now the last time I looked, I found AutoCAD far too expensive for what is only a hobby, and I for one have better things to spend my money on. For amateur use there are other CAD programs such as TurboCAD available at more reasonable prices, however being a very satisfied user, I would highly recommend DesignCad 3D Max. This program is now at version 19, but V17.2 is readily available on Ebay for around £25. This is now the version that I use, and is more than adequate for our needs.

Peter G. Shaw, by email.

Studer grinder

I am currently refurbishing a Studer type OB cylindrical universal grinder. Does anyone have any information relating to these machines. From the brief manual that I have, I'm guessing the machine dates from around the early 1950's.

Graeme Walker, by email.

WRITE TO US!

We would love to hear your comments & questions and also feeback about MEW

Write to the Editor, David Clark, Model Engineers' Workshop, MyHobbyStore Ltd., Berwick House, 8-10 Knoll Rise, Orpington, Kent BR6 0EL. Alternatively email: david.clark@myhobbystore.com

THE STAR LETTER OF THE MONTH WINS A WORKSHOP PRACTICE BOOK

SCRIBE A LINE

Novice engineers

I enjoyed the welding article by Jayne Reeve - I still feel like a novice after 8 years or so of hobby welding. Even after all this time I still cut the rods in half to use them - I have much better control. Although 20mm is wasted, I feel that I would waste even more with poor welding using a long stick.

I hope that you have more articles for the novice in the pipeline in both magazines. For example, I have a milling machine (old and small) and struggle to use it properly - making a 15mm long, 4mm slot in a piece of mild steel strip 3mm thick (repair to a strimmer engine) was successful eventually, but tore the cutting edges off the cutter. I've got no idea where I went wrong, speed too slow, too fast, trying to cut too deep at each pass. Most articles just say things like "I milled the edges", or from MEW149, p47, "The Vee is milled with the corner of an end mill, with the block set at 45deg in the machine vice". These do not help me. Taking the latter as an example - these accessories would be ideal for a novice to have a go at, and be useful - making the article newcomer friendly. Perhaps the likes of myself could learn and I would certainly have a go. I feel that too much is written generally for those already in the know - almost another language to the learner.

My apologies for the rant - as I say, I have renewed because I do learn something in most issues - hopefully I will make something simple & useful too eventually.

John Tory (Essex)

Mechanical disasters

The website www.marinediesels.co.uk has descriptions of troubleshooting, mechanical disasters and repairs on a heroic scale to ship's propulsion engines up to 55,000 HP. Some of the engineering techniques, photographs and tricks they show would I'm sure be of interest to readers. Incidentally, the balance of material in MEW suits my own interests perfectly.

John Chapman, Plymouth.

Tommy bars

I've just received issue 148 and would like to comment in reply to Peter King in "Scribe a Line". Peter King is absolutely right in noting another oversight in my series and his concern for our safety is appreciated. I have had a re-think on what exactly I do in my shop and the "tommy bars" are only used by hand for the smaller and finer threads up to about 1/4in. BSF, and even then I release quickly if it 'snatches'. For larger sizes, I tend to adjust the top slide, or toolpost, into the arc of rotation of the outer end of the tommy. For the longer tommy and larger, coarser threads I allow this to impinge onto the top of the cross slide. I'm not sure if it can be measured but there is an inevitable 'push-away' of the holder when this happens though I have not noticed a problem with mating threads from this possibility. I've not tried a welder's glove - I don't have one - but I feel I would rather keep my right hand away from the operation. My left hand is on the clutch lever and well clear.

David Piddington, Birmingham

Beating the rust fairy

Those of us who are unlucky not to possess a heated workshop are thanking our lucky stars that the worst of the winter weather may have passed. I have done a bit of work but it was painfully cold at times.

I did, however, learn a trick to avoid condensation causing rust on work pieces or tools if I took them indoors where it was warm enough to work. I put the bits in a sealed plastic bag and then left them to warm up to room temperature before removing them from the bag.

I completed the reader's survey and commented on wanting to see an article on numbering graduated dials using punches and jigs. There have been a few but the actual set up of the punches, allowances for varying widths of the numerals and how to make a nice job of the appearance seem to get passed over.

I am still battling with making a rotary base for my Quorn and am now trying to fabricate the item. It is a slow and frustrating job!

Brian Corfield, by email.

Scraping machine tools

I have recently being trying to catch up on my reading and noticed in MEW No. 146 - Scribe A Line - that a Mr. Mick Whittingham would like any information on the subject of scraping, in particular frosting.

Hopefully I may be of some little help on this subject/skill. I served a formal apprenticeship (indentured) at a company called Dean Smith & Grace Ltd. I remember well on the first day of my employment being given (along with eleven other apprentices) the task of making a range of scrapers, a couple of which I still have and occasionally use. That basically sets the scene - scraping, scraping and more scraping - everything you touched, (or at least it seemed so) needed to be scratched*. It didn't take long to learn the basic skills of scraping, usually months, but frosting took years. It took me about seven or eight years to become proficient, that is keeping pitch, angle, shape and length of the "Seagulls Wings" consistent enough to frost a lathe bed full length to a reasonable standard. Everybody had their own unique technique; in particular it was noticeable how the holding of the scraper handle varied from individual to individual, some between fingers and others with fingers wrapped around. These variations gave rise to each fitter having his own frosting signature and could be recognised at a glance by the individual.

To get back to Mr. Whittingham's request for information; I suggest initially that he practices the basic scraping technique and gets the hours in (beware of blisters and calluses) and then when he becomes as one with his scraper and it feels as if it's just an extension of his arms, he will then probably find that frosting comes quite naturally.

I'm extremely sorry I do not possess the literary skills enabling me to describe the process of scraping comprehensively, but if Mr. Whittingham would care to get in touch with me, I will glad to be of service and help all I can.

*Scratch, scratched and scratching derogatory Dean Smith's slang term for scraping.

Geoff Swales, by email.

More on Metric

There are two much debated subjects namely metrication and getting new members into model engineering.

I believe you alluded to it recently, but I think it should be expressed more forcefully that these are very closely linked topics. New members are likely to be comfortable with the metric system. In addition someone contemplating the hobby might well balk at the prospect of having to buy endless sets of taps, dies, drills, reamers etc. each in fractional, decimal, Whitworth, BA, BSW etc etc. No end seems in sight. Metric is much less daunting with the coarse and fine M series sufficing for most needs and only decimal measures for everything. Only 60deg. thread profiles. The well established engineers with the well stocked drawers of imperial tools will obviously balk at the idea of abandoning this investment but they should think twice before discouraging designs to be presented in metric. Depends how public spirited you are.

On another note: I occasionally get German model engineering magazines and they definitely have a lot more pictures of younger participants and authors - food for thought?

Eckart Hartmann, Ireland.

Sulphuric acid and Merlin engine

Alan Sayner wanted to know of a source for Sulphuric Acid; has he thought of a car battery supplier as in Lead-Acid batteries ?

I have heard that there is a gentleman in the U.S. that has drawings for a model RR Merlin engine.

Does anyone have a contact for him?

Dave Grainger
(a.k.a. Grave Danger) Australia.

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■ Clarkson tool and cutter grinder, needs TLC, £60. **Tel: 01362 860322 East Dereham.**

■ Myford 'M' type lathe, 3½in., 1948 on wooden bench, single phase in good condition, £375 ONO. Drill press model CDP201B, 13mm capacity, 12 speed, Jacobs taper, single phase, £100 ONO. **Tel: 0208 6867898 Croydon.**

■ Hunton No 2 bolster plus punch holder in good condition, £125. A3 multi position drawing board, Walton rack and pinion type, used once, cost £68, accept £35 including post. **Tel: 01953 718531 Norwich.**

■ Unmachined castings for the Quorn tool and cutter grinder, 13 iron, 3 alloy and 1 gunmetal one, £80 buyer collects or pays post and packing. **Tel: 0121 4266414 Birmingham.**

■ 30 clock wheel cutters, mostly Thorntons, as new, M0.3, M0.4, M0.45, M0.5, M0.6, M0.65, M0.75, M1.0, deadbeat 35deg. Escape, many more, buyer collects, list price £52.25 to £70 each, the lot for £425. **Tel: 01252 842626 Camberley.**

■ Horizontal Axminster bandsaw, good condition, £55. Record BK3 bandsaw with spare blades, £20. **Tel: 01245 250297 Chelmsford.**

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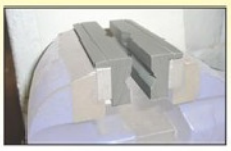

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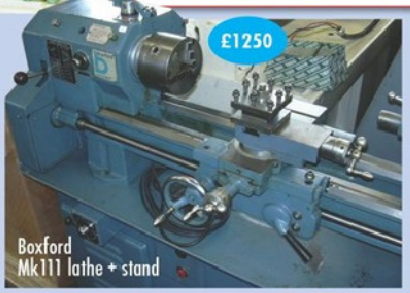

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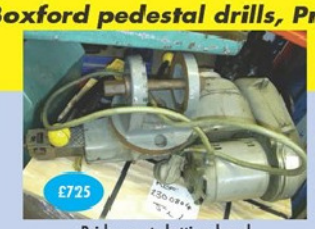

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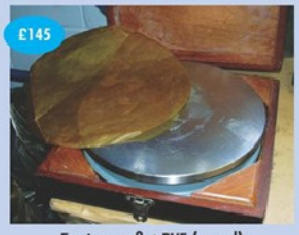

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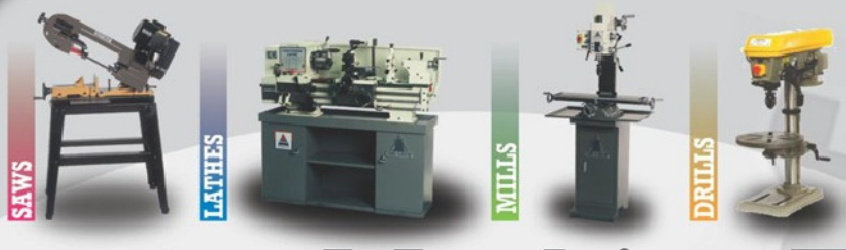

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