made in a wide range of sizes, increasing by increments of 0.05mm, which is equivalent to approximately 0.002 in.

Expanding reamers

Reamers of the expanding type are most useful for sizing holes to an exact diameter. The Morse (Fig. 3) is, perhaps, the most reliable form of expanding reamer as rigidity is obtained by making the blades part of the body and these are expanded by a tapered adjusting screw. The only disadvantage of these reamers is that the range of expansion is only 0.005 in the sizes up to ½ in. dia.

The second type of expanding reamer (Fig. 2) has five or six removable blades, held in place by a cup-nut at either end and supported in the middle by a slotted guide-piece. Although these reamers have a range of expansion amounting to 1/16 in., they are not so rigid as the Morse type.

Another variety of this type of reamer (Fig. 2) is furnished with spirally-ground blades. Both types of reamers are set by adjusting the cup-nuts to slide the tapered blades endways in their retaining slots. Expanding reamers with inserted blades can be bought in sets ranging in size from ¼ in. to 15/32 in. and a second set brings the capacity up to 1¼ in.

Taper reamers

Reamers for enlarging drill holes to receive taper pins are illustrated in Fig. 1; these range in size from No. 6/0, which is 1/16 in. dia., to No. 6 of 9/32 in dia.

The cutting edges are of the same form as those of the ordinary hand-reamer and this type of tool cuts more quickly and more accurately than the less expensive taper broach used by clockmakers. When fitting a taper pin, a hole is first drilled slightly larger in diameter than the small end of the reamer. The reamer is then carefully worked in by turning it in a clockwise direction and applying light pressure.

From time to time the reamer should be withdrawn and the flutes cleared of chips.

Larger reamers are made for finishing bores to the Morse taper or other standard forms. When rectifying a worn or damaged taper bore, care must be taken to maintain the reamer in true axial alignment and, after a single turn, it should be withdrawn and the operation repeated until the smooth surface of the bore is restored.

To form a Morse taper bore in a machine spindle, the bore is first roughed out by step-drilling and then machined to the correct angle of taper. Finally, the bore is corrected with a reamer, which should be supported at its rear end in exact axial alignment.

Fig. 2. A set of hand reamers.

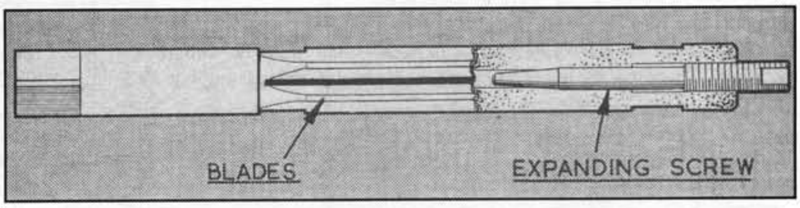


Fig. 3. Constructional details of the Morse expanding reamer.

M.E. 138 1235 (1972) & 115 482 (1956)

Hardening and tempering R.F. Willetts / J. Whitton

Many articles over the years have contained helpful advice on this subject, but these two old entries have most of the important points. I have included the second entry since it relates temper colours to temperatures.

HARDENING AND TEMPERING

by R F Willetts

EXPERIENCED tradesmen have numerous methods of determining heat treatment temperatures, indeed one could write a book on this subject alone - many have! - without recourse to the instruments available to industry. Since amateurs have neither the instruments nor the experience, it is felt that a few hints on this subject will assist in obtaining satisfactory results with silver steel, ground stock, spring steel and coil springs.

A quick word or two on the phenomenon of hardening may put the matter into perspective. The temperature at which a high carbon steel can be hardened by rapid cooling occurs over a comparatively narrow range, called the upper and lower critical temperatures. If we quench at the lower temperature, hardening may be problematical or even a failure. At the higher temperature hardening will be sure and effective. The human eye, even an experienced one, is hard put to detecting this from the colour, and frequently, "to make sure", this temperature is exceeded, bringing in its train cracking, de-carburisation (or loss of carbon), and grain growth. Fortunately, as any metallurgist will confirm, at the correct temperature the steel becomes non-magnetic, and we can thus, by testing with a magnet, determine when to quench to a nicety. This is far better than "cherry-red" methods (whatever colour *that* may be!).

Industry uses atmosphere-controlled furnaces to protect the heated steel; we cannot, so do not "cook" your work slowly in an inadequate flame, but using say, a 1½ in propane torch as for boiler work, heat the steel evenly but quickly with firebricks surround if needed, and have a deep, adequate volume of coolant near to hand. For silver steel and similar high carbon steels, use ordinary tap water. A more severe quench can be achieved in a 10% brine solution, and for every delicate work, oil quenching, but for most needs, water is best. Test with a file - you *could* have picked up mild steel! For gauge steel (ground stock) always quench in oil. Plunge deep and decisively, don't mess about, leave until cool. Flat springs from annealed stock, oil harden, do not clean these - for reasons which will become apparent later. Coil springs are not quench hardened - the wire is in a hard drawn condition and must be heat treated after coiling - more on this later.

Tempering

The hard but brittle steel must now be "tempered" to suit its duty. A table of oxide colours is shown to assist in this. The relatively low temperatures involved are not as critical as for hardening and this visual method will suffice for most of our needs, but even so, must be applied correctly for good results, and in daylight too. Since the temperature of our torch flame is several thousand degrees and the temperatures we require range between 150 deg. and 350 deg. C, it follows that tempering should not be done by direct flame contact. We can conduct the heat from the shank in the case of shanked tools, or use heated convection currents in the zone above a flame. We can immerse in a substance whose melting point is known, or bury in hot sand - the methods are legion, but all avoid direct contact with a flame.

Large tools are frequently tempered for one hour; for our work, three to five minutes will suffice. The writer prefers hot air above a bunsen burner and has a wire tray attached to an adjustable stand. Experience will show just where the temperature zones occur, but it is better to start high up - one can always come lower. Before tempering, a good polishing of the work will expose the surface to the oxidizing effect we are seeking, the better the finish, the easier the results.

Flat springs - tempering after hardening

For material above 0.020 in. approximately, immersion in "just molten" lead, poking the floating springs under the surface occasionally, is ideal. Leave them in for about five minutes, keeping a low flame under the pot. The oily surface of the uncleaned springs will prevent lead adhesion. For thinner springs, polish and air temper to blue, light blue or purple. Blue is the limit of colour tempering range - after that clear, hence the lead bath at approximately 325 deg. C. - which of course can be exceeded by careless heating. In practice, the lead bath may be about 350 deg. C. but it suits our purpose admirably, and forms a useful extension of the blue range of 300 deg. C.

Blueing

This much admired glossy blue oxide finish often found on springs is achieved in industry by tumbling barrel methods and recirculating hot air furnaces. The glittering batch of springs is placed in a tray already in the furnace held at approximately 300 deg. C. and removed when experience or observation indicate the desired colour. They are then cooled, oil dipped and centrifuged - and look lovely! Our problem lies in achieving a high burnishing - and the lustre is proportional to the finish, also, finger prints show up very well indeed. Obviously, anything already tempered, at say light purple, would be impaired by heat blueing and would not be so finished, but fortunately, most springs are tempered above blue range and can be finished thus after burnishing. Here, we can use the hot air method, but avoid quick blueing, which produces a thin oxide layer, easily damaged.

TEMPERING COLOURS FOR VARIOUS TOOLS

Colour	*Duty*
Yellow	Scribers, Turning Tools, Small Milling Cutters
Straw Yellow	Taps and Dies
Dark Yellow	Reamers, D Bits
Light Purple	Punches & Dies, Drills, Snaps, Gauges
Dark Purple	Drifts, Hand Chisels for steel, very Light Flat Springs
Light Blue	Wood Chisels, Needles
Blue	Screw-Drivers, Light Flat Springs

Heat to cherry red

J WHITTON.

HEAT to cherry red and plunge into clean, cold water. The direction is particularly familiar to readers of this journal. It is, of course, the usual instruction for the hardening of silver steel.

Much more should be said about this material. It is one of the handiest in the home workshop and is used principally for making the odd lathe tool or D-bit; the model engineer being particularly adept at making something to make something else.

It can, however, with the aid of careful tempering be used for a wider variety of purposes. High-carbon steels with this carbon content, have in the past been used extensively in industry. Today they have been superseded by high-speed steels in many cases. Yet for the small workshop silver steel has the unrivalled advantage of being inexpensive in price plus the fact that it requires only 760 deg. C. to attain maximum hardness. Against this, high-speed steels require from 1,100 deg. C. to 1,500 deg. - temperatures which are practically unobtainable with modest equipment.

Provided that the following points are adhered to there are no reasons why a satisfactory efficiency cannot result from its usage.

First, it is vitally important that during any heat treatment the steel should not be overheated. A fine grain structure will be the result of care in this direction. It should also be brought to the hardening temperature gradually and preferably uniformly, by heating in a muffle.

Tools which require re-hardening should first be annealed, in order to relieve the strains set up during previous hardening. This is done by heating the steel to a point just below the hardening temperature and allowing it to cool slowly. Failure to do so may bring about cracking and distortion.

It is not absolutely necessary that the water for quenching be cold. Indeed, in the case of intricate cutters it is preferable to quench in warm water. This also reduces the possibility of cracking.

After hardening, it is essential that the tempering operation be carried out immediately, particularly in tools of irregular section. This is because the quenching operation causes a stressed condition which requires relieving. If this is not done the tool may fracture due to the inherent strains asserting themselves.

Heat treatment of any kind in industry is done under rigorous control. Unfortunately, in the small workshop lack of equipment makes this impossible; so it is necessary to carry out hardening and tempering by the old colour method. The hardening colour has been dealt with, but the tempering colours for different applications can be seen from the chart, together with their respective temperatures -

Temperature (Centigrade)	*Application*	*Colour*
220	Engraving tools, paper cutting tools, small turning tools, scrapers, razors, reamers, gauges	Light straw
230	Milling cutters, wood engraving tools, large turning tools, drills	Straw
240	Taps, screwing dies, small punches, axes, hammers	Dark straw
250	Stone-masons' tools hand shears, scissors, pneumatic tools, wood chisels	Orange
260	Large taps, rivet snaps chipping chisels, punches	Light purple
270	Saws, drifts, cutlery, smiths' tools, ivory cutting tools	Purple
300	Springs	Blue

M.E. 156 546 (1986)

Stress relieving, annealing & normalising

by Tubal Cain

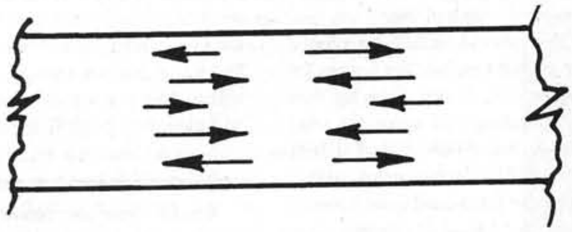


Fig.1.

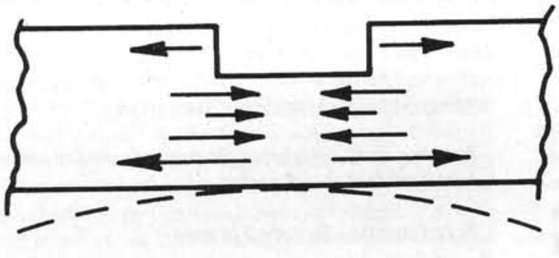


Fig. 2.

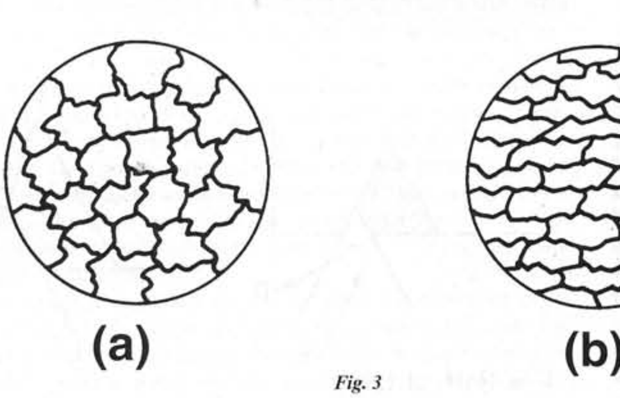


Fig. 3

THERE has been some increase in interest in these subjects recently in the pages of Model Engineer. Most people realise that after (say) welding parts together that there will be considerable temperature differences between the line of the weld and the rest of the metal so that, after all has cooled, local stresses must be set up. They are, however, often puzzled as to why it should be necessary to "stress relieve" a brand new and untouched piece of steel.

The answer lies in the way the steel was formed. With hot-rolled bar the metal has, it is true, been subjected to considerable deformation - a large rolling mill may have a 30,000 h.p. motor to drive it. But at the end of the process the metal is still red-hot, and its yield strength will be less than any internal stresses which may have been set up, so that these stresses ease themselves automatically.

With bright-drawn steel, however, the situation is very different. As the name implies, the bar is pulled, cold, through dies which are successively smaller in dimension until it reaches the desired shape and size. This process puts a tensile stress

Annealing & Normalising Tubal Cain

Little clear thinking on these topics has been published, but this is an excellent example of Tom Walshaw's lucid writing.

into the skin of the bar and, at the same time, a compressive stress into the core - Fig. 1. The summation of these internal stresses exactly balance each other (or should do so, normally) and in the case of a round bar, used unmachined, will have no adverse effect. However, if we chew a piece out of one side, e.g., when cutting out for the horns of a locomotive chassis - the system is then quite unbalanced and the piece will distort. Fig. 2 shows that the direct line of tensile stress on one side has been interrupted and the piece will tend to bend as shown by the dotted line, because the remaining internal compressive stresses are not completely balanced. The situation is made worse when more complex shapes are machined from rectangular section, but may not be noticed at all when turning cylindrical parts from round bar. The phenomenon can be removed completely by the process of STRESS RELIEVING the bar before undertaking any cutting operations.

The case of cold *rolled* steel is rather different. This process is used almost exclusively for the production of sheet to closer tolerances on the thickness than is possible with hot rolling. Cold rolled sheet does contain locked-up stresses but rather more important is the fact that the metal has been WORK HARDENED. In addition, the material may exhibit a greater strength along the grain than across it. Most cold-rolled sheet (of mild steel, that is) is best ANNEALED if much subsequent forming has to be done. A grade known as "Cold Rolled Close Annealed" (CRCA) is used when any pressing or deep forming operations will be used.

Even hot-rolled steel may require some treatment, especially hot-rolled plate or sheet around ⅛ in. thickness. In its "normal" state steel will exhibit a microstructure of *Grains* which, though irregular in shape are, on average, of regular size. The process of hot working, whether by forging or rolling, can distort these grains into an elongated shape - Fig. 3. The strength of the steel part as a whole depends on the resistance to rupture at the grain boundaries, and in the form of Fig. 3b this will differ along and across the grain. In many cases we take advantage of this, and the forgemaster will, for example, carefully plan the forging of a crankshaft to "get the right strength in the right places". But for machined parts from bar the "normal" grain of Fig. 3a is preferred. The process of NORMALISING is a heat treatment which restores the grain shape to "normal". Most hot-rolled plate is normalised after rolling at the steelworks.

So, we have these three treatments, "Stress Relieving", "Annealing" and "Normalising"; they are *not* merely different names for the same process, but each has its purpose. (Though it is worth noting that both Annealing and Normalising will automatically bring about a stress relief). How are they carried out?

STRESS RELIEVING is comparatively easy in the case of Bright Drawn stock (BDMS). It is only necessary to heat the metal (slowly) to a temperature at which the yield strength is less than the locked-up stresses. For mild steel this is about 500 deg. C - barely red heat - but it will do no harm if it is somewhat hotter. However, the metal *must* be kept at that temperature for long enough for the stresses to work out, and the rule is one hour per inch of thickness - 15 minutes for a piece of ¼ in. x 1½ in stock. It can then be left to air-cool. The process is by no means critical, but it is fairly important to heat evenly on both sides, especially in the early stages, and I turn the piece over frequently when flame heating. This is not necessary if a muffle furnace is used.

ANNEALING is a different kettle of fish, and further, whilst a hardened tool-steel can be annealed at quite a low temperature, a low or medium carbon steel must be brought up much higher.

Annealing temperatures	
Carbon Content %	Temperature deg. C
Below 0.1	910
0.2	850
0.4	820
0.6	800
0.8	790

Typical figures are as follows:

910 deg C is really bright red, 820 is about "bright Cherry" and 790 is about the temperature you would use for hardening silver steel. Again, the temperature must be raised slowly, and held at the final figure for one hour per inch of thickness, to give time for the process to work inside the metal. (And also, be it said, to make sure that the metal is hot all through; you would be surprised at the time it takes to get even ½ in. stuff red hot to the core if you were able to see inside!) The metal must be cooled slowly this time. Burying in hot ashes is the usual recommendation, but I usually set a heat insulating brick behind the work and then set this hot side down on top of it after heating for the required length of time.

NORMALISING should seldom be needed by a model engineer, but I include the figures for completeness. In general, 20 deg. C higher than that needed for annealing will serve for steel below 0.9% carbon but NOTE THAT HIGH CARBON TOOL STEEL needs much higher temperatures than those for annealing it - between 900 and 925 deg. C for 1.0 - 1.2% carbon steel. The procedure is otherwise as for annealing. There is one material which I have found does benefit from normalising - old bedstead angle. The old stuff, that is. Modern material, less than 45 years old, is made from folded sheet, but prior to that date it was most frequently made from rerolled tram-rails. High in carbon and manganese, very tough to start with, many of the small jobbing mills converting it would be taking the last few passes through the rolls with the stuff barely red! It is murder on hacksaws, tough on drills, but a very useful material for that reason. Both normalising and annealing can be effected by heating to 850 deg. C. And - if ever you weld this stuff, *never* quench it, for a 0.6 to 0.8% carbon content it is definitely "heat treatable" and you may well find that odd things happen. Anneal after welding, always, with old bedstead angles!

A final point. Scaling is not normally a problem with smaller sections as the heating time is relatively short, but if you wish to avoid it, coat the work with a paste of powdered chalk (or lime) and water, and set a piece of similar size alongside to give you a temperature check - the chalk will glow very brightly.

(Readers who are interested in furthering their studies of this subject may be interested in the Author's book, Hardening, Tempering and Heat Treatment available from Nexus Books, price £6.95 plus 70p p&p - Ed.).

M.E. 146 994 et seq (1980)

Miscellaneous Machining Techniques

Here is a small selection of the many machining techniques which have been described over the years.

Screwcutting George Thomas

Many of you will remember George's demonstrations of screwcutting at exhibitions. His words on the subject should be heeded. This is a small part of a long series of articles.

SCREWCUTTING PROCEDURES

by Geo. H. Thomas

THE original object in writing these notes was to provide some information on a screw-cutting method which seems to be not generally known to model engineers and which I cannot recollect ever having seen described. I shall not deal with tools and tool-holders nor gear-trains, all of which have been touched upon in previous articles, but as soon as I started to write I realised that some preliminary explanations would be necessary so we shall run quickly through the methods in general use and consider their good and not-so-good features.

The first to be considered is the 'straight-in' method in which the tool is fed in by means of the cross-slide which will give a direct indication of the depth of cut. The tool will have to cut on all edges at the same time which will tend to cause 'crowding' of the chips. More serious to my mind is the fact that it is impossible to apply a side rake to the tool which must be left flat topped because it is expected to cut equally on both edges. Another serious drawback is that, in the absence of any means of rapid withdrawal, the tool must be wound out at the end of each pass by using the cross-slide which has subsequently to be returned to its last setting (if not forgotten!) plus the next cut - a completely unsatisfactory process to have to repeat many times.

Whilst a well-honed flat-topped tool can produce a superlative finish on M.S. it is not really suitable for anything more than fine shaving cuts. As the topslide is not used in this method it can be slewed round a little which gets its right-hand end out of the way of the tailstock when cutting small diameter threads on work between centres but if this is done the slide should be locked in order to prevent accidental movement. See article 'Topslide Locks' Vol 144 p. 506. This is the simplest, or most straightforward, method of working and the one which is probably used by the majority of model engineers.

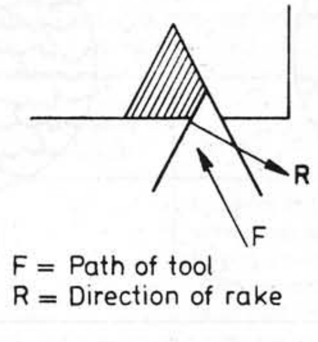


Fig. 1.

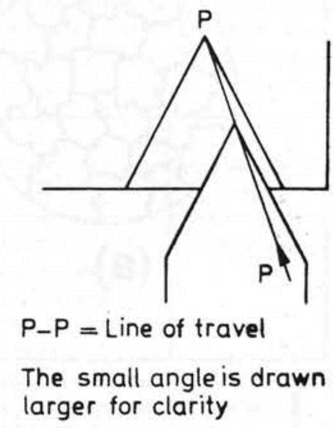


Fig. 2.

A variant of this method is one in which a cut is applied not only by the cross-slide but also by moving the tool sideways by means of the topslide. For 55 deg. and 60 deg. thread forms this sideways movement can be approximately, but not more than, one half of the in-feed. It can be claimed for this method that a small side rake can be applied to the leading edge of the tool

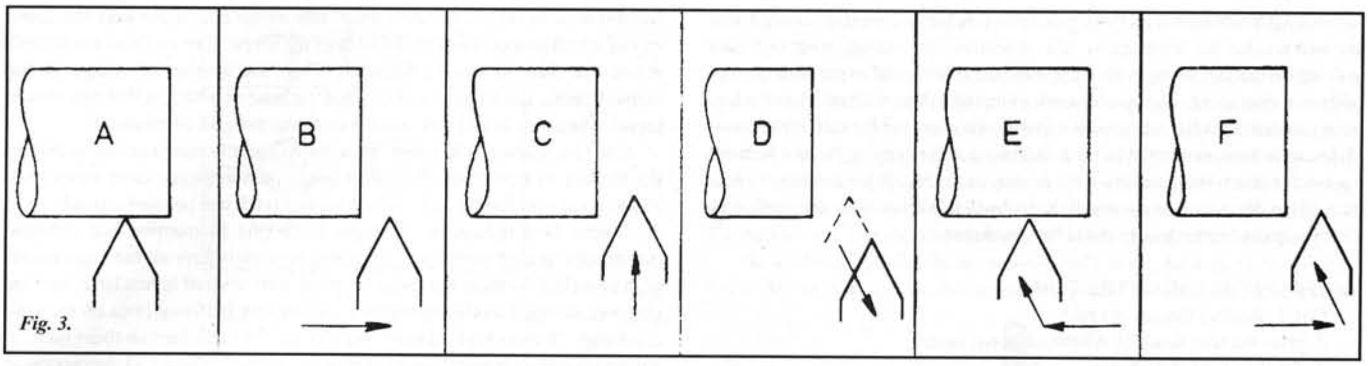


Fig. 3.

but this advantage is to some extent offset by the fact that the topslide must remain parallel to the work and cannot be moved to clear the tailstock. On the whole, not a very satisfactory method.

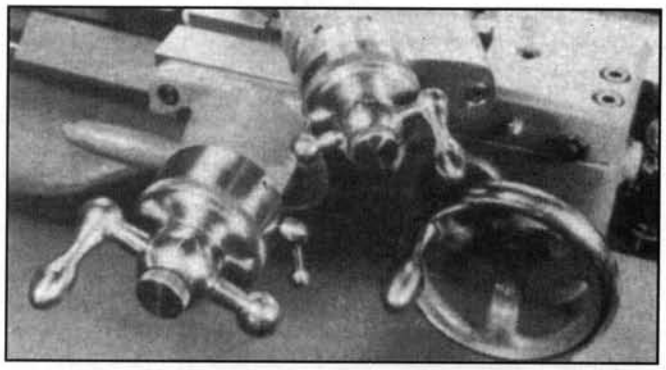
Setting over the topslide

The remaining systems are based on an oblique in-feed of the tool which is accomplished by setting the topslide round to such an angle that the tool follows down the trailing flank of the thread. See Fig. 1. The effect of this is to confine all the cutting to the leading edge of the tool which can be given a positive rake but this must not be too large for two reasons. (a), a large rake would interfere with the correct geometry of the tool resulting in a thread of incorrect form. It would be possible to correct for this by making the tool to specially calculated angles but this would involve excursions into solid geometry which is outside the scope and interest of the amateur. (b), A large positive rake at the leading edge would be accompanied by a large negative rake at the trailing edge which would not suit my own method of working. I have found that, for all usual threads, a rake of about 7 deg. is beneficial and, by calculation, the effect on the thread form is minimal. An obvious advantage of this system is that the cross-slide is not used for feeding and it can, therefore, be used as a convenient means for withdrawing and returning the tool after each cut, the slide being returned to its zero position each time and successive cuts added at the topslide so there are no figures to remember or forget.

It will probably be observed also that the amount by which the tool must be fed in by the topslide will be greater than the true depth of the thread (640/t.p.i.) and will amount to D/cos ? where D equals the true depth and ? is the angle between the topslide and the cross-slide - nominally one-half of the thread angle. This correction is regarded by many workers as a serious objection to the method though it is difficult to understand why. Reduced to its simplest it amounts to this: For a Whitworth form thread D/cos 27.5 = 1.127D which, for all practical purposes is one and one-eighth times the true depth. A Whitworth thread of 8 t.p.i. has a true depth of 640/8 = 80 thou so we must feed the tool in - using the topslide - by 1.125 x 80 = 90 thou. or .090 in. In case this is too much trouble, I am appending a table giving depths of cut for a range of pitches and useful angles which is a shortened version of one which hangs in my workshop. It will be observed that apart from the 27.5 deg. half-angle for Whitworth form threads there is also a column for 25 deg. which will require a little explanation.

Some years ago, when cutting some fine threads on drawn phosphor bronze rod, using the 27.5 deg. setting, it was noticed that the trailing flank of the finished thread was scored or abraded near the top. Careful observation during the cutting revealed that the scoring was caused during the early stages when the cuts were relatively deep and the tenacious and springy chip met, and was deflected by, the opposite flank. Owing to the setting of the slide at half the thread angle, no further cuts would be taken on the trailing flank and so the scoring remained to be seen. No harm was done but it didn't look good. The remedy was a simple one which I have used ever since, namely to set the topslide to a slightly finer angle - 25 deg. instead of 27.5 deg. - so that a small part of the cut is transferred from the leading to the trailing edge of the tool. See Fig. 2. This means that there is always a shaving cut amounting to about one-ninth of the cut on the leading edge. Another effect of the reduction of the angle by 2.5 deg. is to reduce the depth correction from one-eighth to one-tenth so that the 8 t.p.i. thread will now require a feed of 1.10 x .080 = .088 in.

It is most important to remember that all references to depth of thread assume that the work is turned to the correct diameter and that the tool being used has the correct radius - or, as I prefer, flat - on the tip. If this is not the



The geared screw topslide with large dial on Geo. Thomas's Super 7 (see M.E. 7/10/77).

case, one is lost before one starts. If the radius (flat) is too small, compensation can be made by increasing slightly the depth of the cut but nothing can be done to correct for a radius that is too large. For a Whitworth form thread the width of the tip is ⅙T where T = threads per in. The tip width of our tool for 8 t.p.i. will be 1/(6 x 8) = 1/48 = .021 in. Some useful notes on screwcutting tools and the measurement of tips will be found in the article on Worms, Vol 145 (1979) pp. 754 et seq.

The tip of a tool can be finished to a radius if desired by careful stoning and using a screw pitch gauge as the standard. In view of the remarks already made one should be very careful not to overdo this operation. The gauge should be thoroughly cleaned out to ensure that there is no dirt, grease or oil in the teeth. Hold the gauge and tool up to the light and use a glass to examine the fit. The tool should just rest in the bottom, leaving no more than a suspicion of light at the two edges but on no account should it be possible to see light at the extreme tip of the tool because this would indicate that the radius is too large.

We come now to the final method in which the tool is fed at an angle by means of the topslide but in which no compensation is consciously made for the angular path of the tool. This method was demonstrated to me well over fifty years ago by the "star" turner in a shop engaged entirely on experimental work and for which, together with the drawing office, I was responsible at that time. It is simply a matter of procedure which will be made clear by the series of diagrams illustrating the steps in setting up. The initial preparations for this method are the same as for the last one, i.e. the topslide is set round to the desired angle which can be either one half or near-half of the thread angle. The topslide is fed in a forward direction until its collar reads zero and, finally, the cross-slide is fed forwards until the tip of the tool just touches the work which can be determined, if desired, by nipping a cigarette paper. At this point the cross-slide collar is set to zero and we have the situation which is shown at (A) in Fig. 3 - the tool is touching the work and the two collars read zero.

At (B) the carriage is moved to the right so that the tool is clear of the end of the work.

(C), The cross-slide is fed forwards by an amount equal to the true depth of the thread and its collar is then set to zero again.

(D), Leaving the cross-slide untouched, withdraw the tool by means of the topslide until the tool is clear of the O/Dia. of the work. The tool will travel along an angular path as shown by the arrow on the diagram.

(E), After moving the carriage back to the left, feed the topslide forward until the tool touches the work again. This determines the starting point and after moving the carriage along to clear the work, the first cut can be put on at the topslide as shown at (F). The correct depth of thread will be reached when the topslide micrometer collar reads ZERO. During the course of the cutting the cross-slide can be used conveniently for withdrawing and returning the tool between passes, the return being made to zero reading each time. It is interesting to note that during the cutting of the thread the tool will be advanced by the topslide by D/cos without anyone having made the calculation.

NOTES ON THE USE OF THE TABLE

Col. 1. denotes threads per inch.

2. gives the true depth of Whitworth form thread.

3. Topslide feed at 27.5 deg.

4. Topslide feed at 25 deg.

5. TDI indication.

All depths are in thousandths of an inch.

Included in the table of thread depths is a column giving information on the use of the T.D.I. for all the listed threads. I know that many workers do not properly understand the working of this device and so do not obtain the full benefit from its use. The following is the key to the use of the letters 'a' to 'd':

a. Engage anywhere - 16 positions round the dial. Used only for numbers divisible by 8.

b. Engage at any whole number or any position half-way between - 8 positions. Used for numbers divisible by 4 but not by 8.

c. Engage at any whole number - 4 positions. Used for even numbers not divisible by 4.

d. Engage on any pair of opposite numbers i.e. 1 & 3 or 2 & 4 - 2 positions. Used for any odd number.

Note that it is never necessary to engage at the same point on the dial every time EXCEPT for numbers containing one half a thread e.g. 11½ t.p.i. which is used in U.S. as a pipe thread.

It is not proposed to deal in this article with the cutting of internal threads which are, admittedly, not quite so straightforward as most external work but the basic principles remain the same. Difficulties are usually due to one or more of the following: (1) Bore not correct to size. (2) Cutting tool not of the correct form. (3) Tool rubbing due to faulty clearances (very common). (4) Tool insufficiently rigid. All of these can be aggravated by the fact that it is often impossible to see what is going on.

AFTERTHOUGHTS. Too often one reads articles in which the author writes "By the way, I have omitted to mention that ...", by which time it might be too late! The following jottings, however, are in a somewhat different category and my only excuse for lumping them together at the end is that it will save retyping the whole manuscript. Much of the foregoing has been concerned with the attainment of the correct depth of thread and all the methods described are based on the use of micrometer collars on the feed-screws. Many old lathes were not so equipped and a method of working which was commonly adopted was to turn a small step on the end of the work the diameter of which was the correct core-size of the screw. The tool was fed in until it just scratched the smaller diameter. There are obvious advantages in the methods using micrometer collars - not the least of which is that one always knows where one is and how much has, at any time, to be removed.

Use of a Screw Pitch Gauge. Readers will hardly need reminding that, in the absence of a reliable screw pitch gauge (and there are some ropey ones about) a tap - preferably G.T. - of the correct pitch can be used instead.

Thread Dial Indicators. It might be helpful to mention that different makes vary in their markings. Some indicator dials have all the engagement points marked on them but those supplied with Myford lathes have the four numbers stamped on the top surface and the four half-way lines on the bevelled edge. Earlier Myford dials had only the four numbers on them but it is simple enough to engage the nut at the mid position. The 8 t.p.i. leadscrew as fitted to most popular lathes is ideal for its purpose, especially when a 2 in. base T.D.I. is used in conjunction with it - i.e. one having a 16T wheel.

This combination will readily "pick up" any number of t.p.i., odd or even, with or without a half-thread included. Lathes with metric leadscrews will be found to be much less convenient in this respect - even when cutting metric threads - largely because of the "inverted" nature of metric threads which are rationalised on the basis of pitch instead of threads per unit of length.

1	2	3	4	5
8	80	90	88	a
9	71	80	78	d
10	64	72	70	c
11	58	65.5	64	d
12	53.4	60	59	b
14	45.7	51.4	50	c
16	40	45	44	a
18	35.6	40	39	c
19	33.7	38	37	d
20	32	36	35	b
22	29	32.6	32	c
24	26.7	30	29.3	a
26	24.6	27.6	27	c
28	23	25.9	25	b
32	20	22.5	22	a
36	18	20.2	19.6	b
40	16	18	17.6	a
48	13.4	15	14.7	a
56	11.5	13	12.6	a
60	10.7	12	11.7	b
64	10	11.2	11	a

M.E. 76 279 (1937)

Tool-Makers' Buttons

By R. Hutcheson

Toolmaker's Buttons R. Hutcheson

A rather neglected subject in recent years, toolmakers' buttons are a wonderfully simple concept for really accurate setting out of hole centres in such things as crank webs. I do not know a better method for achieving the finest results without fuss.

THE secret of good tool-making - and, in fact, of all good machine work - is accurate setting-up of the work for machining, and the tool-maker aims at working by methods which are almost mathematically correct. A job which every tool-maker is repeatedly called upon to undertake is the boring of holes in determined positions, the positions of the holes being of the utmost importance. Examples of such work are the making of drilling jigs and press tools for piercing several holes at once.

There are several "standard" methods of obtaining the precise location of holes, of which the use of special jig-boring machines is the best, but a popu-

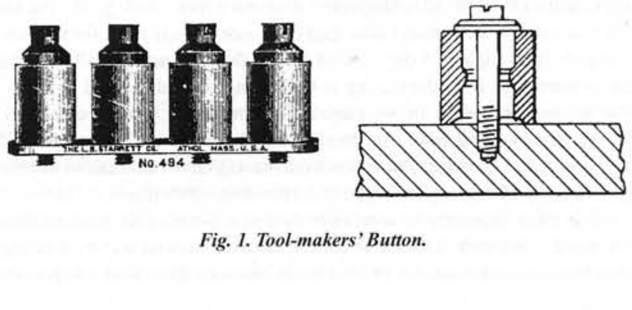


Fig. 1. Tool-makers' Button.

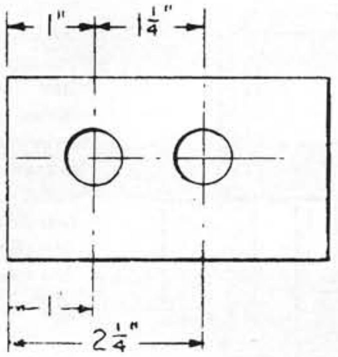


Fig. 2. An accurate hole spacing job.

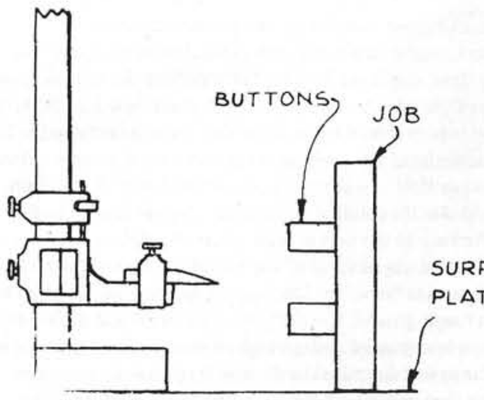


Fig. 3. Setting-up the buttons by means of the height gauge.

lar method, especially in a tool-room having but a modest equipment, is by the use of tool-makers' buttons.

A set of buttons is shown in Fig. 1. All the buttons of the set are of the same diameter, accurate as to size, and having their bottom ends perfectly square with their cylindrical sides; they are of tubular form, and can be secured temporarily to a job by means of the set-screws provided with them. It is frequently advantageous if one button of the set is longer than the others.

The system underlying the use of buttons is that they are located on the job exactly at the centres of the holes to be bored, and then the job is set up on the lathe faceplate, or on a milling machine, and each button, in turn, is centralised, removed, and a hole bored in its place.

In the button method, accuracy is necessary at two stages, namely, in the accurate location of the button on the job, and in the centralising of the button for machining.

Now, let us consider the very simple case of the plate shown in Fig. 2, which plate is to have two holes, exactly 1¼ in. apart, and one of them is to be 1 in. from one edge.

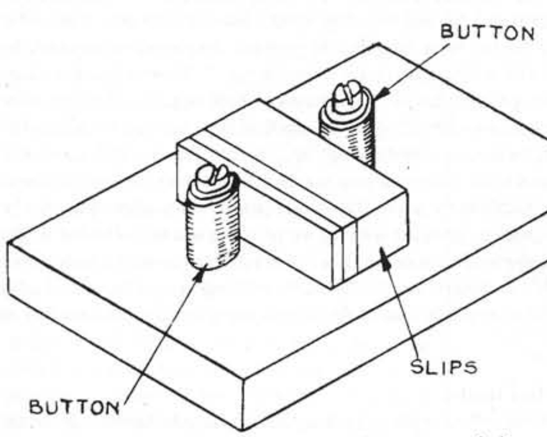


Fig. 4. Setting-up the buttons by means of slip gauge.

The first step is to mark out, in the ordinary way, the centres of the two holes, and to centre-punch, lightly, the centres so obtained. At each centre, a hole is drilled and tapped to suit the set-screws supplied with the buttons, and the burrs made by tapping are carefully removed. The writer has, usually, found it well worthwhile to countersink, slightly, the holes before tapping them, and then there is no fear of a burr protruding above the face of the job. The buttons are then secured lightly to the job by means of their screws.

The next step is to locate the buttons, and this can be done in a variety of ways. At Fig. 3, the job is shown standing on end on a surface plate, and the first button is set 1 in. from that end by the use of a vernier height gauge, which is set to a height of 1 in. + the radius of button, so that the button is in its correct position when the gauge will just touch its top. The second button can be set in exactly the same way, by setting the gauge to a height of 2¼ in. + the radius of the button; but, in this case, a square must be used, resting on the surface plate, to make sure that the buttons lie on a centre line which is square with the end of the plate.

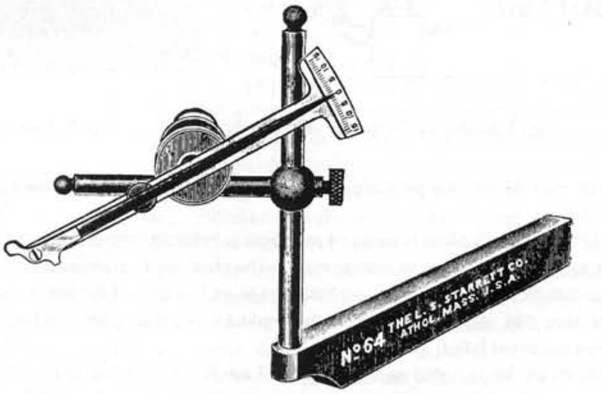


Fig. 5. The test indicator.

All that is necessary is to make certain that, when the second button is at its correct height, the blade of the square will just touch the cylindrical surfaces of both buttons. As each button is correctly located, its screw should be tightened to bind it firmly to the job, but the position of the button should be carefully checked, as buttons do tend to shift during that final tightening.

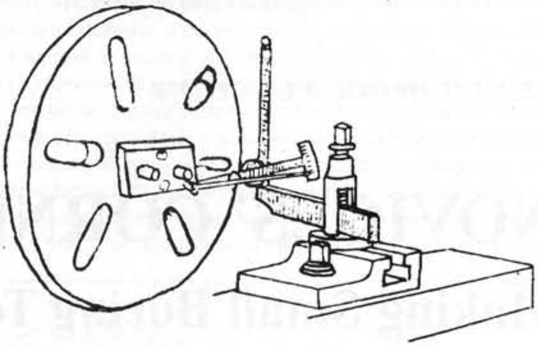


Fig. 6. Setting-up the job in the lathe.

The second button could have been set from the first, by means of blocks or slip gauges, as is shown in Fig. 4, but, generally, in order to avoid an accumulation of errors, in this class of work the centre distances of holes are not quoted, as in the upper dimensions of Fig. 2, but each hole is located from the edges of the job, or from some other fixed lines, as is shown by the lower dimensions of Fig. 2.

The setting-up in the machine is the next stage, and this may be judged by a test indicator (Fig. 5). The job may be bolted lightly to the faceplate of a lathe, and adjusted until one button is running dead true, as shown by the indicator, which is carried by the slide rest, shown in Fig. 6. When the button has been centred, the job is clamped firmly to the faceplate, and the button is removed. The small, tapped hole is opened out with a larger drill, and the hole is bored out to the correct size with the certainty that its position coincides

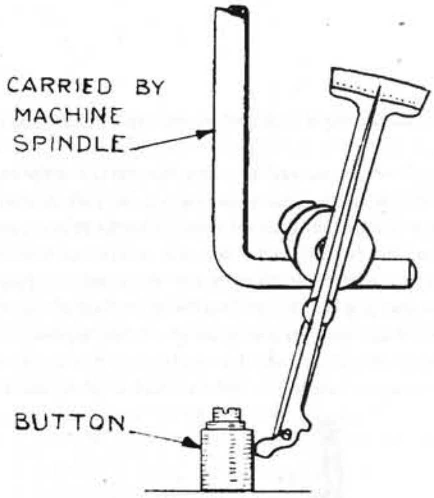


Fig. 7. Setting-up for boring on the miller.

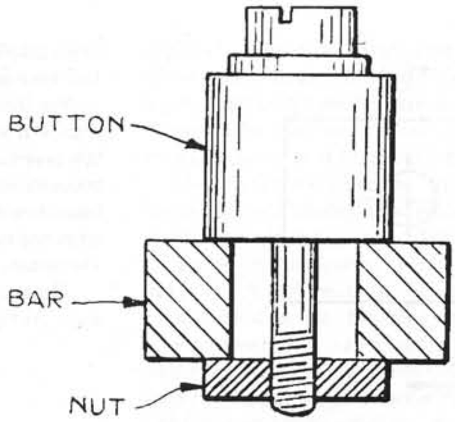


Fig. 8. Method of clamping button truly over a large clearing hole.

exactly with the position formerly occupied by the button. This is repeated for each button.

The final test for true running of each button before its removal should be done with the job rotating at cutting speed. The greatest of care must be taken to see that the faceplate is perfectly balanced at each setting of the job, as lack of balance will not be conducive to the production of truly round and accurately-positioned holes.

When the job is bored on a milling-machine, it can be bolted to the table, or to an angle-plate, according to its shape. In Fig. 7, the method of setting up on a vertical milling-machine is shown diagramatically. A bar is carried by the machine spindle, so as to rotate therewith, and acts as a support for a test indicator. The job is bolted to the table, and the table is so adjusted that, when the feeler of the indicator bears on the button, and the spindle is rotated to move the feeler round the button, there is no oscillation of the indicator pointer.

It is essential that the face of the job should be flat, or, at any rate, if it is stepped, that the steps lie in parallel planes, or the buttons will be inclined towards one another, and it will be impossible to make accurate measurements between them. The face of the job which is to receive the buttons, should be machined.

Most tool-room marking-out is done on a bright metallic surface, which must be coated in order that the scribed lines shall show up. The whitewash of the machine-shop is not used to a great extent, as it is not capable of receiving very fine lines, and it is easily rubbed or washed off. Special proprietary brands of paint, or lacquer, are used, to a certain extent. Another method is to heat the job, if of steel, to blue its surface, the coating of oxide thus formed being cut through by the scriber to give a clear-cut line. This is not always to be recommended, as even a heating to the comparatively low temperature necessary may cause warpage, and it would soften a hardened job if, for any reason, marking-out (say, for grinding) was necessary. If the job is of cast iron or steel, copper sulphate forms an ideal marking agent. Copper sulphate crystals (blue stone) are dissolved in water and the solution painted on to the surface of the job. A coating of copper is deposited on the bright surface of the job (which should be perfectly free from grease), and, if lines are scribed on the surface, the scribing point cuts into the copper deposit, to expose the iron or steel as a sharp, clearly defined line. A few drops of sulphuric acid added to the solution will ensure a copper deposit having greater powers of adherence to the iron or steel. Copper sulphate is poisonous.

A little practical application of the use of the button method is in the making of a 5 in. sine bar of the kind having its plugs pressed into holes.

The bar is rough-ground, and the holes marked off and drilled undersize. The bar is then heat-treated and ground all over, including the holes, in a manner similar to that described in the article on making sine bars.

One hole is then ground out to size, with several light finishing cuts, and one plug is pressed into it. Then, in the manner shown in Fig. 8, a large tool-makers' button is located over the other hole, so that its centre is exactly 5 in. away from the plug which is already in place, and this is most conveniently done by pressing the button against a pack of slip gauges, the length of the pack being 5 in. - (radius of plug + radius of button). The button is then set to run truly in the machine for grinding the second hole, and the hole ground to size, with several light cuts, to receive the second plug.

M.E. 105 23, 490 (1951) & 144 339 (1978)

Boring Tools Novices Workshop / George Thomas

The original article here was published anonymously in 1951, but I have also included a short part item from the pen of George Thomas, since it illustrates a tool shape that I have found extremely useful.

NOVICES' CORNER

Making Small Boring Tools

SMALL boring tools, forged from a single piece of steel, have the disadvantage that the slender shank must be made long enough to enable the cutting point to reach to the bottom of the deepest hole likely to be encountered; this means that, in the smallest sizes, these tools are apt to spring and so may give rise to inaccurate machining. If, however, the tool is made in two parts, so that the tool itself can slide in a holder, the overhang can be reduced to the minimum necessary to machine to the end of the bore, and the maximum degree of rigidity will then be obtained. The boring tools illustrated have this form of construction; that is to say, the tool itself, or cutter bar, is made from a length of round silver-steel, and the holder is machined from a piece of square bar. As this holder is split on one side, the complete tool will be securely held when clamped in the lathe toolpost.

The Cutter Bar

The first operation is to bend one end of the rod to form a right-angle. For this purpose, the steel is slowly and evenly heated to a cherry red, so that when the rod is gripped in the vice or hammered on an anvil, it can easily be set to shape.

Nevertheless, working the metal after it has cooled must be avoided, or cracks may form and the tool will then break when put into use. Next, after the end of the rod has been cut off to the required length with a hacksaw, the tip is formed with a file to the shape shown in Fig. 2. When filing the clearance below the cutting edge, the tool should be tried against a drill gauge by selecting the hole corresponding to the smallest bore the tool is required to machine; this method is illustrated in Fig. 3A, and the finished tip should appear as shown in the accompanying Fig. 3B. There is no need, at this stage, to file the tip exactly to the angles specified, for the cutting edges will later be accurately finished by grinding with the aid of an angular rest. But before the tip is ground, the tool must be hardened and tempered in the manner previously described in these notes; furthermore, grinding is best postponed until the tool can be more easily held at the correct angle by being mounted in its own holder.

Making the Tool Holder

As these tools will generally be held in place on the lathe top-slide by means of the toolpost clamp-plate, the holder is accordingly made $2\frac{1}{4}$ in. in length in all sizes. For tools with shanks up to $\frac{1}{4}$ in. in diameter, the holder is machined

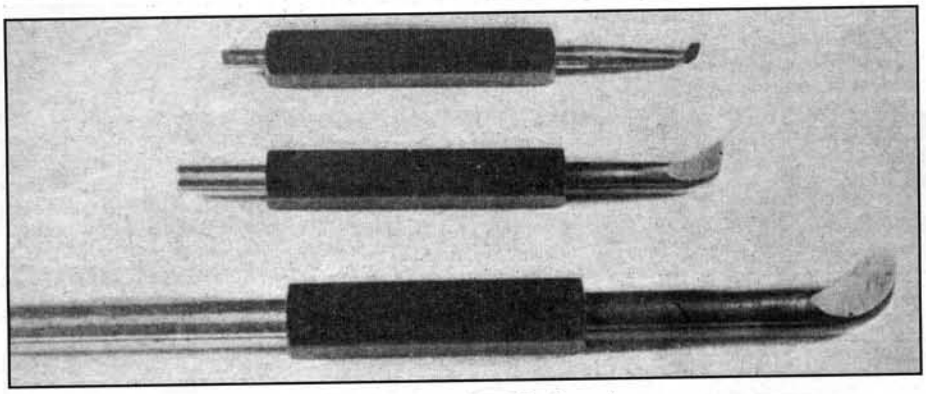


Fig. 1. Three sizes of small boring tools.

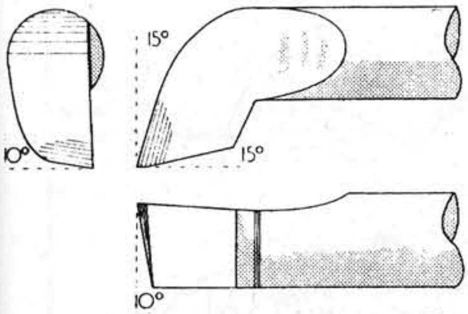


Fig. 2. Showing the form of the tool tip.

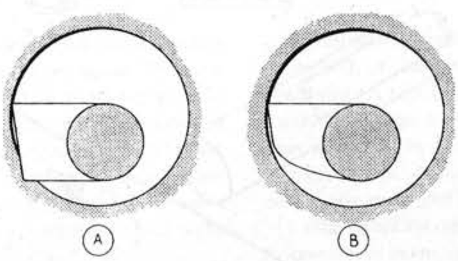


Fig. 3. Forming the working clearance.

from ⅜ in. square mild-steel, but larger tools will require a square holder of ½ in. diameter or more. After the material has been cut to length, the square bar is mounted to run truly in the four-jaw chuck by using the dial test indicator mounted either on the lathe bed or in the toolpost. If the square material is accurately formed, the easiest way of centring the work is to apply the test indicator to each corner in turn, and to adjust the chuck setting until a uniform reading is obtained.

Where the centring is carried out with reference to flat faces of the bar, the indicator should be mounted at exactly lathe centre height, and the lowest reading of the indicator is taken on each face as the mandrel is rocked to and fro. Other ways of setting the work to take readings with the indicator are: by bringing a try-square, resting on the lathe bed, against each face in turn: by using a distance-piece to locate the four chuck jaws from the lathe bed: or by indexing the mandrel setting with some simple form of dividing gear. When the work has been set truly in the chuck, the end of the bar is faced with a knife tool. Next, a centre drill is entered in the work and, if a ⅛ in. diameter centre drill is fed in for some distance, the ⅛ in. diameter pilot drill that follows will automatically be given a true start. For drilling quickly and accurately right through the bar, this pilot drill should be run at the highest mandrel speed, but the drill must be withdrawn at frequent intervals to clear the accumulated chips from the flutes and, at the same time, to give a fresh supply of cutting oil. The small pilot drill is best followed by a ¼ in. diameter drill when machining the holder to take a ⅜ in. diameter tool. Finally, the work is drilled with a reaming-size drill, but only a very small amount of metal should be left for the reamer to remove, otherwise bell-mouthing of the bore may result. After the bore has been reamed to size, a cut is made with a hacksaw through one side face of the holder, as shown in Fig. 4; this is, of course, to allow the holder to contract and grip the tool when clamped in position.

It will be found easier to keep the saw cut straight if the work is first accurately marked-out with two parallel lines to indicate the path of the saw blade. Where the bore for the tool is small as compared with the diameter of the holder, the saw cut may be continued for a short distance into the opposite side, in order to allow the holder to close more easily on the tool.

Finally, to finish the cutting edges, the tool is placed in its holder and a toolmaker's clamp is applied to the holder to secure the tool in place. This will enable the tool to be more easily handled for accurately grinding the cutting edges, with the aid of the angular grinding-rest set to the appropriate angles. As represented in Fig. 5, when mounting the tool in the lathe, the toolpost clamp-plate must be set so that it bears on the holder along the edge immediately over the slit formed in the side face of the bar.

Boring Bar

The small boring bar illustrated in Fig. 6 is shown mounted in a square holder for clamping in the lathe toolpost, but the bar, when removed from its holder, can also be gripped in a chuck carried on the lathe mandrel nose. Where the tool is mounted on the lathe saddle, a component held in the chuck can readily be bored to any required diameter with the aid of the cross-slide index, and whether the bore is formed parallel or tapered will depend on the setting of the lathe slides. If, however, the bar is mounted in the lathe chuck, and the work is attached to the lathe saddle, the diameter of the bore then machined is regulated either by adjusting the setting of the cutter in the bar or, within limits, by altering the setting of the four-jaw chuck. In any event, a bar of this kind is apt to spring and so cause inaccurate machining if mounted with too much overhang.

The other type of boring bar in common use, shown in Fig. 7 is centred at both ends so that it can be mounted between the lathe centres and driven by a carrier from a dog attached to the lathe catch plate. Clearly, if the bar is of sturdy construction, there will be little possibility of the tool springing when rigidly supported in this manner. The work-piece, a cylinder casting, maybe, is clamped to the boring table of the lathe saddle, and the boring bar will then machine a truly parallel bore in the component; moreover, the axis of the bore will be parallel with the guides of the lathe bed.

To regulate the diameter of the bore formed, the position of the cutter-bit in the bar is adjusted as required, and various methods of making this adjustment have been devised. If the cutter is secured with a wedge, there is always the danger that the setting will be upset as the wedge is tightened, or the tool may shift when actually cutting. These difficulties can usually be overcome by using a clamping-screw to hold the cutter, and fitting a second screw to move the cutter forward; this adjusting-screw will also serve to keep the cutter from moving back away from the work under the pressure of the cut.

As one of the great advantages of the boring bar mounted between

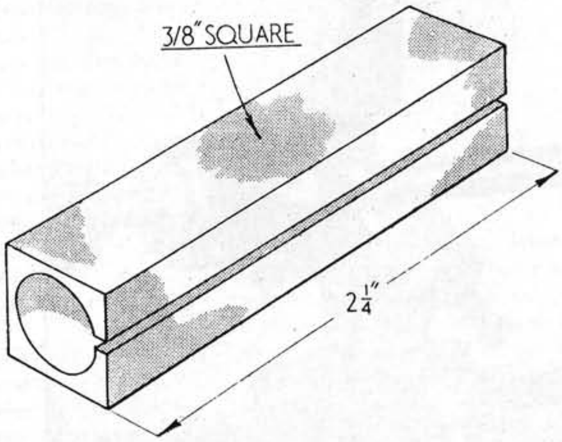


Fig. 4. The tool holder.

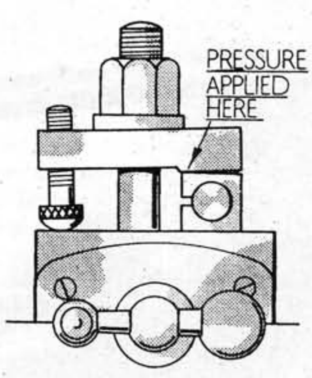


Fig. 5. Method of clamping the tool in the lathe.

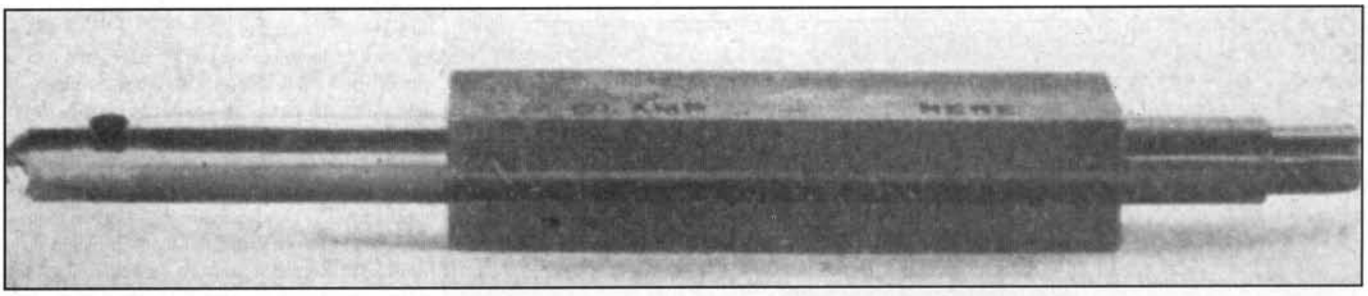


Fig. 6. A small boring bar with its holder.

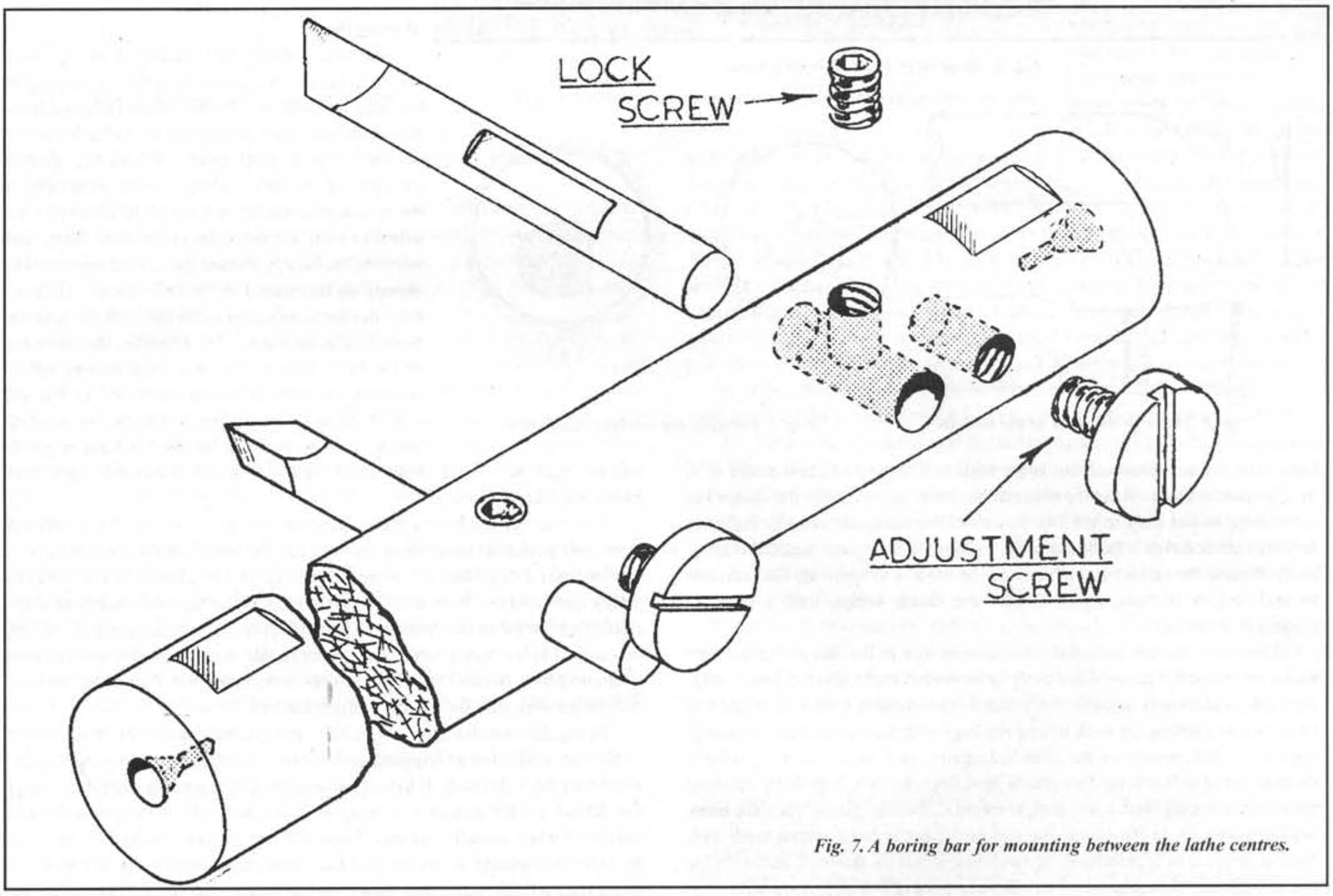


Fig. 7. A boring bar for mounting between the lathe centres.

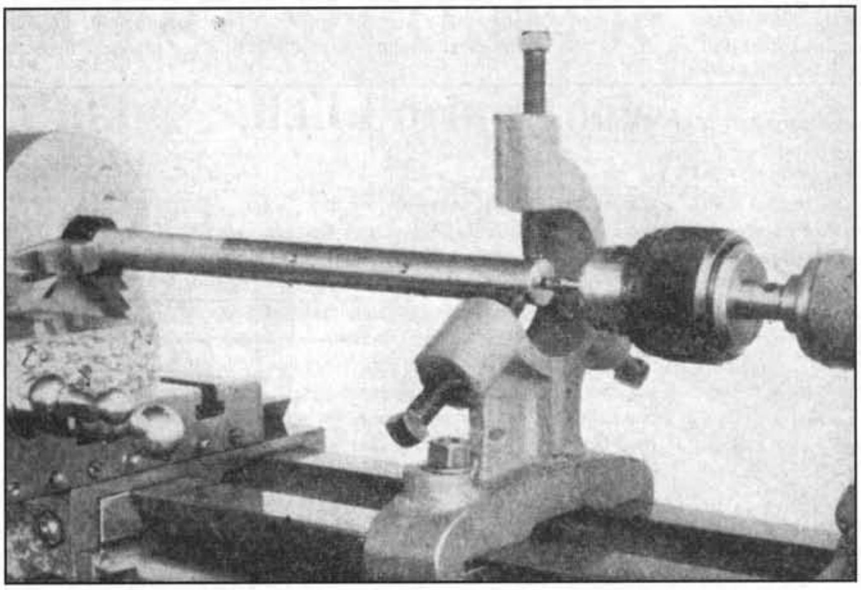


Fig. 8. Using the fixed steady when centre-drilling the ends of the bar.

centres is its rigidity, this must not be sacrificed by making the bar too slender. That is to say, if a lengthy bar is used, the diameter should be increased accordingly; moreover, if the bar is intended for machining a bore of small diameter, the length should be kept as short as possible in order to maintain rigidity.

The boring bar illustrated has a diameter of ¾ in. and a length of 9 in. with these proportions, the tool has been found capable of doing quite heavy but accurate machining.

When making a slender boring bar, the weakening effect of the drill holes for mounting the cutter should be taken into account.

Making the Boring Bar

The construction of small boring bars and their holders for use in the lathe toolpost has already been dealt with in these articles, and the making of a boring bar for mounting between the lathe centres will now be described.

As already stated, a bar ¾ in. in diameter and some 9 in. in length will be found sufficiently rigid for all ordinary work, and if the size of the bar is reduced for any special purpose, these proportions are best adhered to.

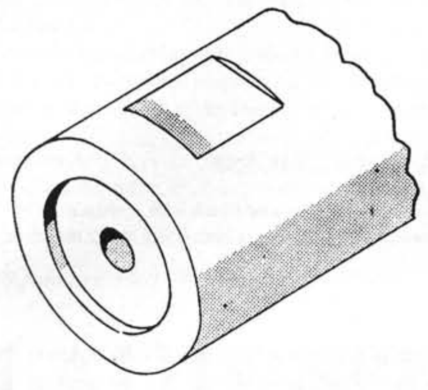


Fig. 9. Showing the recessed end of the bar and the driving flat.

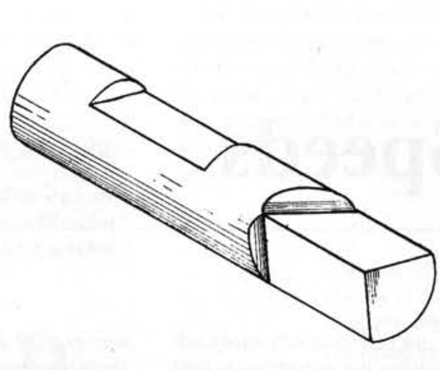


Fig. 10. A round cutter-bit for use in the boring bar.

After a straight length of mild-steel rod has been selected, the next step is to machine a centre at either end to engage with the lathe centres. To enable the bar centres to be machined accurately in line, the rod is gripped close to one end in the chuck, as illustrated in Fig. 8, and the other end is supported in the fixed steady clamped to the lathe bed. The overhanging end is next faced, and then deeply drilled with a centre drill. To finish the centre so as to protect it from accidental damage, the centre of the bar is recessed as shown in Fig. 9. The work can now be reversed, and the other centre machined in the same way.

In addition, it is advisable to turn that portion of the bar where the cutter is to be fitted, as this will facilitate the accurate adjustment of the cutter itself when the bar is in use.

To afford a secure seating for the lathe carrier used to drive the bar, a flat, or a shallow drill-hole, should be formed on both ends of the bar, so that if required, the tool can be reversed and driven from the opposite end. Before cross-drilling the bar for the cutters and their fixing screws, the question of whether to fit round or square tools must be decided, for high-speed steel cutter-bits of either form are obtainable from the tool-merchant. However, round silver-steel will serve well for making these tools, and, when this material is used, the cutter can easily be filed to shape before being hardened and tempered.

The round cutter shown in Fig. 10 is easily fitted, as the mounting hole in the bar can be accurately reamed to size, but a square hole for the other type of cutter is not so readily formed by filing. The tool illustrated has both side and end clearance, and the amount of cutting rake given will, of course, depend on whether brass, steel or cast-iron are being machined. A rake of 15 deg. to 20 deg. will be found suitable for steel, and rather less for cast-iron, but if a rake angle of about 5 deg. is exceeded, the tool may tend to dig in when machining brass.

The rake is, of course, formed on the upper surface of the tool and lies at an oblique angle with line of the tool's travel.

When marking-out the bar for the position of the cutter, it is a good plan to provide for mounting two cutters, as this arrangement will at times be found useful when machining the two end portions of a lengthy component; moreover, an alternative position for mounting a single cutter may also be required.

The holes to receive the cutters and their fixing-screws can be accurately drilled by using the small cross-drilling jig described in a previous article.

Boring Tools

by George Thomas

The notes on boring tools have been very popular and there have been a few requests for more information regarding the proportions and dimensions of the integral boring tools which are used in the small holder, p. 168 (3, 4 and 5). There is a fair amount of latitude possible in the dimensions of these and it was suggested that a stock of blanks be prepared which would cover all normal work and leave very special cases to be dealt with as they arise. The essential dimensions are indicated in Fig. 2 (1) and the following notes should give all the guidance that is necessary; other details have already been given.

1. The diameter of the shank "D" is of no importance apart from the fact that it determines the maximum width of the head "W" and must, of course, be of a standard size for which a collet is available, say $3/16$ in. or $1/4$ in.

2. The head "W" can be up to about three-quarters of the starting size of the hole to be bored. It could be smaller at the expense of stiffness. For example, a full-size head, $3/16$ in. wide, on a $3/16$ in. shank can be used to bore out a hole starting from a minimum of $7/32$ in. to $1/4$ in. diameter.

3. Neck "d" is normally from .7 to .8 W. The larger it is made, the stiffer the tool but the shorter its useful life because there will be less material for subsequent re-sharpening, but this is a minor consideration as it will be found that these tools last for a very long time.

4. Length "L". For short holes use a short tool. Try not to use a tool longer than is necessary, so make a few at different lengths.

5. The above remarks all apply in particular to boring tools, but tools for screw-cutting and recessing might need to have a greater difference between "W" and "d" - in other words, the neck might have to be made smaller, say $2/3$ "W" or less, depending upon the depth of the thread or recess.

Since a back-stop was fitted to my retracting top-slide which enables it to be used for cutting internal threads by turning the tool upside-down and feeding into the back of the bore it has become obvious that the same procedure could be adopted for boring. Fig. 2 (2) is a diagram showing a boring tool in a hole; all proportions being as outlined above. If the diagram be turned upside-down it will be clear that the space for chips at the bottom of the hole is now increased and there is the added bonus that increased cuts are additive on the dial instead of being subtractive. This should be of help to those people who say that they are no good at mental arithmetic!

Admittedly, small holes are usually bored at fairly high speeds so that the chips don't settle down comfortably at the bottom of the bore but, on the whole, they do tend to collect there more than at the top.

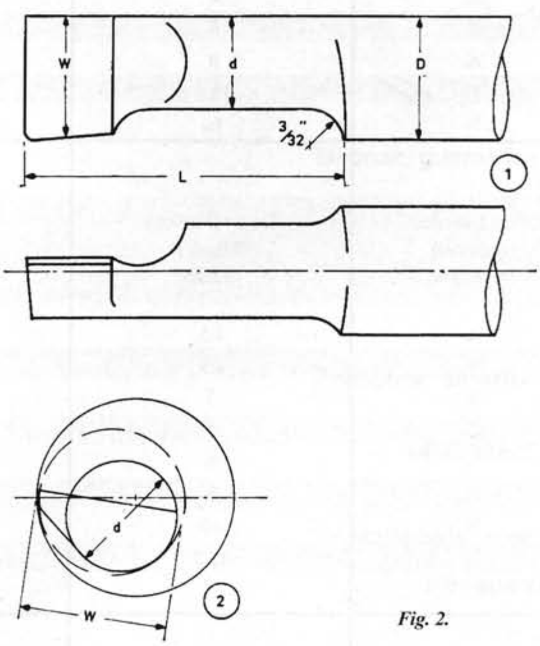


Fig. 2.

Cutter Speeds

Speed and Feeds J.A. Logue / Stan Bray

We start off with a useful nomogram and finish with a simple set of tables. How often I have seen the wrong speeds being used; this does nothing for tool life!

No matter what type of cutter is in use, the correct spindle speed will be the ultimate test as to finish, assuming that everything is held rigidly in place.

Cutting speed depends on the metal being cut as well as the diameter of a HSS cutter. There can also be some variation in speed according to the type of cutter in use. One of the first things an engineering apprentice learns is to work out the correct rotational speed. He will carry the formula with him for the rest of his life. For the model engineer it is a different kettle of fish. Firstly, more often than not, the model engineer's machine is nowhere near as rigid as the large industrial machines bolted onto concrete floors. For this reason speeds must be somewhat slower. Also the range of speeds available on the home machine is possibly not as great as those in industry. The other deciding factor is the best cutting speed of the material being machined. Every material has its own best cutting speed, which the manufacturer can supply. It is doubtful whether the model engineer will have access to the cutting speed of the metal he uses. It becomes obvious then that compromises will need to be made and, for that reason, I do not propose to give the formula for working out spindle speeds. Instead I am including

End Mills

Cutter Diameter (Imperial) in inches	Cutter Diameter (Metric) in mm	Spindle Speed in rpm for Cast Iron/Bronze	Spindle Speed in rpm for Mild Steel	Spindle Speed in rpm for Brass/Aluminium
3/32	2.5	2,500	4,000	7,000
1/8	3	2,000	3,000	6,000
3/16	4	1,000	2,000	5,000
1/4	6	950	1,640	3,750
5/16	8	750	1,000	2,500
1/2	12.5	450	750	2,000
5/8	16	350	600	1,500

Slot Drills

Cutter Diameter (Imperial) in inches	Cutter Diameter (Metric) in mm	Spindle Speed in rpm for Cast Iron/Bronze	Spindle Speed in rpm for Mild Steel	Spindle Speed in rpm for Brass/Aluminium
1/16	1.5	4,000	6,000	10,000
3/32	2.5	2,500	4,000	8,000
1/8	3	2,000	3,000	7,000
3/16	4	1,200	2,000	6,000
1/4	6	1,000	1,500	4,000
5/16	8	800	1,200	3,000
3/8	10	700	1,000	2,250
1/2	12.5	500	750	2,000
5/8	16	400	650	1,750

Fly Cutters

Cutter Diameter (Imperial) in inches	Cutter Diameter (Metric) in mm	Spindle Speed in rpm for Cast Iron/Bronze	Spindle Speed in rpm for Mild Steel	Spindle Speed in rpm for Brass/Aluminium
1	25	120	150	225
1½	35	80	100	150
2	50	60	80	120
2½	60	50	60	100
3	75	40	50	80

a chart of suggested speeds. These are only a guide, and they will suit some but not others.

Anyway the machine speeds shown, possibly, may not be available. In this case take the nearest lower speed. If chatter occurs go down one more. Do not be tempted, whatever happens, to go above the speeds given.

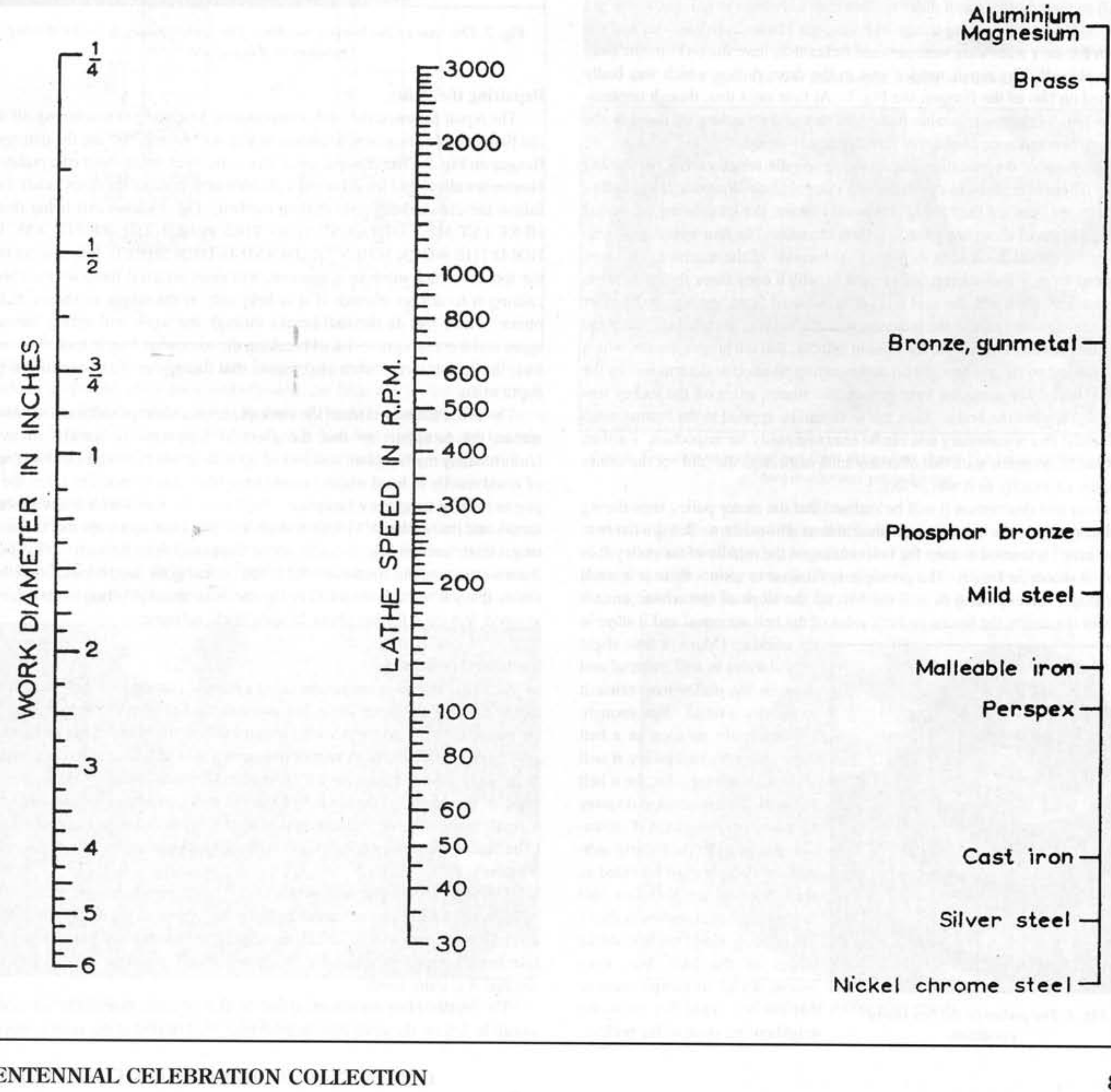
Cutter Feeds

Feeding the cutter involves another important calculation for the professional engineer. He has a power driven feed however. Most model engineers will have only hand feed. This need not be too much of a problem, as, if things feel right when feeding the cutter, it is right and leave it at that. If chatter occurs speed up a little but don't overdo it. It is surprising how brittle milling cutters can be when too fast a feed is used. Remember that too slow a speed or feed is as bad as one that is too high. The only difference is that there is more tolerance down the scale than there is up. So somewhere a happy medium will have to be found.

19 January, 1961

LATHE SPEED CALCULATOR

Cut out and hung on the workshop wall, it will be a lasting boon for which many ME readers will be grateful to J.A. LOGUE of Clondalkin



M.E. 156 160 (1986)

Trepanning Tubal Cain

Done the wrong way this is the best recipe foa a tool "dig-in" that I know, but Tom Walshaw sorts out the problem clearly.

TREPANNING

A repair completed and a workshop technique described

by Tubal Cain

TREPANNING - parting-off on the face of the work - is seldom mentioned in these pages so, having just undertaken a repair job which involved this process, I thought that a description might be of interest. The work arose from the recent acquisition of a very old Honing Machine. I already had such equipment, some home-made and two Delapena honing mandrels, but their use involved messing up either the lathe or the drilling machine with honing fluid and (worse) abrasive mud. The machine was of the bench-mounted type which older readers may have seen in garages in the old days. Used for honing out things like king-pin bushes, valve-guides and the like in the days when cars were repaired rather than have the bits thrown away and replaced! The repair needed was to the drive pulley, which was badly chipped on two of the flanges, see Fig. 1. At first sight this, though unpleasant to look at, is a serviceable pulley, but an understanding of the way the machine worked soon shows that this damage is serious.

The basis of the machine is a revolving spindle which carries the honing arbor. There is means - in the shape of a control knob alongside the spindle - whereby the "cut" of the honing stones may be set, the knob being calibrated with divisions of about one tenth of a thou increase. The four-speed drive pulleys are at the back, as seen in Fig. 2. At the side of the machine is a lever, operated from a foot-stirrup, movement of which does three things at once. On pressing down with the foot a brake is removed from bearing on the inner flange of the large pulley; the jockey seen at the right of the photo tightens the belt, thus starting the drive to the honing spindle; and the honing stones, which are retracted so far, are brought up to the cutting position as determined by the control knob. Releasing the lever retracts the stones, eases off the jockey tension, and applies the brake. Thus the work can be applied to the honing mandrel whilst this is stationary and can be removed easily for inspection. Further, the control system is such that after any such inspection the "cut" of the stones remains set exactly as it was before.

From this description it will be realised that the motor pulley slips during the idle periods - the belt tension is then almost non-existent. Being a flat belt, "crowning" is needed to keep the belt running in the middle of the pulley face - this is shown in Fig. 3. The principle is familiar to most - there is a small centrifugal force tending to pull the belt up the slope of the crown; once it reaches the centre the forces on both sides of the belt are equal and it stays in the middle. (More or less; slight irregularities in belt material and wear on the pulley may cause it to wander a little). Fair enough. Unfortunately, as soon as a belt slips on a crowned pulley it will slide off the edge. So, for a belt liable to slip it is usual to do away with any crowning. Or, if crowning is essential, then fairly substantial flanges must be fitted as well. You will see, therefore, that the ragged edges shown in Fig. 1 are not only likely to chew up the edges of the belt, but, even worse, act as an escape route so that the belt could flop on to the neighbouring cone of the pulley.

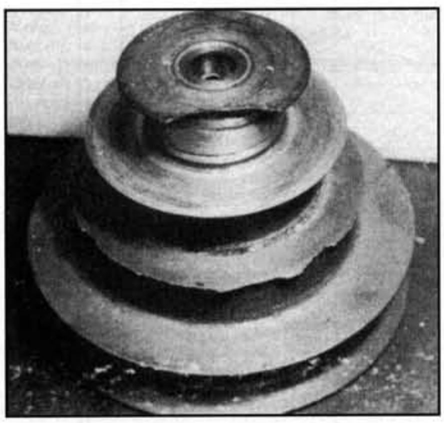


Fig. 1. The pulley in the "as found" condition.

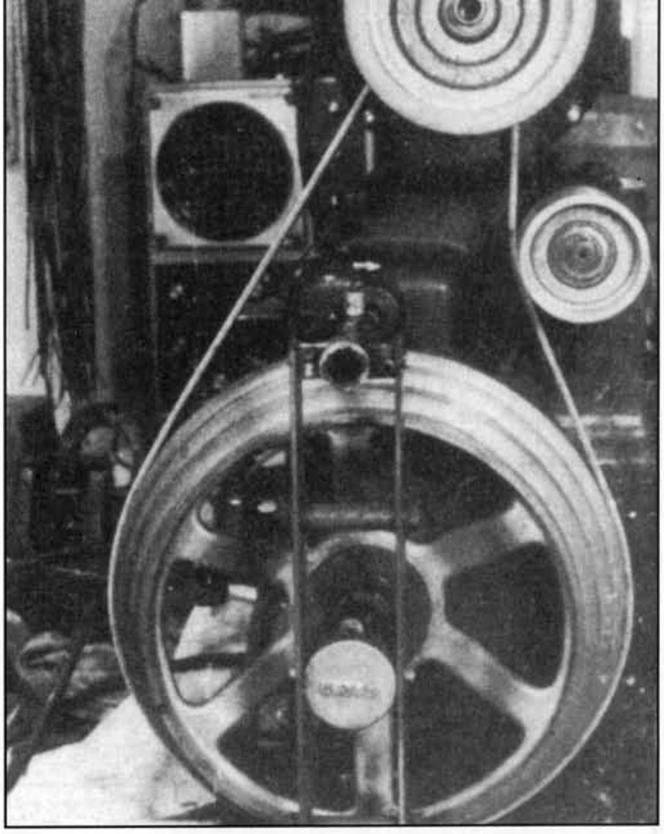


Fig. 2. The rear of the honing machine. The jockey pulley is in the driving position in this picture.

Repairing the Pulley

The repair followed the fairly conventional procedure of machining off the old flanges and fitting new, as shown in Fig. 4 - "A" and "B" are the damaged flanges on Fig. 3. The material used was 1/16 in. thick brass sheet (the pulley is aluminium alloy) and for economy I decided to trepan out the discs rather than follow the classical multiple drilling method. Fig. 5 shows this being done. HERE LET ME EMPHASISE THAT THIS IS NOT THE RIGHT WAY TO HOLD THE WORK WHEN TREPANNING THIN SHEET. It is evident that the tool, of which more in a moment, will exert an axial force on the sheet, causing it to deflect inwards if it is held only at the edges as shown in the photo. Then, just as the tool breaks through the work will spring forward again and there is a grave risk of breaking the somewhat fragile tool. Not only that; the spring in the work also means that there is no firm control on the depth of cut.

The PROPER way is to set the work-piece on a sheet of soft metal or wood set on the faceplate, so that the sheet is supported uniformly all over. Unfortunately my faceplate was locked up with another job and I had no piece of wood readily to hand which I might have been able to machine up in the 4-jaw to make a temporary faceplate. So, I took the risk - with a few precautions - and (to be blunt) "Got away with it!" But I had to accept that the outer ring, clearly seen in Fig. 5, could not be trepanned right through. What I did there was to take the cut down until I "felt" it had gone deep enough, and then finish the job with saw and file; the cut was about 40 thou deep when I stopped, leaving a feather about 25 thou thick, no more.

Tools for Trepanning

As to the tool, you can trepan using a normal parting tool, provided that it has a fair front clearance angle, but you will have to take successive cuts side by side so that the groove is wide enough to allow the blade to penetrate without fouling on the side. A proper trepanning tool will have the shape shown at "a" in Fig. 6. Indeed, I have a set intended for trepanning out deep cores in ivory or machined on the blade to a curved form, each tool corresponding to a small range of groove diameters! Far too expensive to make these days! (The blades are about an inch deep vertically and can cut to a depth of about 3 inches).

The tool I use is shaped as in Fig. 6 "b", with zero clearance on the inner edge, but sufficient on the outside to clear the groove. It is, in fact, made from an ordinary parting tool. The cutting edge is that normal to a parting tool - no rake brass or iron, and just a little for steel. Fig. 7 is a close-up, and you will see that it is quite small.

The square plate was marked out so that a small machining allowance would be left on the discs after trepanning. This started at the centre, leaving

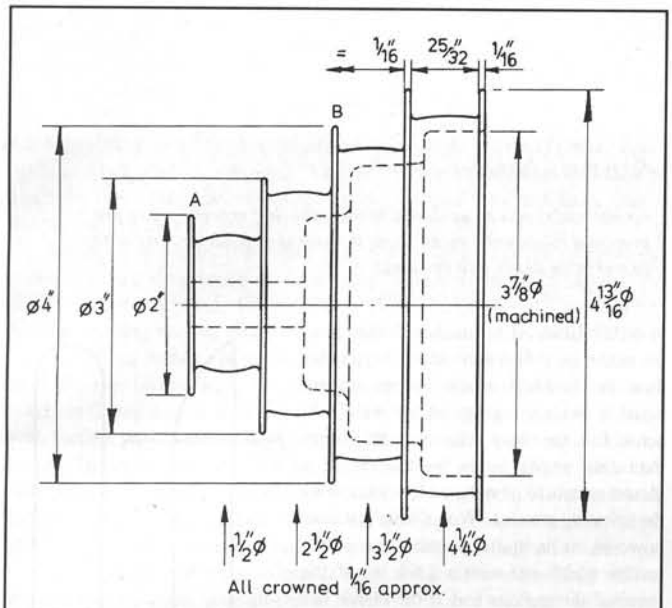


Fig. 3.

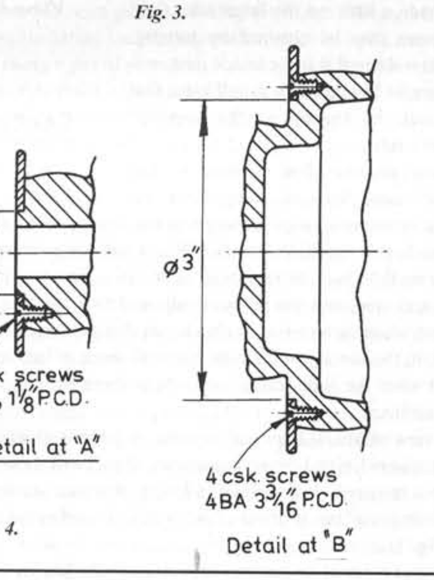


Fig. 4.

a disc only ¼ in. dia. as waste (but "kept in case it comes in useful!") and working outwards. As I have already said, the final cut on the outside was taken only a little beyond half-way through the metal. The discs can be seen in Fig. 8, and you will note the feather edges left on breaking through - entirely due to the spring in the sheet.

Machining the Discs

The discs were machined on the periphery just to clean up, and then bored to size as shown in Fig. 4. The pulley was then machined to suit, held in the 4-jaw with the jaws on the inside - fortunately the larger cavity was machined true, which made things easier. The discs were then attached with countersunk screws with a dose of Loctite on the faces as well, after which the periphery of the two discs was trued up to size also. It was at this stage that I found that at some time the pulley bore had been somewhat crudely rebushed, so this was trued up and a new bush fitted. Fig. 9 shows the finished pulley.

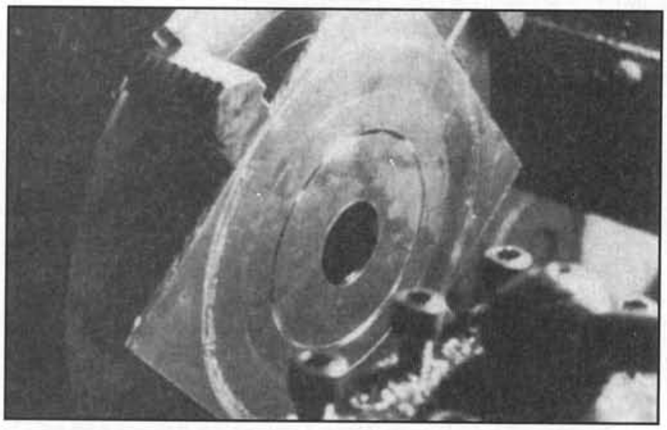


Fig. 5. The trepanning operation in progress. See text regarding the use of the four jaw chuck for this operation.

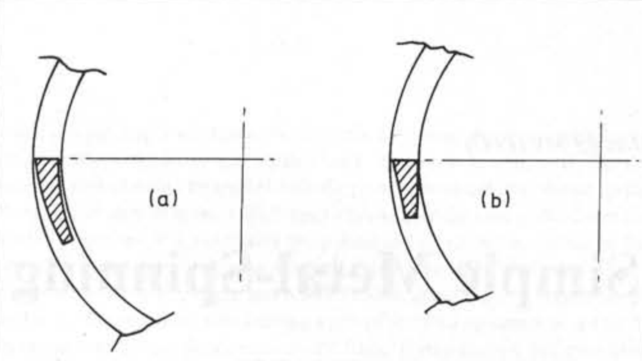


Fig. 6.

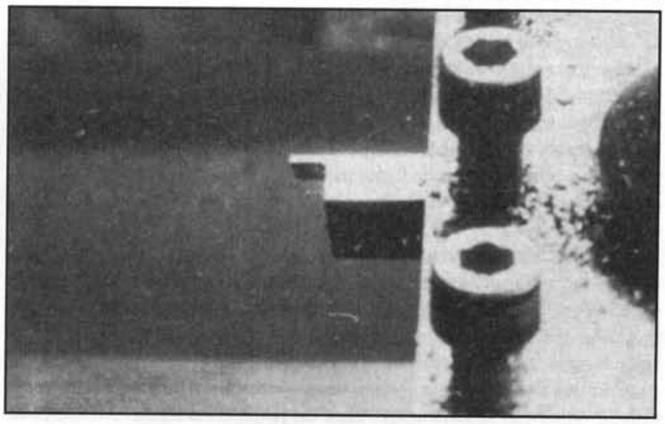


Fig. 7. The tool used in fig. 5, seen in close-up.

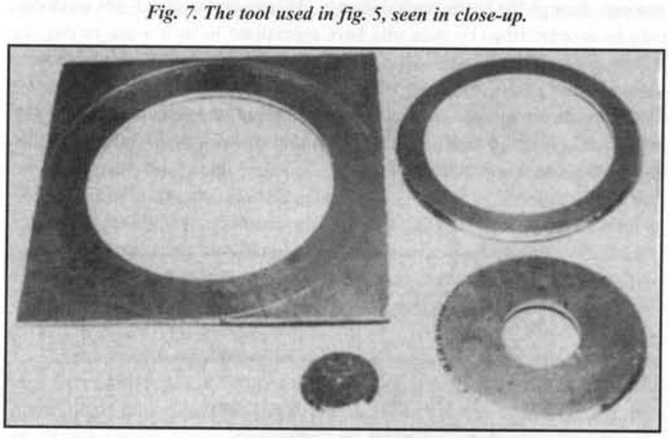


Fig. 8. The discs trepanned out from the parent sheet. The final outline of the larger disc has yet to be cut.

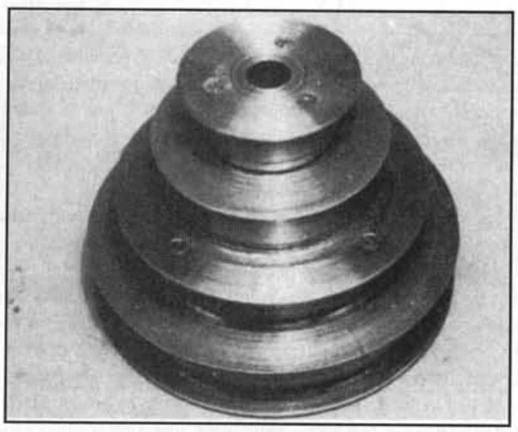


Fig. 9. The pulley after repair.

M.E. 89 349 (1943)

Simple Metal-Spinning

Spinning Turner

Great results can be achieved by the spinning process if you are prepared to obey the rules. Here is some sound advice, one of the few articles devoted to the topic.

By "TURNER"

IN the few articles which I have contributed to The Model Engineer, it has been my aim to describe the more unusual jobs which the professional turner may be expected to tackle in the usual run in any average general workshop. Most of these, although not generally included under the heading of turning are passed over to the long-suffering turner, firstly, because it has become a sort of habit, and, secondly, because there are really very few jobs which cannot be accomplished with the aid of "the king of tools". Such jobs as the straightening of bent shafts, or planing of small keyways and oilways, may be included.

In addition, a number of metal-spinning jobs may be encountered, and those of the more simple types, such as dust-caps, lids and such like, are to be expected. Of course, complicated spinning work must be undertaken by the professional metal-spinner, as, in its higher branches, this is a very highly skilled trade. Vase and bottle-shaped objects are often spun from metal discs, entailing the use of complicated sectional formers (or "chucks" as they are called), which may be dismantled when the job is finished, and withdrawn in sections through the bottle-neck opening. As may be imagined, this work can only be accomplished by men who have specialised in such work, calling, as it does, not only for a knowledge of the technique of "chucks", but also for a close acquaintance with the ductility of the metals used.

However, simple spinning may be undertaken with success both by the professional and the amateur turner, provided that a little knowledge of the tools and method is acquired.

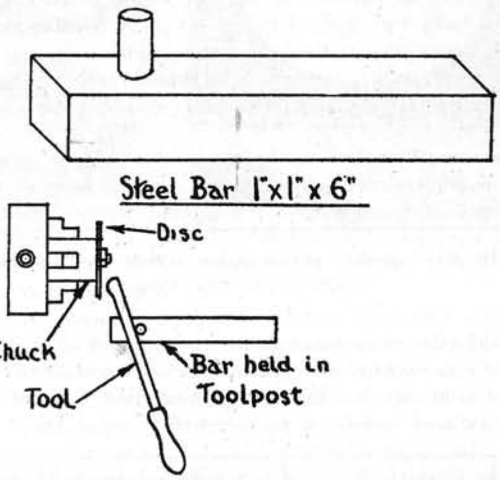


Fig. 1.

Metal-spinning lathes are usually of the "plain" type, without compound slide-rests, in fact, the carriage often consists of a plain fitting which may be moved by hand, along the lathe bed and clamped into the desired position. Tools are operated by hand, and not clamped in a toolpost; this latter being a plain, steel tool-rest having a series of holes, into which a steel pin is placed in a vertical position, and against which the tool is levered against the work. The tools are of hard steel, such as nickel-chrome or chrome-vanadium, and are provided with wooden handles. In many cases the complete tool is three or four feet long, and the operator obtains leverage by placing the butt of the handle beneath the right armpit, thus using the weight of the body. However, work requiring such tools is beyond the scope of the home worker and I will confine my remarks to such appliances as we may find necessary.

As is generally known metal is spun over wooden or metal formers, which have been turned to the desired shape of the article to be produced. The making of simple formers or "chucks" entails only ordinary turning methods, but it must be remembered that the thickness of the material must be allowed for when it is desired that the outside sizes of the finished article must conform to certain limits. The chuck will, therefore, be made to a diameter which is smaller than the finished article by an amount equal to twice the gauge of the metal. In actual fact, the chuck will be slightly larger than this would imply, as the metal is almost certain to be reduced in thickness by the spinning process. With a little practice, however, it is quite possible to obtain results which are within 1/64 in. of the required dimensions and if the chuck has been made a little on the large side, final dimensions may be obtained by turning. When it is desired that the inside measurements are to be correct, it is sufficient that the chuck be turned to the required measurements.

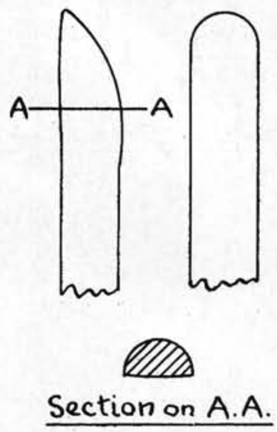


Fig. 2.

Many amateurs find it easier to spin metal by using the tool clamped into the toolpost in the usual way, feeding it in the desired directions by means of the cross-slide and top-slide screws. Whilst sufficing for many jobs, the hand turning method is to be preferred, in so far as one can then "feel" the metal under operation, and the pressure adjusted to a nicety. This is particularly apparent when using wooden chucks, as there is a danger of depressing the metal into the chuck, owing to the entire absence of feel between the hand and the job when the slide-rest is used. Also, there is danger of a tear-up in the metal surfaces.

In view of this, it is as well to make up a tool-rest which may be clamped in the tool-holder, and the accompanying sketch will show what a simple component is required. It consists of a length of square section steel into which a tight-fitting steel pin is driven. The sketch also gives the method of using the rest (Fig. 1).

Several types of tools are used professionally, but for our purpose only one is required. This follows closely the design of the most usual professional tool. It consists of a length of cast-steel or tool-steel of about ⅜ in. in diameter and some 8 or 9 in. long. One end should be flattened into a tang which should be driven into a wooden file-handle. A cast-steel file may be used for the tool but in this case it must be softened throughout its length, as hardened files are extremely brittle and liable to fly into pieces if a "jam-up" occurs. There is one urgent word of

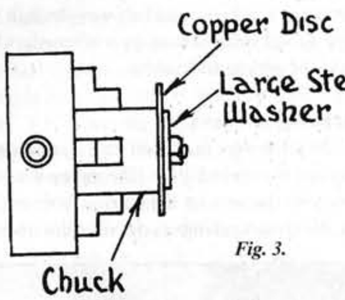


Fig. 3.

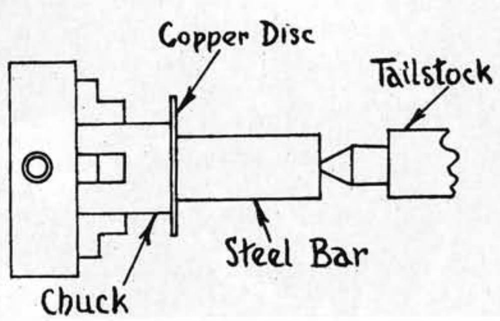


Fig. 4.

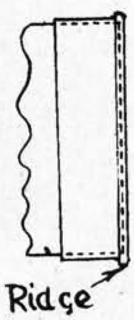


Fig. 5.

warning needed here. Do not, on any account, use a steel tool for hand operation without a wooden handle. Should the unprotected tool accidentally catch the revolving chuck, there is a good chance of the shank being driven deeply into the hand or wrist.

As may be seen in the drawing (Fig. 2), one side of the tool tip is ground into a domed shape, while the other side is ground into a very shallow radius. This side, in fact, is almost flat. The grinding or filing of these shapes is not difficult, but the finishing may be rather tedious. This is because a very high finish is required on the surfaces of the tool; in fact, the better the finish the better the work that may be produced. Professionally, the tools are polished on a buffing-head, but failing this, as good a finish as possible must be produced by rubbing with successively finer grades of emery cloth, and finally polishing with metal polish. The tool tip should be hardened and tempered, and polished again with a fine oilstone slip, emery cloth and metal polish. If a high polish is not obtained, the great danger is that the tool will tear the spinning metal thus making ridges and rings which are almost impossible to remove from the finished article.

The most difficult metal to spin is steel, and the amateur will do well to confine himself to the more amenable metals, such as aluminium, copper and brass, until experience has been gained. Within this range many most useful articles may be spun, including such indispensable model accessories as copper boiler-ends and many types of wheels and cowlings for model aircraft. All these non-ferrous metals must be annealed before operation is commenced and even during operation. Copper is annealed by bringing to a dull red heat and immediately plunging into cold water. Brass may be heated to a dull red and left to cool off. Aluminium may be similarly treated, except that it is desirable that the heat be not too excessive. I have seen metal spinners annealing aluminium discs, and have noted that they determine the correct heat by rubbing the hot metal with a piece of ordinary wood noting the point where the wood begins to char. At this stage the heating is stopped. On very complicated jobs it may be necessary to anneal the metal several times, as the spinning tends to harden it again, and I have been told by metal spinners that after too many annealings the "nature" of most metals is destroyed. Brass, for instance, is reckoned to deteriorate after seven times annealing.

Articles in which a central hole is permissible may be held to the chuck in the manner shown in Fig. 3. Here, a screwed spigot is turned on to the chuck and the metal disc secured by means of a nut and washer. Many articles, however, such as dust caps, boiler ends, and small petrol tanks for model engines, may not have this central hole and these must be held to the chuck by the method shown in Fig. 4. In this instance the disc is held to the chuck by means of compression by the tailstock.

Taking a length of metal rod, both ends are faced off in the lathe, and a centre hole drilled in one end by means of a centre drill. This length of metal is then pressed hard against the metal disc, thus holding it firmly against the shaped chuck. The illustration should make the matter clear. The disc may be roughly cut to a circular shape with tin-snips, and may be trued to run centrally by holding a piece of wood to the edge while the job is revolved. During this operation, too great a pressure should not be exerted by the tailstock, as this will prevent the disc moving into a central position. It is as well to keep one hand on the tailstock wheel and adjust the pressure as may be wanted, while the disc is pushed true by the piece of wood held in the left hand.

Once the disc is running reasonably true, the tailstock pressure should be considerably increased and maintained until the disc has been spun over sufficiently to prevent it flying off the chuck. During this period the lathe centre should be well lubricated, and watched continually for any signs of burning or seizure. When it is assured that the disc cannot fly off, the pressure may be decreased to an amount just sufficient to ensure that the job will revolve with the chuck while being operated upon. The above matters are considerably simplified by the use of a revolving lathe centre, and those who intend to do a considerable amount of spinning are advised to make one of these centres for themselves.

Spinning a Disc

The operation of spinning the metal may be best illustrated by taking a concrete job, such as a copper boiler end. Having cut our copper disc to a circular shape of suitable size, it must be annealed by the method given above. We now make our chuck by turning a suitable piece of steel held in the three-jaw lathe chuck. In this case no central hole is permitted, so it must be clamped up and trued by the method described.

We must now coat the disc with a layer of soap, which is the approved lubricant for metal spinning. Now revolve the lathe at its fastest speed, and apply a strong pressure to the point on the disc where we desire it to fold over. It will be found that the copper will readily bend over in the desired direction and it should be gradually worked over into a sharp bend. It is important, however, that the pressure should always be applied from the point of bend and from thence up the flange. If we attempt to form the flange by pressing on the edge of the disc at the start of operations, it is most likely that a good corner will not be formed, as the metal has a tendency to bulge out along the line of bend. The illustration (Fig. 5) shows what is likely to occur and it will be seen that a ridge of surplus metal builds up along the bend, thus forming a sort of lip. This lip cannot be got rid of by any amount of manipulation, unless the flange is very shallow, and, even then, the metal is liable to be stretched excessively in the operation. With articles having a deep flange it is impossible to remove the lip except by pleating the metal by which time the job may be considered to be destroyed. In all spinning operations, unless the lip is specifically wanted, this principle holds good.

During the spinning operation, it will be almost certainly necessary to remove the partially spun job and anneal it. In the case of the copper boiler ends, about three annealings are desirable; in fact, as soon as the metal shows any reluctance to follow the desired shape it should be annealed. If operation is persisted when the metal requires annealing it will probably split.

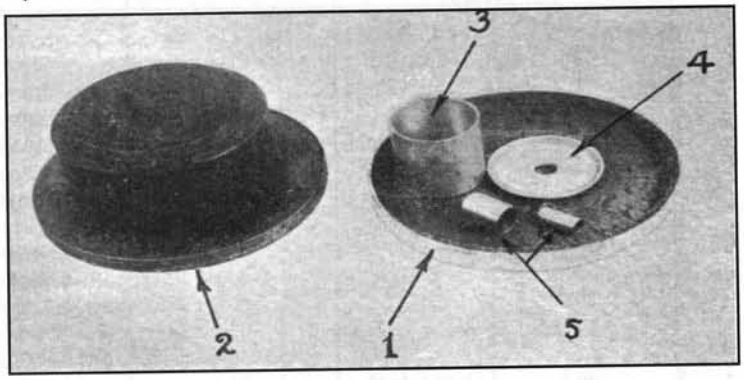
Turning

A certain amount of turning is usually required on the finished article, as the edges are apt to be ragged and misshapen. This turning may be done with the job still mounted upon the chuck, together with any polishing operations with emery cloth. Flanges which must fit into other components may also be turned to size. Most amateurs will find that they obtain best results from metal chucks, as the corners of the job may be formed more squarely. Really sharp corners, however, are difficult to obtain, and a small radius will be more easily formed. This is not important for the majority of spinning jobs, as sharp corners are not often required.

When articles with a deep "draw", such as small petrol tanks, are spun, the job often holds extremely tightly to the chuck, and is most difficult to remove. They may, however, be removed by the following method. Keep the job spinning on the chuck, and turn the tool with the flatted face upwards. Now exert pressure on the underneath of the job, gradually working the tool away from the chuck. In this manner the job will gradually work itself off the chuck, and when almost off, the lathe may be stopped and the article removed by hand. If it is worked right off with the tool there is a liability for the job to spin off into the air with dangerous results. Similarly, do not stand in line with the spinning job, especially when centring the disc, or before the article is spun over sufficiently to hold firmly.

On the usual 3½ in. lathe, discs of copper and brass up to about 16-gauge may be readily spun to quite complicated contours if properly annealed. Aluminium is the most easily spun metal, except for special spinning metals in use in the trade. Aluminium up to ⅛ in. in thickness may be operated upon.

In conclusion, the amateur is advised to start with some comparatively simple job and to feel his way to the more complicated undertakings. The field of application is exceedingly wide, and it is a most useful art, especially as the turning by ordinary methods of thin, disc-like jobs is no simple matter. If one desires to see to what heights professional spinning can attain, I advise you to inspect some of the ornamental knobs which graced the four posts of the old fashioned brass bedsteads. Then go back to your lathe and spin a perfect boiler end.



(1) Copper boiler end. (2) Chuck on which boiler end was spun. (3) Aluminium tank for 1-c.c. engine. (4) Aluminium washer with internal chamfer. (5) Brass ferrules.

M.E. 115 766 (1956)

Graduating feed dials

Graduating Martin Cleeve

This approach is a good one, although there are many ways of skinning the cat. Over the years Martin Cleeve's contributions on the subject of tooling were extremely valuable.

MARTIN CLEEVE describes his system and gives notes on vernier indexing and feedscrew selection

THE CROSSFEED is the micrometer of the lathe, and as such, the screw and graduated dial are worthy of rather more than superficial attention.

It is appreciated that many amateurs show greater than average skill by carrying out first-class lathe work without even possessing a micrometer; but I think it will be conceded that with reliable devices for fine measurement the possibility of disappointment or accident is considerably reduced, allowing for more speedy working and the completion of components before the tedious state is reached.

A previous article described my method of mounting feed dials and indicated that it was preferable to have the assembly free from loose washers. The reason for this is that washers are seldom dead flat with opposite faces parallel, therefore if the apron is slightly off square (as some are) the washers, being free to rotate, are liable to act as swash plates, causing the slide to take up varying positions for any give dial reading; a circumstance especially undesirable in those cases where a vernier is fitted.

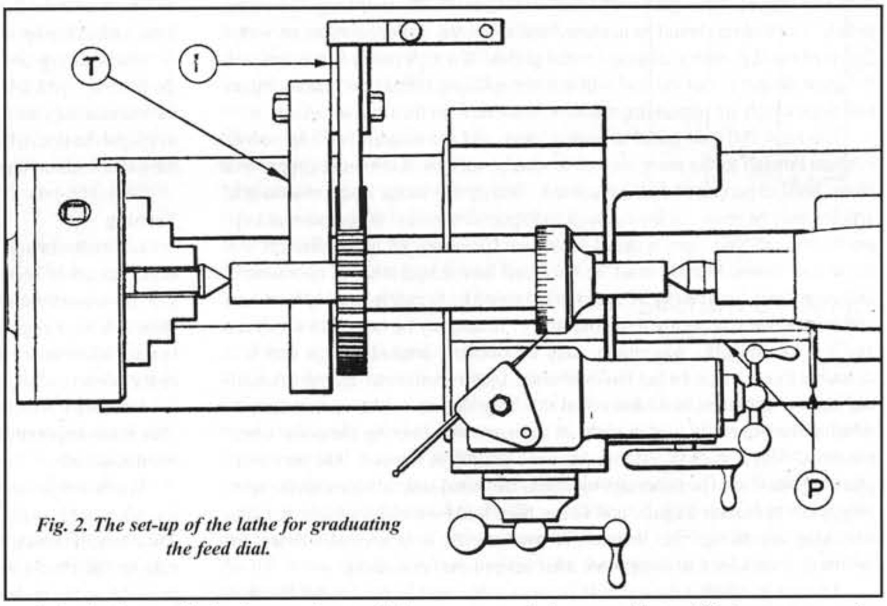


Fig. 2. The set-up of the lathe for graduating the feed dial.

Feedscrews

With regard to the feedscrews themselves, as the subject of dial graduation cannot be logically dealt with without taking these into consideration, I am including a table (Fig. 1) showing the number of divisions with which a dial may be marked to obtain spaces of 0.001 in., or a close approximation thereto. Here, it will be observed that where a dial cannot be made to give exact divisions of one thousandth of an inch, two alternatives are possible.

Where exact thousandths cannot be obtained my choice is always with the lower value per division as I think this acts as a kind of safety margin, always leaving the work a fraction on the large side. For instance, with a 16 t.p.i. screw and 65 divisions, advancing the tool 10 divisions with view to removing 20 thou from the work will, in fact, leave the jib 3-4 thou oversize - assuming the lathe is adjusted to respond to the dial settings with exactitude.

Referring again to the table (Fig.1) the left-hand column has been compiled on the assumption that it will be desired to use standard taps and dies in the preparation of the feed-screws and nuts.

In choosing a feedscrew, the diameter will depend upon the size of the slide, and in selecting a pitch, or number of threads per inch for the screw, it is as well to effect a compromise between a coarse pitch giving rapid feeding but requiring a large number of closely-spaced thou divisions on the dial, and a very fine pitch having the advantage of very widely-spaced thou graduations but with the disadvantage of a slower feeding movement.

For the past 20 years I have favoured 16 t.p.i. (⅜ in. Whit.) for the cross-feed and topslides of 3½ in. lathes, and 20 t.p.i. (⅜ in. B.S.F.) for vertical slides, the latter being based upon the fact that vertical slides do not need so much "winding", a more usual requirement being to set and lock them to some definite reading.

Threads per inch	Nominal size	No. of Grads. on dial	Exact value of each division	Remarks
10	Special	100	0.001	Exact thous.
12	½ in. Whit.	80	0.00104	
12	½ in. Whit.	85	0.00098	
14	7/16 in. Whit.	70	0.00102	
14	7/16 in. Whit.	75	0.000951	
16	½ in. B.S.F. or	65	0.000961	
16	⅜ in. Whit.	60	0.00104	
18	7/16 in. B.S.F. or	55	0.0010	
18	5/16 in. Whit.	60	0.000925	
20	⅜ in. B.S.F.	50	0.001	¼ Whit. or 9/32 x 20
22	5/16 in. B.S.F.	45	0.00101	
22	5/16 in. B.S.F.	50	0.000909	
40	¼ or 5/16 x 40	25	0.001	Micrometer thread

Fig. 1. Showing the number of graduatons required for screws of various pitches.

Exact graduation

For the slides of smaller lathes, 5/16 in. B.S.F. is a convenient size although it should be noted that Messrs. Nuckey, Scott and Co. Ltd. the makers of Warrior taps and dies, list a 20 t.p.i. with a diameter of 9/32 in., this having the advantage of giving exact thou divisions with 50 spaces on the dial as well as being somewhat stronger than the ¼ in. Whit. thread which, having a core diameter of only 0.186 in., could not be recommended for any but very light or temporary work.

At the very bottom of the list I have included 40 t.p.i. as some may like to consider this for small precision slides such as might be fitted to lathes in the watchmakers' class.

It has been my practice to prepare feedscrews from silver steel and nuts from mild steel. I find that this combination has good wearing qualities, but for those who cannot condone two similar metals for such purposes, a nut made from cast iron would be satisfactory. I am unable to

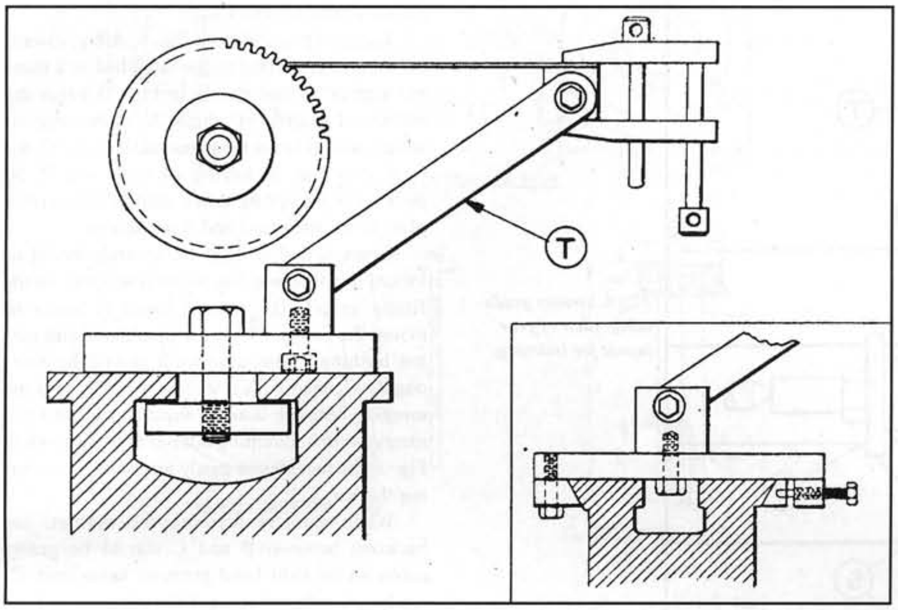


Fig. 3. Method of mounting the index strip. Inset, fixing for V-bed lathe.

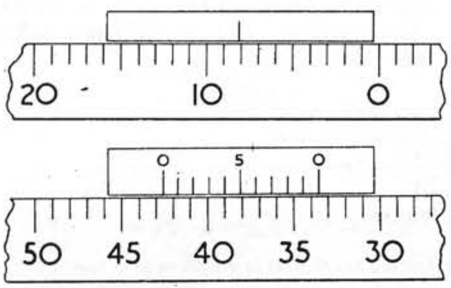


Fig. 4. Plain scale (x) and vernier scale (y)

recommend phosphor bronze for nuts.

When I converted the crossfeed of my ML4 to one of 16 t.p.i., I drilled away the original nut (which had been tapped directly into the saddle) by means of a ½ in. drill held in a carpenters' brace, and inserted a mild-steel flanged nut secured by two No 4 B.A. countersunk head screws passing through the flange into tapped holes in the saddle. Such nuts are easily made from a piece of 1¼ in. to 1½ in. dia. stock, but the flange and outer surfaces of the nut should be finish machined upon a truly running threaded and shouldered mandrel.

The axis of the nut must be parallel with the slideways; to achieve this it is sometimes necessary to square the front portion of the saddle or fixed slideway. When taking sights with the try-square it is helpful to rest a length of round stock in the vee of the slideway.

For smooth working, especially when the slide is approaching the closed position, the feedscrew thread should be exactly concentric with the bearing within the apron bush. I achieve this by firstly machining the handle and shoulder end of the screw and, for reference skimming what will become the feedscrew shoulder.

The plain handle and bearing portion may then be chucked in the four-jaw, with the interposition of a wrapper of sheet zinc to prevent marking, and clocked true, using the skimmed shoulder portion as a reference.

With tailstock support, screws up to about 5 in. in length and ⅜ in. or ⁵⁄₁₆ in. dia. may be screwcut without a travelling steady. The thread may be roughed out and finished with a die and castor oil. It is worth noting that if more than the barest minimum is left for the die to remove, this will sometimes wander off centre. The die should therefore be tested from time to time upon the first few threads of the screw.

Dial graduating

I invariably graduate feed dials by means of a set-up similar to that shown in the drawing (Fig. 2). Indexing is taken from the appropriate lathe change gear which is controlled by means of a spring strip, I, held to the lathe bed by assembly, T.

The graduation lines are marked by means of an ordinary scriber and their length determined by the stop pieces, P, these being arranged between the saddle and the tailstock body.

Mounting between centres renders the indexing very sensitive to exact positioning, and when the index strip, I, is arranged so as to engage the teeth of the gear, as in Fig. 3, a kind of self-locking action is automatically obtained.

The use of stop pieces to control the lengths of the graduation lines eliminates the necessity for a pair of unsightly circumferential datum lines, while the scriber will be found to produce those fine clean-cut graduations so dear to the hearts of followers of catalogue literature.

The scriber should be arranged so as to be at approximately the angle adopted for normal hand use, but with enough overhang to give perceptible spring. Commence marking at the inner end of the lines, put on a modest pressure of about 5 thou in. by means of the lathe crossfeed and traverse the scriber off the dial by the saddle handwheel; make three such passes for each line.

For a scale such as that shown at X (Fig. 4) the mental drill would be: "One long, four short, one medium, four short, one long", etc., while for the scale at Y, the drill would be: "One long, four short, one long," etc.

Scale X is suitable for dials containing multiples of 10 divisions, and Y should be used for multiples of five. In this connection it is interesting to note that if scale X is adopted for a dial with 65 divisions, it would "end up" with two full-length graduation lines only five spaces apart.

When number stamping the dial, a set-up like that shown in Fig. 5 may be used to ensure that the numbers fall nicely in line. The punch shank is held against the flange. With a good light and a comfortable seat it is possible to judge quite accurately where the number will be impressed.

Please remember that the numbers must increase from right to left, also note that numerals like 1 do not require such a heavy blow as 4: have a rehearsal upon an odd piece of material.

The vernier scale was invented by Pierre Vernier 325 years ago, and by its means it is possible to sub-divide "normal" scale units into a further number of fractional parts, but without the disadvantage of having these so crowded that it would be difficult to take a reading.

Instead of cramming (in this case) 10 little spaces between every unit graduation, M. Vernier conceived the idea of spreading these out in the form of another scale with a series of 10 divisions equal in overall length to nine divisions on the main scale, thus each vernier division will have a length equal to ⁹⁄₁₀ of a division on the main scale.

To read the vernier, note the nearest unit reading on the main scale, under the right-hand zero on the vernier, and if this is not exactly coincident glance along the vernier (from right to left) and note which vernier graduation is coincident with a line on the scale. In the case of the example given in Fig. 4, a line on the main scale coincides with the sixth vernier graduation, therefore $6 \times \left(\frac{10}{10} - \frac{9}{10}\right) = 6/10$ should be added to the units, giving a complete reading of 33.6.

When using the dial in the reverse direction as for putting on cuts for a boring tool, read the units

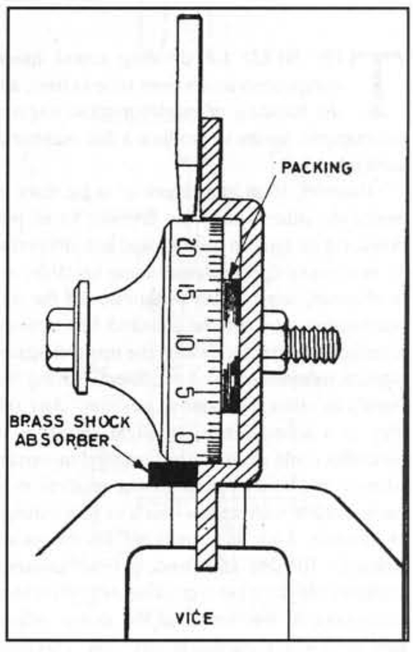


Fig. 5. Setting the figures in line.

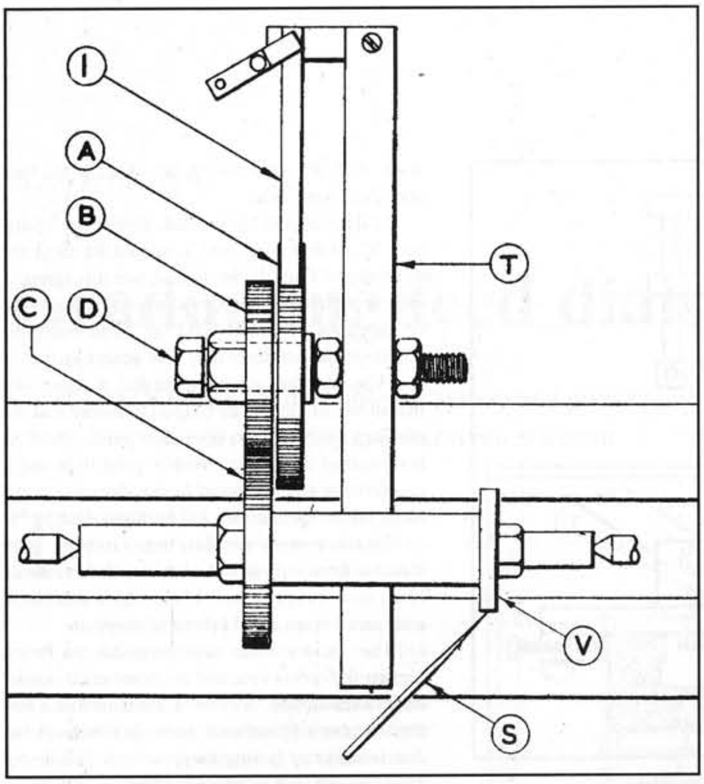


Fig. 6. Vernier graduating: plan of gear layout for indexing.

as before from the right hand vernier zero mark, but knock off tenths by reading the vernier from left to right - this is why the vernier is marked 0-5-0 instead of 10-5-0 by the way.

To graduate the vernier with 10 equal spaces having an overall length of nine spaces on the main dial scale, the main scale index wheel is used with the interposition of a pair of gears giving a ratio of 9 to 10.

The set-up is shown in Fig. 6. Here, assembly, T (which is fixed to the lathe bed in a manner similar to that shown in Fig. 3) holds the additional gearing of which, A, is the original wheel used to index the main scale, B and C, the 9:10 reduction, B, having 45 teeth and, C, 50 teeth. I is the spring index strip, V the vernier plate to be graduated and S the scriber.

Gears A and B must be securely keyed or locked together, but free to revolve upon a well-fitting spigot, D. I have found it handy to mount the two gears upon a shouldered and nutted bushing. The gear teeth should be thoroughly cleaned with a stiff wire brush, and the meshing between B and C must be adjusted to a nicety; with a mounting similar to that shown in Fig. 3, the meshing is easily arranged by swinging the bar, T.

When actually scribing the vernier, the backlash between B and C should be gently taken up by light hand pressure upon gear, C, tending to rotate A against the index strip, I.

A reasonable style to adopt for the vernier is shown at Fig. 4, and with regard to the actual size of the numbers, I find that ¼ in. for the main scale and ³⁄₁₆ in. for the vernier looks quite well.

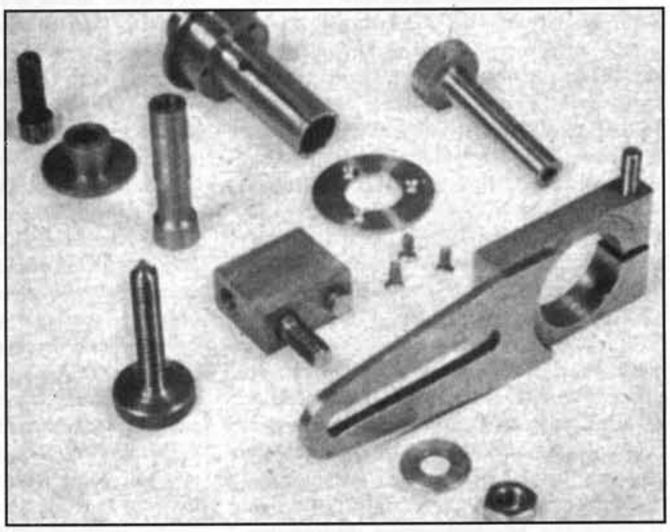
M.E. 136 74 et seq (1970)

DIVIDING IN THE LATHE

Dividing in the Lathe L.C. Mason

Although I included a mandrel dividing attachment in my previous volume in this series, I think that this one is worthy of consideration, especially if you do not possess a dividing head. Note that it does not cope with all the prime numbers.

L.C. Mason describes the construction of a simple dividing attachment for the lathe.



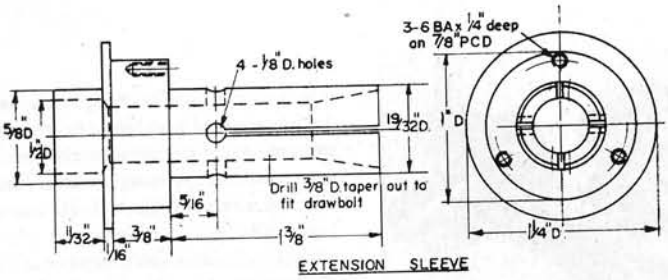
Components of the lathe dividing attachment.

THE NEED for dividing round model components arises from time to time, and the building of model traction engines, for example, seems to produce a fair number of such jobs.

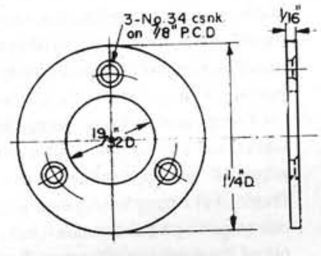
However, if an attachment is to be made to enable the lathe to carry out dividing for all purposes, the design can be improved and elaborated, so as to make the attachment more versatile, and to eliminate some of the weaknesses of the simpler version. It would be a distinct improvement to make provision for locking the mandrel against rotation independently of the detent, leaving that merely to select the required position. Any side play in a screw detent, or slight spring in its mounting could allow a slight mandrel movement where a machining operation was required to be carried out at each station - such as gear cutting - as distinct from just marking in the points indexed. Rigidity and freedom from unwanted backlash are the main requirements in a dividing attachment of this sort, and the design offered here looks after these points very well. This again is proportioned for use on the ML7.

As in the other attachments, use is made of the lathe's own change wheels as dividing plates, and the carrier for the wheels, locking into the back end of the mandrel, follows much the same lines. It will be seen that while a screw detent is used, this works in a tapped block deep enough to ensure that there is no side play in an easily working screw. Holding the mandrel in the selected position is looked after by the provision of a large diameter collar on the mandrel plug which can be locked in position by a split block encircling it, rigidly anchored to the lathe structure. Not only does this relieve the detent of the duty of holding the mandrel, but leaves undisturbed any change wheel set up on the quadrant, through not having to attach the detent mounting to the quadrant.

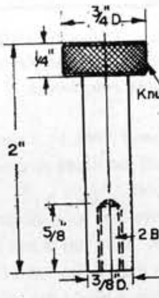
The plug extension to the mandrel is held in position in the conventional way, by a taper headed draw-bolt which not only expands the split end of the extension in the mandrel end, but clamps the



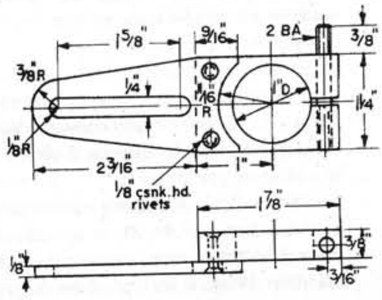
EXTENSION SLEEVE



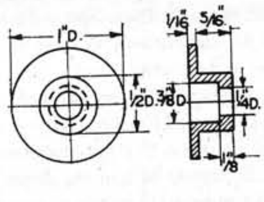
CLAMP RETAINER RING



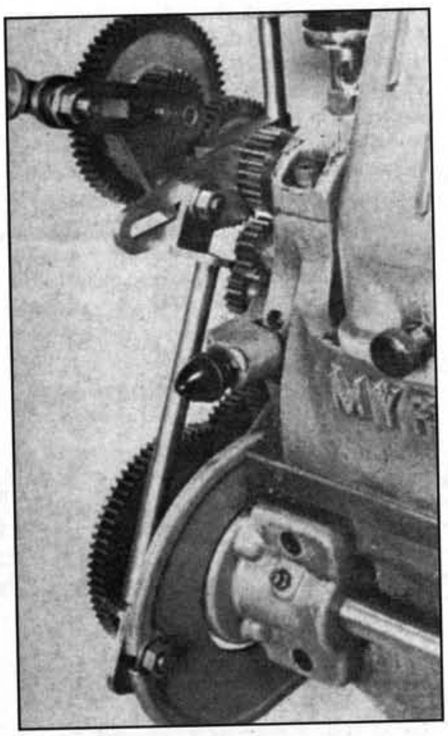
CLAMP FINGER NUT



LOCKING CLAMP & DETENT CARRIER

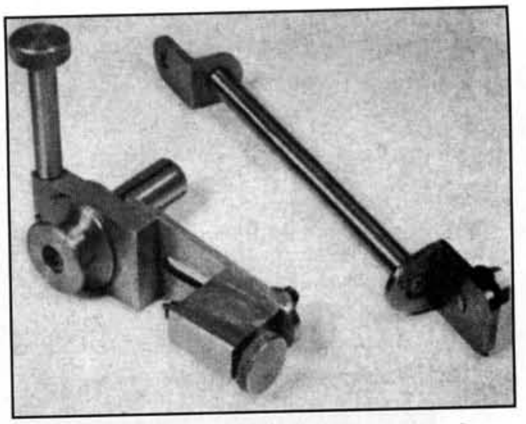


CHANGE WHEEL CLAMP WASHER



Left: The dividing attachment in use on the ML7 lathe.

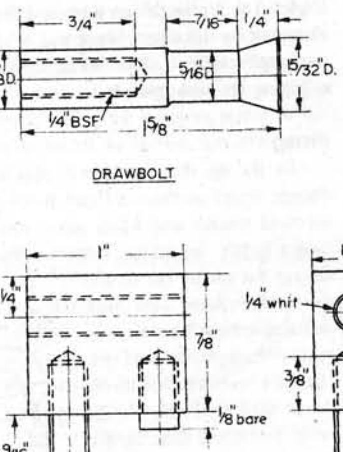
change wheel in position on the outer end. This draw-bolt is a good item with which to start making the attachment, as when the top-slide has been set over for turning the taper on the bolt head, the top-slide setting can be left for boring the taper in the end of the extension sleeve to match.



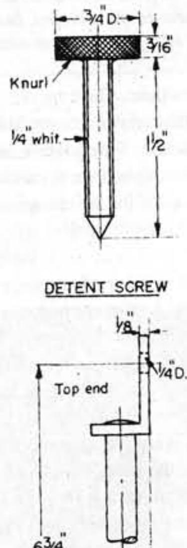
The dividing attachment complete and ready for use.

Chuck a piece of ½ in. dia. steel rod in the three-jaw and turn the shank of the bolt first, drilling in the end No. 3 for ¾ in. depth and tapping ¼ in. BSF. Part off, leaving enough to face the head back to ¼ in. thick. Run the head down to ¹⁵⁄₃₂ in. dia., and set the top-slide over 10 deg. to give a 20 deg. inclusive taper. Turn the taper on the underside of the head till the large end of the taper meets the top face with a sharp edge.

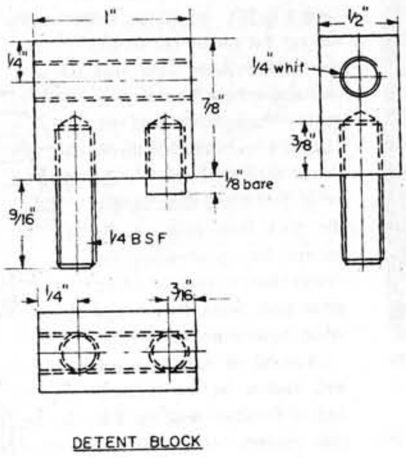
The sleeve is all plain turning and drilling in the three-jaw from a piece of 1¼ in. dia. bar, machining the mandrel end first. This should be a close sliding fit in the mandrel bore - ¹⁹⁄₃₂ in. for the ML7. Check for fit in the bore of your own mandrel when getting close to nominal size. Using the top-slide already set over, bore the taper seating in the end for the bolt head, opening it up by very light cuts till the bolt head seats flush when pushed in finger tight. Reverse in the chuck and turn the wheel seat end, checking with a change wheel for a really close fit in the wheel. When finish turned, drill the four ⅛ in. holes round the plug end of the sleeve and make



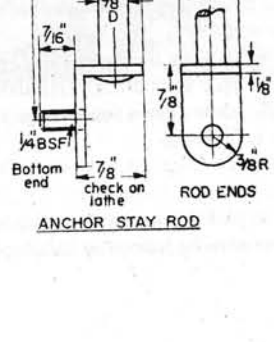
DRAWBOLT



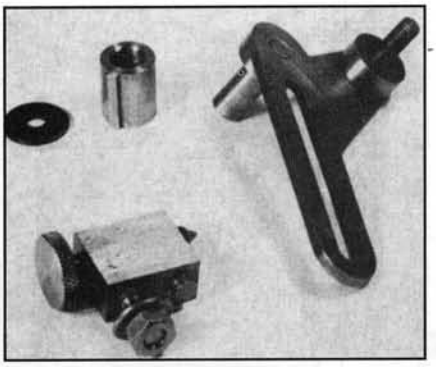
DETENT SCREW



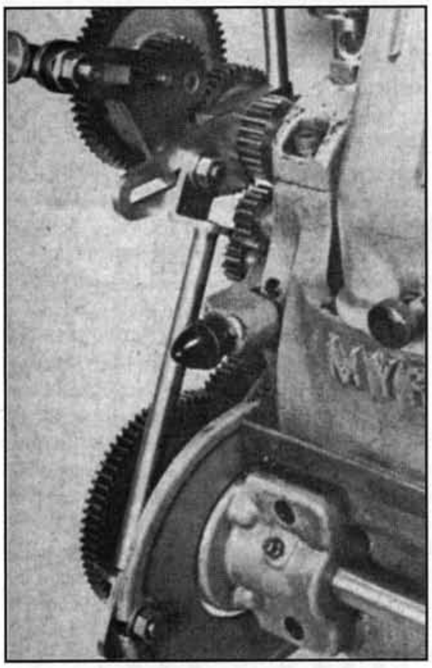
DETENT BLOCK



ANCHOR STAY ROD



Parts of the compound dividing gear.



The compound dividing attachment in use on the lathe. The big index wheel is 60 t., keyed to the 25, gearing with 45 wheel on the mandrel. Indexing round by "threes" gives 36 divisions.

the sawcuts down into them. The 1 in. dia. portion, around which goes the clamp block, could be left a few thou wider than the 3/8 in. shown, until the clamp block has been made, then it can be faced back to provide a snug fit for the clamp.

Clamp block

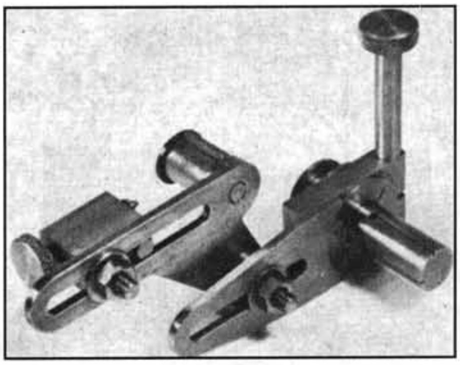
The clamp block is retained in place on the sleeve by a 1/16 in. thick ring, turned up from a piece of sheet, and drilled for three 6 BA countersunk holding screws. The tapped holes for these in the edge of the collar are spotted through from the ring.

The clamp block is shaped up almost entirely in the four-jaw chuck, the ends being faced square and the 1 in. hole bored a close running fit over the collar on the extension piece. Drill for the 2 BA clamp stud No. 26 to depth, split the piece with a sawcut, open out the top half of the hole to 13/64 to clear the stud, tap the lower half of the hole and fit the stud.

It will be seen that the finger screw operating the clamp is quite a tall affair. This allows free access to the screw when a large change wheel is in position for dividing.

Tail piece

The 1/8 in. thick tail piece is filed up from strip, with the curved end machined on the faceplate. It



The photograph above shows the additional compound dividing bracket assembled to the original dividing attachment.

is attached to the clamp block by a couple of 1/8 in. rivets from mild steel rod, flush riveted both sides and filed down smooth.

This piece carries the long detent block, in which are two studs. One has a nut on its outer end, serving also to clamp the top of the anchor bar, and fixing the block along the tail in the correct position relative to the change wheel being used for dividing. The other stud also engages the slot in the tail, but is cut down short to fractionally less than 1/8 in., serving only to keep the detent block aligned to the change wheel.

The detent itself is plain turning from a stub of 3/4 in. dia. rod, its thread being run down in stages, adjusting the die till a free but shakeless fit is obtained in the tapped hole in the detent block. Thread the detent by using the die in the tailstock dieholder.

The rigid anchoring of the attachment and mandrel is effected by fixing the tail end by a stiff bar to the nearside hole in the change wheel casing backplate. The earlier ML7's had a plain hole here; later ones had this slotted out to the edge for ease of fitting the guard casing. It pays to make this slight modification on lathes not so fitted, as it makes fitting the dividing attachment simplicity itself. The anchor bar is merely a length of 3/8 in. dia. rod, turned down to 1/4 in. at each end and riveted over in 1/4 in. dia. holes in a small piece of angle. The top angle has a plain drilled hole for clamping by the detent block nut, while the bottom angle carries a short 1/4 in. stud and nut for engaging the cover plate hole.

Fixing

To fix up the attachment, slip the chosen change wheel on the outer end, holding it by the recessed washer and Allen screw run in lightly finger tight. Insert the sleeve in the mandrel, engage the anchor bar stud in the slotted guard stud hole, and screw the Allen screw up tightly enough to hold the change wheel firmly. Run the detent back until only just the point protrudes, then tighten the nuts both ends of the anchor bar, positioning the detent block so that the detent point just clears the change wheel when retracted.

Instead of a normal nut and washer on the screwed end of the draw-bolt, the fitting shown is a turned recessed washer housing the head of an Allen screw. This is to permit of another change wheel overlapping the centre of the mandrel wheel when using that attachment in a slightly different way. It will be appreciated that by using the lathe change wheel direct, it is not possible to divide into such numbers as 16, 24, 22, or any number which is not a multiple of a factor of the number of teeth occurring in some change wheels. In gear cutting, for instance, the need for such numbers often arises, and by making a small addition to the basic attachment shown, the range of divisions possible is greatly extended by the ability to carry out compound dividing.

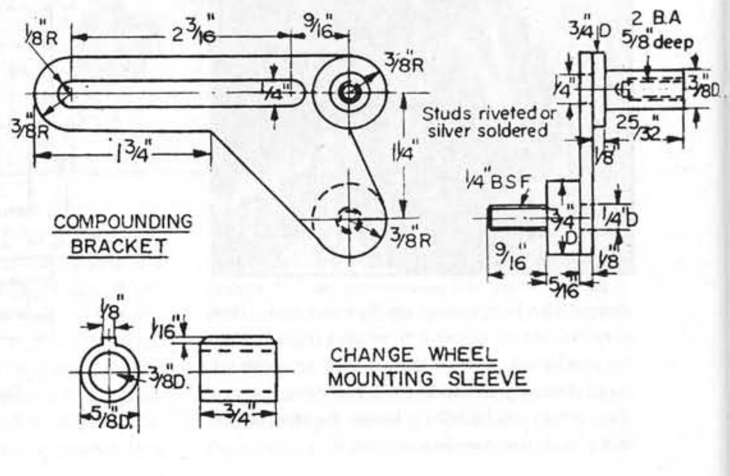
Compound dividing, using the lathe's change wheels as dividing plates, very greatly extends the range of numbers into which it is possible to divide. For example, it is easy enough to divide in one stage to give 8 divisions, but any other multiple of 8 (other than 40) using the standard wheels is not possible.

With the compound attachment, it is equally simple to divide into 16, 24 or 32. Scores of other numbers are equally easy, such as 39, 56, 18, 42, or some of the "awkward" numbers sometimes required for gear cutting by clockmakers.

The procedure is to select a change wheel that can provide a factor of the number required, then attain that number by gearing down by means of an additional pair of gears.

Taking 18 quoted above as an example, 9 is available from the 45 wheel by indexing round every 5. All that is needed from there is to index round the 45 wheel for 9 positions, but to gear the 45 wheel down to the mandrel by 2:1 with say, a 40 and 20 pair of wheels. The 40 wheel goes on the mandrel extension, driven by the 20 wheel to which is keyed the 45 wheel. On indexing round the 45 wheel, the resulting 9 positions will only have turned the mandrel half a turn, because of the 2:1 gearing, so a second turn round the 45 wheel is required to move the mandrel one complete turn, providing a second set of 9 positions. Thus the two turns of the indexing wheel provide 18 points around the one turn of the mandrel.

As a further example, 28 can be obtained by way of indexing round the 70 wheel by 5's to give 14, and gearing down in the same way by 2:1 to give a final 28. Should 56 be needed, both this and 35 have common factors of 7. Dividing both by 7, the ratio between them is seen to be 8:5. Therefore by indexing round every tooth of the 35 and gearing down 8:5 by the 40 and 25 wheels, the



result is the required 56 divisions.

The easiest way of bringing a second pair of wheels into action is to provide a bracket to carry them, adjustable as to position so that various sizes can be meshed with a wheel on the mandrel. On the extra bracket, too, will have to be mounted the detent block to engage the outer wheel of the extra pair. All that is required, therefore, is a simple plate equipped with a slot the same as the original bracket to carry the detent block, a stud on which can be mounted a sleeve for a pair of change wheels, and a fixed mounting stud by which the whole can be attached to the basic bracket in such a position that the extra wheels can be meshed with the mandrel wheel.

The photographs and drawing show this to be quite a simple affair, filed up from 1/8 in. steel plate, with two studs either riveted or silver soldered in position. The mounting stud goes in the detent block slot of the original bracket, utilising the adjustment provided by the slot for adjusting the mesh of various sized gears. The stud at its attachment point with the bracket incorporates a larger diameter collar, the thickness of which serves to line up mandrel gear and driving gear. This stud also clamps the top end of the stay rod as did the detent block stud in the simple version. The detent block is naturally transferred to the similar slot in the extra bracket.

A sleeve to carry the extra pair of gears keyed together can be made up from the job, rather than disturbing a change wheel train already set up on the lathe quadrant to borrow a sleeve from the lathe's own set. The drawing shows the dimensions, the key being silver soldered in a slot milled down the length of the sleeve. In setting up, the compound bracket is positioned for the correct mesh of the extra wheel with the mandrel gear, and the nuts holding the anchor stay fully tightened. Then the detent block is positioned relative to the indexing wheel.

The proportions shown allow of any standard ML7 wheels to be used. Should some odd numbers of divisions be required that necessitate the use of a larger than standard wheel, the length of the extra bracket - and therefore the detent block slot - should be enlarged accordingly. In this connection, it is useful to remember the possibilities offered by the Myford metric conversion wheel, having 21 teeth.

In indexing round with this set-up, it is advisable to keep to a procedure which eliminates any slight backlash between the gears. This is best done by turning the mandrel through movement of the indexing wheel, letting the wedging action of the detent move the wheel the last fraction of a degree to the correct position. In this way, any backlash which may exist is always taken up the same way, and to the same degree of loading. Should a position accidentally be overshot, turn the wheels back to a position well short of the correct one, and go through the whole indexing motion again for that station.

TABLE 1

Selection of numbers possible only by compound dividing.

No. of Divisions	Mandrel Wheel	Second Index Wheel	Index Wheel	Every
16	50	25	40	5
18	40	20	45	5
21	60	20	35	5
22	40	20	55	5
24	40	20	60	5
26	40	20	65	5
27	60	20	45	5
28	40	20	70	5
32	40	25	60	3
33	60	20	55	5
36	45	25	60	3
39	60	20	65	5
42	60	20	70	5
44	40	50	55	1
48	40	50	60	1
49	35	50	70	1
52	40	50	65	1
54	30	25	45	1
56	40	25	35	1
57	60	20	38	2
63	35	25	45	1
*64	40	25	40	1
66	30	25	55	1
72	30	25	60	1
76	40	20	38	1
77	35	25	55	1
78	30	25	65	1
80	50	25	40	1
84	35	25	60	1
88	40	25	55	1
90	40	20	45	1
96	40	25	60	1
98	35	25	70	1
99	45	25	55	1
100	40	20	50	1
180	75	25	60	1

*A number used by clockmakers, requiring a second 40 wheel.

M.E. 144 333 (1978)

HAND-TURNING TOOLS

By Tubal Cain

Hand Turning Tools Tubal Cain

Tom Walshaw was a master of this art, so it's good to heed what he advices on the subject of tool shapes and the basic approach to the technique. His complete articles on the subject of hand turning make very interesting reading.

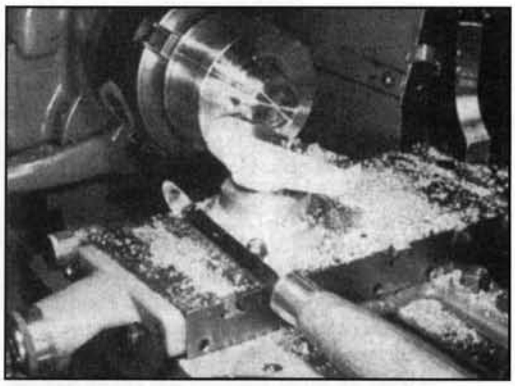


Fig. 9. Note the finish, even from the roughing tool.

Tools

I don't propose to say anything about the techniques of hand-turning - though if readers want a piece about this I could do one - but as I have mentioned tools in passing it might be as well to look at these for a moment. Fig. 7 shows some of mine. Those on the left are some of a set passed over to me by a journeyman brass-finisher when, sadly, our last brass-turning lathe was replaced by a capstan. There are 18 in the complete set, including a burnisher and a parting tool all except the last being between ¼ in. and ⁵⁄₁₆ in. thick. Those on the right are a set of four more delicate tools, about 100 years old, probably made for the "amateur" market, and are ³⁄₁₆ in. thick. The very long tool at the top is, in fact, made from a 12 in. file.

The first point to notice about all these tools is that they are "well handled"; indeed, one would have a job to remove the handles from all of them. This is essential, as very slight alterations in the

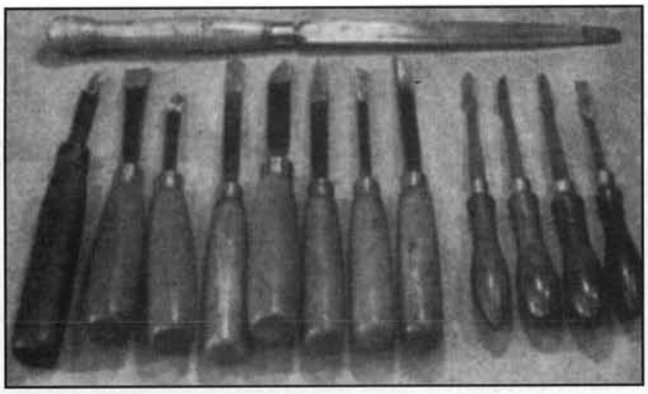


Fig. 7. Eight brass-finisher's tools, lower left, tool from an old file, top, and four lighter tools, right.

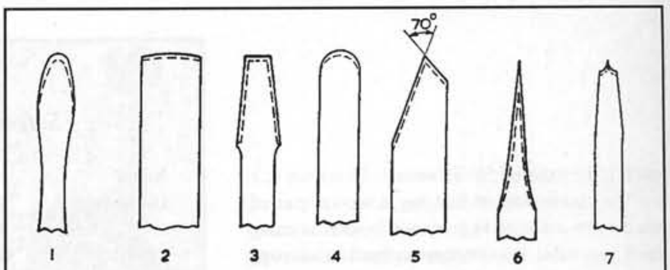


Fig. 8. SHAPES OF TURNING TOOLS

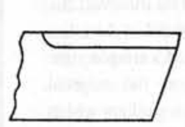


Fig. 8a. SHOWING COMPOUND CLEARANCE ANGLE.

attitude - the angle of attack, as it were - of the cutting edge make a big difference to the cutting behaviour. It is quite impossible to control this if the handle is not really secure. Besides which a loose, or even not quite tight, handle can be very dangerous. Then, though you can't see this, the underside of most of the tools is almost flat, though some have a slight curve so that they can be rocked sideways. The technique is totally different from wood-turning; softwood turning, that is, where the gouge or chisel is more or less tangential to the work.

These brass-finishing tools are used dead flat on the rest, the cut being adjusted by the very slightest raising or lowering of the handle, hence the importance of having a truly flat top to the tee-rest. Finally, the edges are very keen; whilst a slightly blunted slide-rest tool can be forced through the work by mechanical pressure, this is almost impossible with hand tools, and when from laziness or necessity such a practice is used, can be hazardous. The advantage that follows from this necessity for keenness is that the finish from the tool can be such as to need no polishing, and certainly there should be no need for "showing it the emery cloth". The burnisher, not shown in the photo, is a tool with a highly polished rounded work-end which is pressed against the metal after finish turning. It needs some skill in use, but the effect is a mirror-like finish only needing lacquer to enhance it. Burnishing also closes the pores of the metal, as they used to put it, and not only workhardens the surface but also seems to preserve the polish.

Tools from Files

For casual use the model engineer is unlikely to want to purchase a set of brass-finisher's tools, even if he could find any. Many use the flat scrapers, anyway. Satisfactory tools can, however, be made from worn-out files and in my view, provided they are properly made, these are more effective than ones made up from carbon tool-steel. No benefit accrues, by the way, from making inserted tooth type of tools, with high-speed steel let in or brazed to the shank. (Not for brass or gunmetal, anyway.) True, you can run faster, but the finish is not as good simply because HSS won't take the smooth polished finish from the stone which can be had on carbon steel.

The main problem with using files is to get one thick enough, and this may mean either having a very long turning tool, or breaking the end off first. I prefer the former, especially now that the slide-rest no longer gets in the way. The first essential, and it is essential, is to get rid of the teeth. This must be done, and it's hard work even for a decent ½ h.p. bench grinder, so if you can it's best to seek out a blacksmith or foundry that has a man-sized grinder with 12 in. wheels or more. Grind off all the teeth of the file, both sides and edges, and then take a little more off, for the metal will be workhardened where the notches were. Keep it cool with plenty of water, especially at the business end. Naturally, it helps if the file is well-worn to start with, and if you do have a blacksmith locally it may well be that his old files are more worn than yours! Try for a swap.

The next essential is to draw the temper of the main body of the file, as a brittle turning tool can be a real hazard. However, it's best not to temper the cutting edge - not until you have tried it out, anyway. The way I do it is to have a fairly large dish filled with about 1 in. depth of water, and stand the file upright in this. Play the flame on the body up and down, bringing as much as you can to blue. Don't let the part at the water's edge get darker than pale straw. The water may fizz a bit, but tempering at 100°C is very mild. As soon as most of it is blue, quench in a good bucket of cold water - if you don't the heat may run fast into the point. Now examine the file, and if the straw colour comes within an inch of the cutting edge-to-be, leave it. If it doesn't reach that far, then reheat gently at that end until pale straw comes within ¾ in. of the end and quench.

You must now handle the tool. Unless there is absolutely no alternative, don't use a file-handle; and, if there is no alternative, use a very large one, but it's better to find a good piece of beech or boxwood (or even rosewood if you like!) and make one if you can. A good ferrule is essential - and again, those provided for file handles aren't good enough. Make one of brass or steel, of reasonable thickness, machine the handle to fit it, and shrink or drive it on; secure it with three dimples from a centre-punch. The tang must fit into the handle right down, and this does present problems. If you use the old trick of drilling a hole with a succession of larger drills, it will only fit at the sides for half the depth. I have tried using a chisel but it's tedious and not very effective, so instead get another file with the same size tang or file up a piece of steel, get it hot, and (after drilling a hole equal to the thickness of the tang or a trifle less, of course) drive this in and pull it out again quickly once or twice. This will char the wood and should give a good bed. Be satisfied when this tang goes in, say, ⅞ of the way. Now drive the tool right in and I think you'll find it stays put all right.

The final job is to form the end and then sharpen it. Grind the flat top face of the tool till it is flat, and then stone out the grinding marks with a medium coarse oilstone. Next, form the front profile. I have shown a few shapes in Fig. 8, and of these I find that I use Nos. 1, 2, and 5 more than any others. No. 3 is the same as No. 2, but ground to cut on the sides as well as the front. No. 4 forms concave surfaces, and in a "set" there will be several of different radii. (It is not used as a form-tool, by the way, but swept over the surface being cut.) No. 6 is used for marking-out, but is also handy for forming decorative grooves, whilst No. 7 is a sort of form tool for making "posh" decorations. No. 1, of course, is the roughing tool, and this also comes in various sizes of head. There are variations on these, of course, but chiefly in the matter of size rather than shape. No boring tools? Yes, certainly, and internal screw-cutting tools too, for that matter! But you do have to learn to bore with hand-tools. It's not easy and you can't just "pick it up" (though if you try without instruction you may well be picking up bits of workpiece, tool, and possibly lathe as well), so I haven't shown these.

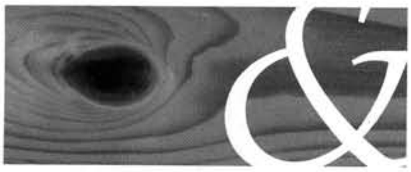
Having formed the profile as near as may be, put on the front clearance. This should be 30° for roughing, working down to 20° for the finishing tools. It's important, especially on curved tools, to get this uniform, otherwise the tool will cut more or less as you present different parts of the tool. You must now carefully stone the clearance face and if need be the top face as well to remove the grinding marks and to correct minor discrepancies in the shape. I use a medium India stone for this. Take care to keep the cutting edge sharp, but don't leave a burr or wire edge. Give the underside of the tool a look at the stone, too, so that it will slide easily on the rest.

Finally, to sharpen it. Use a fine stone; Arkansas if you have one, though it's a bit slow. I find "CF7 Superfine White" toolmaker's stone is faster and gives a more than adequate finish. Failing either of these, your finest India provided it's flat.

Stone the top face, taking great care to keep flat, then the clearance face, and finally, form a secondary clearance angle of 20° on the rougher and 10° on the finishing tools (Fig. 8A). This is the part you stone when you resharpen, not using the grinding wheel till this angle reaches about half-way. For really fine finishing some workers use zero clearance - i.e. a 90° cutting angle - and the chap who gave me my tools actually used negative rake as well on some tools, the cutting angle being about 100°. But for general work those I have suggested should suit well enough. The tool is now properly sharp, and you should find it cuts like nobody's business and leaves a finish like glass. If it doesn't, practise a bit more! See Fig. 9.

One last word. Don't forget these are carbon steel tools, and adjust your cutting speed accordingly. Say 60 ft/min. for roughing, and 80 ft./min. when finishing. You can work faster, but you will only take the edge off quicker and may even draw the temper of the cutting edge, after which the tool will be no use at all.

The International Woodworking & Turning Exhibition 1999



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