Cutting worm threads

By GEOMETER

Methods of machining, and precautions for ensuring accuracy

So long as its pitch is a simple fraction of an inch, and capable of being expressed as t.p.i. without running into decimals, the tooth profile or thread of a worm can be cut in a lathe in a manner similar to that employed for other threads. It can be a single-start, double-start, and usually a three-start without any difficulty.

But the more numerous the starts, the longer the axial movement for one revolution, and the more rapid the saddle action. Six-start threads are quite possible on a component screwcut in a lathe, though it is getting away from a worm towards the driving member of a pair of skew gears.

Preparatory work consists of drilling and reaming the bore, or finishing with a boring tool, then turning the outside or top diameter to size. A small blank may well be screwcut on the parent bar before parting off, supporting the open end with a tailstock centre, as at A. Where, however, this would involve running at a large diameter on the centre, or when desiring to retain the principle with a bore larger than the centre, a centred bush can be used for support, though it should be fairly long and a good fit in the bore. Again, particularly in larger sizes for which a casting may be used, the blank after boring and facing can be mounted on a mandrel to run between centres.

In many instances, it is useful to leave at one end, or both ends, of the blank, a portion which is the root diameter of the thread, to serve as a reference down to which eventually to take the tools in a series of cuts, working from the cross-feed micro-meter collar.

It is important for the lathe spindle and slides to be in good adjustment. There must be no endplay apparent on the spindle; and support given from the tailstock should be as uniform as possible, the handwheel tightened with the same touch on each occasion, and the barrel clamped to the same degree of tightness. This is to say, the endwise position of the job can be varied slightly by the force, or lack of it, applied from the tailstock, even on quite powerful lathes; and the effect is, of course, particularly apparent when work is run between centres.

In ordinary turning, chatter, roughness, or binding might ensue; but in any screwcutting, and particularly where the thread form is deep, variations in depth of cut may result in serious tearing, or jamming and breaking of the tool.

Slides should be adjusted to eliminate play, and backlash on the topslide feedscrew taken up to oppose the thrust of the cut, right- or left-hand. For screwcutting steel, lubrication is also important, and there should be a good supply of suds or cutting oil flowing over the tool in use.

The carrier for a mandrel mounted blank must be tightened firmly, and care exercised that its leg is against the driving pin before commencing a cut. To ensure this, a stud can be fitted to the driving plate, as at B, or an angle piece under the pm, as at C. With either arrangement, it may be advisable to locate the carrier outside first, to check touch on the tailstock. A stud can, of course, be screwed in afterwards.

The thread form is best taken to depth in two stages, employing front-cutting and right-and-left-hand tools, with cuts 0.002 in. to 0.004 in. deep. In the first stage, the front-cutting tool provides a square groove of half depth which is opened out at the sides with angle tools. Then it can be used again to full depth.

At D1, the tool is in a finished thread, while 2 illustrates its section; and 3 shows the side view with hollow grinding at X for the chips to curl off freely. Right-and-left-hand tools, as at E and F, are shaped as 1, with sections 2, and hollow grinding Y and Z.
SUCCESS in producing good threads with a single-point tool (screwcutting in the lathe) depends on quite a number of factors — the condition of the lathe, the setting of the tool, the type of material, and, by no means least, the manner or sequence in which the cuts are taken.

To obviate shake and endplay, the lathe spindle bearings and thrust must be in proper adjustment. Indentations of centred work should be clean and accurate, and sufficiently large for firm support and resistance to wear — on the tailstock centre, which should be constantly lubricated and from time to time checked for setting. The cross-slide should be adjusted to noticeable (but not heavy) friction against the feedscrew; while topslide friction should be fairly heavy to prevent inadvertent movement. Saddle and leadscrew must also be well adjusted.

Using a gauge, as at A, tools can be checked as they are ground to shape and given clearance, and as they are afterwards set up. Holding edge W-WI to the face of a chuck or the work, an internal tool can be checked for setting; while an outside one can be verified in a similar manner by presenting edge X-XI to the work. Such a gauge has vees of 60, 55 and 47-1/2 deg., covering metric, US, Whitworth and BA threads. A single face at 14-1/2 deg. provides for checking and setting tools for Acme and standard worm threads.

Given that a thread is fine pitch and consequently shallow, no difficulty is likely to be encountered merely by taking a series of cuts with straight in-feeds, whatever the material. Again, should the material be brass, phosphor-bronze, or cast iron, all of which chip or flake as they cut, or aluminium alloy which cuts easily, unusual difficulties are not likely unless the threads are coarse and deep. But any steel or tough material, even with threads of quite small or moderate pitch, will almost certainly give rise to difficulties-roughness, digging-in, stripping — owing to the converging flows of metal as the thread deepens.

The remedy, of course, is to avoid this self-obstructing flow of swarf, by arranging for the tool to cut, wholly or at least substantially, on one edge at a time, when the swarf runs off as a single flowing ribbon, or in regularly-twisting and breaking curls. That is the merit of a topslide setting, at half the thread angle, as at B, when the tool is fed straight down one flank of the thread, as at C.

Such an arrangement, however, contains a number of drawbacks, and has no advantage over a regular sequence of cuts. The “generated” flank of the thread is rough and requires finishing by a backcut. With a whole-form tool, there is still a risk of a dig-in at times-ovibiated by using a relieved tool as shown. Tool overhang is fairly large, and a special clamp may be needed. The slide may obstruct either the chuck or the work, and double or multiple-start threads can be finished only at some risk of their being out of accurate phase. Depthing requires use also of the cross-slide.

A regular sequence of cuts is based on the principle at D. On one flank of the thread, a cut of equivalent depth can be obtained by a topslide feed Y, or a cross-slide feed Z. Thus, a cut Y will be on one flank, and the cut Z following will be of the same depth on that flank, and cutting also on the other flank at the bottom, bringing the tool into the full form of the thread.

Proportions vary according to thread angle, and may be held from zero on the micrometer collars. Taking Z as 0.100 in., Y is 0.060 in. for metric and US threads; 0.052 in. for Whitworth; and 0.044 in. for BA. A first cut taken as E1 can be followed as E2 (Y), then as E3 (Z); and a backcut E4 will give clearance and finish, for beginning again. The same is true for internal threads, as at F1 and 2.

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Preparing for screwcutting

By GEOMETER

Unless an external thread stands proud of any adjacent features, as on a worm, or an internal one is open each end, as on a nut, some preparation is usually necessary or advisable before screwcutting begins, or sometimes before producing the thread by dies or taps. This is so where an external thread ends at a shoulder, or an internal one at the bottom of a blank hole.

In such an event, too, the mating part may have to run right up to the shoulder, or almost to the bottom of the hole—which necessarily involves precise clear threads as far as possible, and then clearance so that the threads are free for the components to engage in the manner intended. Without such precision, some unnecessary length would inevitably be incorporated on components—to clear the tailing out of threads at the ends—hardly to be regarded as neat compact design.

The means of providing clearances at the ends of threads, external and internal, are grooves as at A, usually produced with a round-nosed tool to the depth of the threads, and generally about a pitch wide for V-threads, and somewhat more than half-pitch for square and other threads.

In screwcutting, the tool can be run along until it is just clear in the groove; then the leadscrew nut can be disengaged, the feed retracted, and the saddle returned for the next cut—all quite deliberately. The alternative, in the absence of a groove, is usually to withdraw the tool quickly towards the end of the thread, perhaps simultaneously disengaging the leadscrew nut-success in which obviously requires unusual skill or luck.

If threads are to be produced by dies and taps, grooves can still help considerably. On a second application of the die, running its square back end up first, the end thread or threads will clear in the groove; and the same happens with a plug tap, when the size of the hole is such that it has been possible to use a boring tool in it.

In preparing an external blank, it is turned to nominal size, and the groove machined and the shoulder cleaned up at the same time if desired. Preparing for screwcutting a hole, it should first be bored to nominal size, less twice the depth of the thread (using a simple turned-up gauge for checking); then the round-nosed tool is entered, touched to the bore with correction of the cross feed micrometer collar, taken to the end touching with the lathe stopped and then brought out to thread depth with the lathe running at moderate speed.

For square threads, a groove can be provided as at B1, though it is sometimes undesirable from the local weakening occasioned. An alternative is a hole or slot produced by milling, or by drilling two holes close together, as at B2; and although overcoming the strength problem, care is required to stop the lathe, or retract the tool fairly precisely.

Another method leaving a neat run-out end to the thread, as at B3, without the risk involved with tricky tool retraction, is to machine a slot with a keyseat cutter of suitable width and radius, as at C, X-X; then the tool can run clear with time for easy withdrawal. If a V-edged cutter is used, the method is also applicable for neatly-finished V-threads.

Work too long for the lathe can sometimes be set up as at D, and a start made in cutting where the thread normally ends. Either a turned groove or a keyseat cutter slot can be used to enter the tool, the short milled or drilled groove, B2, not being practicable.

Screwcut work to be reset for correction, in the absence of reference diameters, may present a problem in truing—which can, however, be overcome as at E. The mounting plate on the sliderest is moved with the V-plunger in the thread, the leadscrew nut engaged and pulling the lathe round by hand, when run-out on the effective diameter can be seen and corrected.
Picking up screw threads

By GEOMETER

WHETHER or not threads will pick up with facility in screwcutting depends on their pitch (reciprocal of their t.p.i.), and on the pitch of the leadscrew. The process may be simple where the lathe has a screwcutting dial, but not all machines are so fitted, and their use without costly mistakes calls for a return to first principles. Of course, if the thread to be cut is short and the lathe can be reversed, the answer may be to keep the leadscrew nut engaged.

Ordinarily, however, other methods are necessary, and the proper picking up of threads, even those with "round" numbers of t.p.i. depends on the leadscrew of which examples may be found with 4, 5, 6, 8 and 10 t.p.i.

Taking as examples, threads of 16, 20, 24, 28 and 30 t.p.i., threads 16, 20, 24 and 28 will pick up anywhere on a leadscrew 4 t.p.i.; threads 20 and 30 will pick up anywhere on a leadscrew 5 t.p.i.; threads 24 and 30 will pick up anywhere on a leadscrew 6 t.p.i.; threads 16 and 24 will pick up anywhere on a leadscrew 8 t.p.i.; and threads 20 and 30 will pick up anywhere on a leadscrew 10 t.p.i. In each case, the others would require care.

The reason is as follows—with a leadscrew 4 t.p.i. as the example. In making one turn, the leadscrew advances the saddle one pitch (1/4 in.) and in that distance, the work must have made a number of whole turns—four for 16, five for 20, six for 24, seven for 28 t.p.i. In the case of 30 t.p.i., there would be seven-and-a-half turns of the work; so engagement anywhere might be the half-turn wrong—and the same for other leadscrews and threads which do not work out completely.

For threads which will not pick up anywhere and are odd whole numbers of t.p.i., the simplest method is to work to the nearest whole inch on the lathe and turn the leadscrew. In turning its full number of t.p.i., a leadscrew advances the saddle 1 in., and any thread with a whole number of t.p.i. completes whole turns. So, stopping the lathe and moving the saddle back any complete inch, the thread will automatically pick up again.

Having completed the first cut, the lathe can be stopped, chalk marks made on chuck and leadscrew, as at A, and a pencil mark put on the bed ahead of the saddle. Measuring back on the bed to a complete inch over the work, another pencil mark can be made, the saddle returned to this, and the leadscrew nut engaged.

Multiple start thread

In the case of a half-thread, it is necessary to work to the nearest 2 in. on the bed, since that is the distance needed to bring such a thread, 43 t.p.i. for example, out to whole turns (nine). In the case of a quarter-thread, such as 5-1/4 t.p.i., it is necessary to work to the nearest 4 in., to bring the thread out to the nearest whole number (21).

On a multiple-start thread, it is the lead which is the effective pitch for screwcutting, and the pitch is a fraction of the lead. It may be necessary to begin such a thread at a definite position, as at B, where there is a hole in the side of the round nut. With the leadscrew nut engaged, the spindle is turned to bring the feature into desired attitude; then the screwcutting tool is advanced by topslide feed to position—perhaps the face of the nut.

Individual threads of multiple-start type can be spaced in two ways. In the case of a double-start, as at C, one thread is cut at the first stage; then working the same, the tool is advanced a whole pitch for the second stage, using the micrometer collar on the topslide. Alternatively, as at D, where X is the spindle gear, Y the intermediate, and Z the leadscrew gear, the gear train can be disengaged, and the spindle rotated a half-turn from one mark to the other on its gear.
Screwcutting long threads

LONG types of screw of square-thread or Acme form, for use as leadscrews, feedscrews, jackscrews— and for many similar purposes—present problems of production which do not occur in shorter varieties of screwed components. With the latter, there is usually no problem of support when they can be held in a chuck or mounted on the faceplate; and even if the tailstock has to be used, a tool set-up can generally be arranged without difficulty.

It is otherwise with very long threads as, apart from anything else, the length demands use of the traveling steady close to the tool position to obviate spring and wobble with the work pushing away from the tool on a normal depth of cut, and digging in when the cut is increased.

That is to say, as in ordinary turning, functions of the travelling steady are to keep the work turning truly, and to provide the rigid backing necessary to control depth of cut. On a long screw, too, with the tailstock close up, a fairly considerable forward overhang of the tool may be necessary for the topslide to pass along by the tailstock for beginning the cut. Because of the rather heavy cut normal for broad threads, the tool would be subject to spring and chatter, unless supported with packing between it and the cross-slide table, as at A.

Position of steady
Setting of the steady in relation to the tool can be important; and normally the two should not be directly opposite, as there is a good chance of swarf from the tool running round and getting between the work and the steady jaws—which would have the immediate effect of greatly increasing the depth of cut and possibly breaking the tool. Hence the steady is usually somewhat before or behind the tool.

Of course, in a position before the tool is not practicable if the thread diameter is less than that of any plain portion or boss further along, as there would be a shoulder obstructing the steady jaws before the tool arrived at the end of the thread. With the steady positioned behind the tool, the tailstock alone supports the work at the start of the cut, as at B1; then, after the first few turns, the steady comes into action, as at B2, providing support to the end of the cut.

A number of cuts must be made to bring a square or Acme thread to depth, and after the first one the steady jaws are running on reduced support, touching only at the original diameter. With several cuts on long traverse, this can result in wear on the steady jaws, which become grooved from working always in the same relationship to the tool, as at C. It may be noticed by irregularities or difficulties in the cut, and by a "clicking" as the saddle is returned. On a one-off job, the effect may be slight and not occasion difficulty, though there are often points to watch.

Alteration of tool
Any alteration of the tool sideways, such as if it has to be removed and sharpened (which is best avoided, if possible, in the course of cutting a square-thread screw), may result in very thin edge support, as at D1, with impending variations in cut. If the steady runs before the tool, there will almost certainly be variations in cut with any type of grooving of the jaws. With the steady providing proper support, at position D2, there would be slack support on the thread; while firm support on the thread would give extra depth of cut at the position shown, with the possibility of tearing the work, or breaking the tool.

Given that the tool cuts freely, many difficulties can be avoided by ensuring the steady jaws are true, and bed on the work to maximum curvature, as at E. This demands preliminary machining, and truing when necessary, with a fly-cutter bar of work radius, adjusting the jaws and traversing the saddle, as otherwise the flat ends of the jaws would wear ridged.
Accuracy in thread cutting

By GEOMETER

It is a merit of a screwcut thread that, whatever faults it may possess, it is always true with the end face or any shoulder on the work-assuming, of course, that all operations have been performed at a single setting, or that for the screwcutting operation the work has been properly set up. The thread may be fine or coarse, badly-shaped, undersize or taper, but at least it is never out-of-square.

This inherent squareness can be an important or even vital feature in the practical construction and assembly of components. It does not follow automatically when, for speed or convenience, threads are produced by other means such as taps and dies; and in its absence, assembly or functional difficulties may occur.

Two faces, whether shoulder-type or taper, pulled together by accurate screw-threads, abut extremely firmly, and the reaction is a purely axial one completely free from tilt. Parts such as caps and plugs, or screwed-on heads of engines, can be pressure-tight without effort or precaution; and squareness of alignment follows when, for example, such a construction is employed for attaching a web on a crankshaft.

In the absence of squareness and accuracy, a wedge-shaped gap is left between the faces of screwed components, as at A, and this can result in pressure leakage, or difficulty in making a joint with a washer; or strain, malalignment and insecurity in the case of a constructional feature. Where the fault is on the thread of studs, or in the directional alignment of tapped holes, there may be direct assembly difficulty from inability to fit a cover.

For correction, a component with an internal thread can sometimes be mounted on an accurate threaded mandrel in the lathe, and the face trued by a light cut. A faulty stud can be renewed; but if a tapped hole is out of true, about the only thing to do is to fit a stud tightly, screw on a nut, and with hammer blows bring the stud up square.

Better than correction at any time is to ensure that threads are produced squarely, or at least as closely as possible approaching that condition. In many instances, particularly if components are already on the lathe, it may be convenient to screwcut threads to about three-quarter depth, then clean and size them with a die—which will be relieved of a considerable amount of work. The same is true for internal threads large enough to be screwcut before finishing with a tap—a procedure essential for threads too large to tap straight out, but needing to be quickly and uniformly sized.

On work of a size normally tapped, accuracy can be ensured, as at B, by supporting the tap from the tailstock centre with the tap wrench resting on the topslide, pulling the chuck round by hand, and feeding up the tailstock barrel. If there is no centre at the end of the tap, a small hollow centre must be used in the tailstock. For work requiring an external thread, as at C, the principle can be employed with an ordinary die-holder, supporting this from the topslide, and backing up the die from a flat or pad centre in the tailstock—when the die should be fitted the reverse way to normal for its throat, as usual, to run first on the work.

Accuracy of threads in medium and small tapped holes follows from using a guide either tapped squarely itself or drilled square to the nominal diameter of the tap. Location to the hole to be tapped can be obtained from a short length of rod of core diameter when the guide hole is tapped, or stepped when it is plain, as at D. Then guide and work can be clamped.

A bench or pillar drill, its chuck locating, not gripping, the shank of a tap wrench, may be used for accurate tapping as at E, the work held or clamped on the table, and the tap holder turned by fingers. Starting a die squarely, as at C, it will often continue truly on work transferred to the vice, or a guided die-holder can be used, of which a simple example is as at F.
WHILE standard methods of thread production take care of normal cases, problems occasionally occur when, for some reason, such methods are inapplicable. It is so if a thread needs to be cleaned at the far end or extended on a stud or bolt of unusual pitch (metric, perhaps); or if a bolt or component is hard-and so cannot be touched by a die or cleaned by screwcutting in the lathe. Again, if a thread is taper, it raises the problem, in the absence of special equipment, of how to produce it initially, or clean it up when it becomes worn and rounded at the crests.

When work should proceed straightforwardly, difficulties may occur if material is hard or tough—such as cast steel or stainless steel; and extra care is advisable, such as when using a die to bring the thread to depth in two or three cuts. For the first one, the die should be opened to its full extent and worked carefully—with lubricant.

**Bursting force**

Unless the die is a good fit in the holder, the two side screws should be tightened for support after the central expansion screw has been regulated; for without this support, hard or tough material can exert a bursting force on a die sufficient to break it at one of its clearance holes.

For the second cut, which may be all that is needed, the die can be closed as necessary. Then if the thread has to be full depth to the end, the die must be run on finally the reverse way; and again some care is required, since the 'non-throated end will encounter a thread or two of shallow depth, which can easily chip one of the cutting edges.

A thread which is uniformly tight throughout its length can be lapped as required at full form, in the roots, or on the crests. A nut cut through one side, fed with abrasive paste and gripped with pliers will serve at times for a full form lap, and drilled out for clearance at the bottom, it will deal with crests of threads. A component which can be rotated in a lathe can be lapped at the roots of its thread, drawing down on to them an abrasive-fed wire of suitable size.

A taper thread usually found on the ends of polishing spindles for mounting a cloth mop or felt bob, screwing it on as at A, can occasion a problem when it has to be cut or cleaned: Such a thread may, of course, be right-hand or left-hand, depending on which end of the spindle it is, to keep mop or bob fixed by normal rotation; and following it on a normal lathe calls for a sliding tool or separate movement of the cross-slide, since the angle is much too steep for the problem to be overcome by setting over the tailstock.

**Cone and indicator**

Given reasonable dexterity on the lathe, and an easily-read indicator, a solution is to be found as at B. A cone of the same angle as the nose of the spindle is made in a freely-turned material such as aluminium-alloy and attached by a grubscrew. The screwcutting tool is set to the nose, and the indicator to the cone—and in the course of the cut a steady reading is maintained on the indicator by advancing the cross slide.

With a left-hand thread normally rotating, it is standard procedure to begin at the left and finish at the right so the taper thread is simply followed down with the feed. With a right-hand thread, however, it would be a risky procedure easing the tool back to the larger diameter, against continuous advance, and contending with backlash on the feedscrew. For this, then, it is advantageous for the lathe to rotate backwards and the tool to be mounted upside-down, to employ the "following down" technique as before.

A thread which must be ground to finish can be dealt with on a jig, as at C. A nut can be brazed or welded to a holder, mounted on the topslide, the shaped grinding wheel aligned, then the component screwed slowly in. On a more elaborate jig, as at D, location can be from a spring-loaded plunger.
An easy solution to some difficult problems

Thread grinding

By GEOMETER

Compared with machining, the general advantages of grinding are greater precision, smoother finish, improved control of cut, ability to deal with hard or tough materials; and where difficulties would be encountered by other methods, there may be the only possible way of performing the work. All of this is true to some extent in thread production; and for the special or awkward job, grinding may well provide an easy solution to some otherwise difficult problems on external threads.

There are two principal ways of arranging thread grinding set-ups on a lathe, one employing a grinding head (or portable grinder), and the other a jig. Using a grinding head, the set-up can be as for ordinary screwcutting; the job mounted in the chuck, with the shaped grinding wheel substituted for the screwcutting tool and fed into the work from the cross feed, and the saddle traversed by the lead-screw. Using a jig, the grinding wheel is run in the chuck, and the work is mounted and rotated in a holder.

If there is a partly-formed thread on the work—as from a previous screwcutting operation, the essential advance as the work is rotated can be obtained by arranging for a plunger to engage the thread; or the holder may incorporate a threaded sleeve both for mounting and to provide the advance; and the pitch of the ground thread will then be the same as that on the sleeve. By this means, it may be possible to thread cleanly and precisely, one after the other, a number of small or delicate parts—with the added advantage that, whereas a grinding head or portable grinder might be expensive, the jig can, perhaps, be made up from oddments.

Whichever -set-up is employed, the grinding wheel must necessarily be trued to the flank angle of the thread; and in each case this can be done on the lathe itself, given a diamond tool or dresser. For the jig set-up, with the grinding wheel running on a mandrel in the chuck, flank angles can be produced by mounting the diamond tool on the topslide, setting this round each way, and taking fine cuts off the edge of the wheel. Using a grinding head or portable grinder on the topslide, this is again set round each way, so that cross feed can be used to take the running wheel past the diamond tool mounted in the chuck, as at A, and in the tailstock, as at B.

The thread produced can be as at C, with small flats at roots and crests often satisfactory in any circumstances and, in fact, standard in Europe and the USA. But a radius can be produced using the grinding wheel by carefully touching the corners with a piece of broken wheel, while crests can be radiused on the work by subsequent lapping.

With each type of set-up, work and grinding wheel axes should diverge from parallelism at an angle equal to the slope of the thread Y-Z, as at D.

This angle varies according to the pitch and diameter of the thread; and is the angle whose tangent is pitch/circumference at the pitch diameter. For right-hand threads, the grinding head or jig must be set with its rear or right-hand side high; and often a set-up is best made on the vertical slide using an angle plate which can easily be tilted.

For setting up in this way a simple jig for small parts can be made as at E and F. The body portion, a rectangular block of aluminium alloy for easy machining, can be bored and screwcut in the lathe with a thread of the required pitch, drilled and tapped for a gripping screw (to regulate friction), split, and drilled for a mounting bolt. The threaded sleeve, which can be in brass, is bored or drilled and reamed for the part to be a good fit. The nose end is split to close by a clamp, and a filed or milled hexagon at the opposite end provides for turning by spanner.
Without too much time spent on their construction quite a variety of work can be performed with simple grinding jigs—facing, shortening, truing, polishing and similar operations on screws, rivets, nuts, washers, collars, valves and other parts. The problem usually comes down to holding and presenting small parts firmly and expeditiously and even where the actual operation could be done with a file, a grinding wheel may prove much more speedy and satisfactory, as it can make up for in peripheral speed what may be lacking in heaviness of cut.

In fact, in certain circumstances of metal removal, a grinding wheel may be compared with machining or hand processes as a turbine to a reciprocating engine from the point of view of power. High surface speed and light pressure take off metal equally as high pressure and low speed—in the manner that a turbine obtains its power from revs, not torque.

**Problem of holding**

With this in mind, the situation may be crystallised by some circumstance such as the need for a few screws or rivets of non-standard length. Long ones can, of course, always be snipped or sawn, but then there arises the question of finishing, resolving into the problem of holding.

After some essays with a file, grinding appears to have tempting possibilities, though in the absence of an organised method of holding, objections are soon discovered: damaged nails, overheated fingers, screws or rivets varying in length with ends out-of-square, some snicked along the side—and the occasional one flicked on the floor. Holding in pliers, too, leaves a good deal to be desired, as does holding in a vice.

All objections may be overcome, however, using a simple jig, a piece of flat metal of suitable thickness, drilled for screw or rivet to be pushed through. For finishing by filing, there needs to be a clamp on the back—owing to the considerable pressure involved in the process; but for presenting to a grinding wheel, as at D1, screws to be slightly shortened, turned in with a screwdriver can be squared and brought to length in a single operation. Chamfering or pointing on the ends, as may be needed can be done, as at D2, in a plain-hole jig set at the appropriate angle.

Valve ends, or tappet heads that are hard but nevertheless hollowed, can be ground flat and square in a plain-hole jig, as at E, a jig made from a block of aluminium drilled and reamed, or bored to size. Components pushed through it are pressed up to the grinding wheel and rotated by hand.

Using a slightly more complicated jig, as at E, angle faces on valves may be ground. Two drilled plates screwed to a block locate a valve by its stem, and a third plate acts as a stop. With the device angle mounted on the topslide, the cross slide screw puts on feed. The valve, kept pushed down to the stop plate, may be turned by a screwdriver or suction-cup stick, depending on whether or not the head is slotted.
Perhaps because rockers are about the simplest, most compact means of changing or completely reversing the direction of straight-line motion (of a "push" type) through short distances, they are commonly employed in i.c. engines for operating overhead valves.

In multi-cylinder car engines, where they are most numerous, the straight-line motion, in an upward direction, originates with the tappets operated by the cams. Push rods with rounded ends fitting in hollows in the tops of the tappets continue the motion— with a small degree of side-swing at the top. Here, their hollow or socket ends engage adjustable ball screws in the outer arms of the rockers, which, mounted on a fixed shaft, have the function of simple levers with an upward swing. The opposite or inner arms, moving in reverse arcs with a downward swing, bear directly on the ends of the valves, which, constrained by their guides, open straight downwards. Thus, the push-type short-distance straight-line motion is reversed in the simplest possible manner.

Working clearances on the gear are set from the adjustable ball screws, and checked by feeler gauges between the ends of the valves and the rockers, where a radius on each ensures smooth working. However, in the course of time, from the sliding as well as pushing action, and the small area of contact which means high unit loading, fairly substantial wear occurs, marking the end of each valve and indenting the rocker. Consequently, clearances can no longer be accurately set apart from the possible ill effect the change in geometry may have on smooth action.

Jig for valve ends

The valve ends which should be flat and square can be dealt with easily on a simple grinding jig having a drilled and reamed hole through which the stems can be pushed for the ends to contact the face of a grinding wheel; and when wear on rocker radii is slight, correction is possible by hand honing with an abrasive slip. In the case of substantial wear, the rocker radii must be ground either on a forming or a generating principle— for, of course, they are hard. Grinding on a forming principle, as at A, a broad wheel has the appropriate radius. A simple jig, with a flat base to mount on an angle plate on the vertical slide, has a pillar for the rocker, and an angle bracket to bolt up its screw end.

In setting up, unworn parts of a radius locate a rocker into the wheel; and in grinding, the cross-slide puts on feed, and the vertical slide brings the rocker up past the wheel. In this way, a set of rockers can be trued very easily, when the wheel has been prepared, as at B, with a diamond tool set to radius in a swivelling holder, mounted in a built-up bracket on the angle plate.

Using a swivelling holder

For setting the diamond tool, the swivelling holder can be removed from the bracket and laid in V-blocks on a surface plate, so a height gauge, suitably adjusted, can be applied to the tip. Cuts on the wheel should be very light— put on by cross-feed— and the holder swivelled by hand.

Grinding on a generating principle, as at C and D, the rocker must be on a swivelling holder, mounted in a bracket similar to that for the diamond tool. Contact is made on the face near the outside edge of the wheel, which can be a straight type, although a flaring cup or saucer wheel may be needed for some rockers— depending on how the radii are located.

The baseplate of the holder should be slotted to admit of adjusting the pillar, which may be provided with collars to facilitate fitting off-set or "handed" rockers; and an angle bracket, brazed or welded to the baseplate, should carry an adjustable backing screw, to use jointly with the pillar for locating the rocker radius about the axis of the swivelling holder. Setting up must be done experimentally on the first rocker, and feed put on moving the saddle on the lathe bed.
Grinding spherical and annular radii

As in the case of rockers for o.h.v. engines, the requirements of components carrying a radius which is no more than a regular curve along a straight edge can be met by set-ups, either on forming or on generating principles, where the grinding wheel is run on a mandrel in the chuck and the components are mounted on suitable jigs, often in conjunction with the vertical slide.

If need be, quite a lot of work can be done in this way, but the method is not applicable where radii are spherical (either external or internal) or annular, forming a circle round a periphery or in a face, or joining a diameter to a shoulder. For features such as these—common enough for ball pins, ball screws, journals on shafts, ball-race-type components, the work must revolve as well as the grinding wheel, and so should be mounted in the chuck; which means there must be a portable grinder or motorised head on which grinding wheels can be mounted.

Within scope of lathe

Given either of these, however—and suitably dressed wheels—some of the more common spherical and annular radii come within the scope of the lathe, and, indeed, advantageously so from the capacity of a grinding wheel to deal with hard materials, with light regulated cuts on lines of contact, the length of which would inevitably defeat form tools from the heavy chatter induced.

To be certain of good and accurate results in grinding, the wheel should be set up to contact the work at centre height; and it is generally advisable that it should then be dressed before being used. For grinding a plain diameter, this means the diamond dresser must be fixed at centre height, either on a bracket on the bed, or perhaps more conveniently in a holder in the chuck. Then with the wheel running, cut can be put on from the cross slide, and traverse made from the saddle. The grinding wheel will then spin truly, and touch a diameter across all the periphery.

By GEOMETER

The same applies when a swivelling jig mounts the diamond tool to generate a radius on the wheel. The diamond tip must be at centre height and capable of being swung at the appropriate radius. The base of the jig may be adapted to mount on the lathe bed; or the bracket may have a spigot to grip in the chuck. In the case of a build-up jig, as at A, the plate indicated can be flat and bolted to an angle plate on the faceplate. Dimension X to produce a convex radius on the wheel, or Y to produce a concave one, can be arranged by suitably setting the diamond tool. When necessary, the swivelling holder can be held by a sliding plunger tightened by a screw; and it is also advantageous for the plate to carry stop screws, obviating excess movement on the holder.

Finishing internal radii

Thus, in dressing a wheel as at B1, the diamond toolholder can be clamped by means of the screw and plunger at its most remote position for finishing the straight periphery, and unclamped and swung either way for producing the radius at the ends, the holder coming up against stops. The radii at B2, 3 and 4 can be produced simply by swinging the toolholder—and for 3 stops are advantageous to avoid digging in. A mounted wheel, as at B5, easily dressed barrel-shaped with a convex radius on its periphery, can be employed on occasion to finish sections of internal spherical radii.

Typical applications of the form-dressed wheels appear at C, D and E. As at C1, ball pins can be accurately finished-then checked for size by micrometer measurement. In-feed and a radius gauge will finish ball screws as at C2; or a straight saddle traverse and cross set-up will do the same, as at C3. Annular and shoulder radii may be finished with straight wheels as at D1 and 2; while a track in a face and internal radii can be finished with suitably-shaped mounted wheels, as at E1 and 2.
WHEREVER there is a constant need for pieces of accurate material, as in a machine shop to use as packing or gauges, or in a toolroom for making into jigs and fixtures, grinding is almost certain to attain some prominence from the facility with which faces can be finished flat and parallel.

Using either of two types of machine, it is a simple enough matter to clean and true material whether as plate or in bars or blocks, to reasonable basic accuracy. This by itself even in such elementary shapes, solves many practical problems. A vertical spindle surface grinder may be used, or alternatively a horizontal spindle, universal or toolroom machine. Fortunately, the principles of both can be duplicated on a lathe equipped with a vertical slide, though not the speed of production, nor as a rule the facility of setting up—neither of which, however, may be of first importance when a lathe must be used.

Vertical feed

On a vertical spindle machine, a cup type wheel is employed; and the material, clamped on the flat slide or mounted on a magnetic chuck, is moved to and fro beneath the face of the wheel which is large enough to sweep at a pass, over the whole width. Vertical feed puts on depth of cut for what is largely a forming process, though with an element of generation in the sweep of the wheel. This principle is duplicated when, as at A, a flaring cup wheel is mounted on a mandrel in the chuck, with the vertical slide turned so its face is parallel to the lathe axis. Movement of the material past the wheel is given by the vertical slide feed, with saddle feed providing each separate cut 1, 2, 3, 4, and cross feed applying depth of cut.

Grinding characteristics

Both types of grinding have their characteristics. The cup wheel, because of the broad face in contact with the work, requires more power than the other to drive it. But there is the advantage that it is self-truing in working; whereas the other may need dressing straight and true before starting, and also from time to time in the course of working. On a lathe set-up, a limit may also be set on the size of the grinding wheel and the thickness of the material, owing to restricted cross slide movement.

Broad material cannot be ground on the face of a plain wheel; and narrow material can form a ridge as at C, left, tending to rounding one edge. Grinding narrow material on the periphery, it is advantageous to use the whole width of the wheel to maintain truth as in cuts 1 and 2.

Where grinding wheels, either cup or plain, can be run from a motorised head or portable grinder, material can be held in the chuck or set up on the faceplate. Then it may be convenient to bring a long strip parallel by mounting it across the faceplate as at D, clamping as at E, and employing a cup wheel. Turning the faceplate through 180 deg. and locking each time (engaging back gear to do so if necessary) any disadvantage can be overcome which might arise from limited cross slide movement.

To prevent flat material rising from its backing face when edge-clamped, a "rocking" clamp as at F, may be used. The nut on the holding bolt is left a thread or so slack while the clamp is tightened; then tightening it tilts the clamp to the back face and pulls the material firmly to it.
RUNNING a grinding wheel of either straight or cup type on a mandrel in the chuck, a considerable amount of grinding can be done on edges, faces, and ends of material, either squarely or at an angle, when the material is set up on the vertical slide or on an angle plate mounted thereon.

Together, the slide and the angle plate provide, in fact, means as convenient as any for setting up small and moderate sized pieces of material. But occasionally the restricted cross slide and vertical slide movements prove a hindrance in dealing with straightforward but lengthy material. It is then necessary to consider other means of setting up the material, given that grinding wheels can be run in some way from the vertical slide, as from a motorised head.

A suitable "platform" or mounting face must then be contrived for the material. It is to be found in a piece of true rectangular bar for lengthy material, or a piece of flat plate for shorter and wider material. The basic principle is as at A, where the material, however, is to be ground parallel. The rectangular bar is centred one end for support by the tailstock, and held at the other end in the independent chuck. It can be trued on the face and the edge by adjusting the chuck jaws to uniform reading indicator tests in the length.

Verified setting

The face can be brought vertical by indicator from the vertical slide, and kept so by suitably clamping the chuck. Material can then be clamped or bolted to the face; and if it is thin, a piece of heavier supporting material can be placed outside. Assuming one edge to be true, its setting can be verified at the ends X and Y, which should be equal height for the edges to finish parallel, and suitably varying if they are to be taper. The length it is possible to deal with is, of course, controlled by that of the lathe bed.

Where faces rather than edges must be brought into taper relationship by a straight grinding wheel, the chuck can be turned through 90 deg. to bring the locating face to the top, checking the cross-wise setting horizontal with a uniform reading, and the lengthwise setting sloping by a varying reading on the indicator. To avoid strain on platform and chuck, half-round pieces of packing, made by filing short lengths of rod, can be used as at B. Then the material mounted on the locating face can be ground taper. The principle applies using a cup type grinding wheel as at C, when the locating face is vertical.

Apart from lengthwise slope on the platform for faces to be ground taper or angular, tilting it enables long edges to be ground at angles; and using two grinding wheels, straight and cup type as at E, similar angles of 45 deg. can be used on the edges, and grinding both at one setting without moving the material ensures parallelism.

Using one grinding wheel, similar angles arrive from turning the material; but then precise resetting is necessary to ensure parallelism. This can be achieved, however, by a strip screwed to one edge of the platform material as at F, for a roller to be used each end to locate the finished V-edge. Clamping can be at the extreme ends of the slide material, leaving a clear run for the grinding wheel.
GRINDING SQUARE AND VEE FACES

By GEOMETER

Besides flatness and parallelism, common relationships on faces of components, tools, packing, etc., are squareness, 45 deg. angles and Vs, and for these to be produced with reasonable precision it is essential to employ correct principles and some care in setting up and working.

Depending on the size and shape of a part, the problem of grinding square faces can be solved in either of two ways-using two grinding wheels, or locating from a face at right angles to that being worked. Using two grinding wheels, a straight type grinding on the periphery, and a cup (or dish) type grinding on the face, one after the other on the machine spindle, two faces of a part can on occasion be finished without moving it. Then, with two faces finished truly at right angles, the two faces to make a square can be finished by parallel grinding.

Setting up

This principle may be followed on a lathe running the grinding wheels on mandrels in the chuck, and mounting the part on the vertical slide. Even for outside faces it may be more convenient than the other, but is essential for leaving true bottom and side faces in narrow grooves in parts.

The alternative principle of locating from a face at right angles and using one grinding wheel can also derive from the vertical slide, or from the angleplate-either of which can be "clocked" true with a dial indicator. If it is necessary to use a portable grinder or motorised head, the part must be mounted on an angleplate on the faceplate, and the setting up principle is the same as that for accurate turning as at A, B and C.

To set up, proceeding on the assumption that the lathe is ordinarily true, the angleplate, because of possible errors, must be tested on line V-VI, and packed true to its backing on the faceplate if a uniform reading does not obtain. Given accuracy, the front face of the block will then grind true; and with two faces at right angles, the others can be finished by parallel grinding.

However, as this would mean changing the set-up, a backstop can be fixed as shown, and clocked to uniform reading on the cross slide feed when the front face W-WI will grind and test true. By this means with reasonable care the block can be brought longitudinally square. Then for squaring its ends a set-up can be made at right angles, clocking true on line X-XI. If required, a backstop can be fitted and when several blocks are to be finished will obviate need for individual checking and setting.

The grinding of Vs follows principles from which, with care and using only a dial indicator, it is possible to produce an accurate angular gauge for use when setting up: Employing a cup wheel on a mandrel in the chuck, and making a set-up on an angleplate on the vertical slide as at D, a piece of parallel plate with a square end brought to a stop and ground each side will have a central error this will be contained on the plate; and two such plates on a flat surface will reveal the error. By readjustment, splitting errors, an accurate 45 deg. will eventually obtain to form a gauge to set the slide.

From this a set-up can follow to grind V-blocks with either a straight or a dish wheel, as at E. Accurate grooves however, as at F1 and 3, can be finished with both types of wheel.
Grinding on the bench drill

By GEOMETER

Despite its simple construction, it is surprising how frequently the ordinary vertical spindle surface grinder is brought into general use, and how keenly it can be missed when it is not available. It is so quick and easy to go to the grinder to do what is necessary when two or more pieces of packing of the same thickness are required; when a square tool bit-hardened, of course, is oversize and too tight to slip properly into its holder; or when a disc or collar has faced flat one side, but parted off roughly the other—just a few examples of the many possible.

The uneven, out-of-parallel material, oversize tool, or defective part can be mounted or clamped on the slide—often held by magnetic chuck—the cup-type grinding wheel started, cut put on, and the job finished often before it could be chucked in a lathe or set up on a shaper or milling machine. The general layout of such a grinder is that of a pillar drill but much more massive, with fine vertical feed and the horizontal slide moved through rack and pinion from a capstan handle.

Because of this similarity, it is clear that a pillar or bench drill must have possibilities in the direction of a surface grinder for the occasional job and small, simple parts. It has a fair standard of precision, once the two main problems have been overcome—the vertical feed and the means for moving the work to and fro beneath the cup-type grinding wheel.

The grinding wheel can be mounted on a mandrel as large as the chuck will comfortably accept and with minimum overhang to ensure rigidity. For this reason too, the spindle carrier or quill should not be unduly extended. Downward feed or cut, can be regulated from the stop employed when depth drilling, a device which may be improved in facility and sensitivity and whose use overcomes one problem. The problem of moving the work to and fro may be solved in either of two ways—swinging the table round the pillar, or constructing a simple reciprocating slide.

Swinging the table

To swing the table, the arrangement and fitting can be as at A and B. The table should abut to the top of a fixed clamp, which can be fitted and adjusted for height as required, and the normal table clamp set for a moderately easy but shake-free swing. The bottom of the table boss must be true and can be made so by machining with the table clamped face-to-face on the lathe faceplate. The halves forming the clamp may be dowelled, bored, and the functional face trued at the same setting, paper between the halves during the boring giving a "nip" when the clamp is put into use. Given a dial indicator to mount in the chuck, the table top can be tested for truth and the vice for holding material, packed level.

A rack-and-pinion operated slide easy to make from flat rectangular stock using countersunk screws can be as at C and D, with dimensions adapted as required. The bed portion to bolt to the drill table consists of two pieces R, R1, spaced by centre block S (aluminium, say, drilled for holding bolts), and end pieces T. The bed should be built on a flat surface, centre spacing and end pieces faced and clamped between the sides for drilling and tapping holes.

Drilled and reamed holes accept the pinion shaft U, whose outer end can be drilled cross-wise and fitted with tommy bars, while pinion V may be soldered, and pinion V1 also soldered or pinned with the bed assembled—teeth phased to the racks. The flat top W for mounting work or vice has each end side pieces X, XI, with plates at the bottom Y, Y1 and racks Z, Z1, along the sides.
In all kinds of machining—turning, milling, planing, shaping—consistent acceptable results depend on keen tools ground to reasonably appropriate rake and clearance angles. Of course, for ordinary work, unless there is a special reason to the contrary, acceptable results will not arrive only from the use of particular angles. A normal turning tool with a keen edge, for example, may do quite well on mild steel, brass, and aluminium. It may be ground free-hand, honed up, and set by eye on the lathe according to the machinist's judgement and skill.

That is normal practice and as long as it works all is well. Yet inevitably variations occur. Angles are rarely duplicated and when they need to be accurate and consistent, the method of relying on eye and judgement is less reliable than the scientific method of proceeding on ordered lines.

In the case of small tools such as screwcutting tools, external and internal, free-hand grinding and setting by eye are possible. If the tools are large enough, setting can be to thread gauges, when it is necessary to depend on the attitude of the tips in the gauges—so the Vs may not be at fixed angles to the tool shanks. However, the use of a setting gauge is a step in the right direction. Further progress can be made by grinding not only the tool angles as accurately as possible, but also by arranging them in a definite relationship to the shanks, so that these can be referred to in setting up in the case of very small tools and tips.

Preparing tools in this way requires the use of suitable jigs and a tool grinder or a lathe with vertical slide, and grinding wheels of straight and cup types, running as fast as possible on mandrels in the chuck. For the usual straight tool bits and boring tools or internal screwcutting tools with similar shanks, a jig as at A, B, and C meets most requirements.

The mounting block to bolt up to the face of the vertical slide can be in any common material, though aluminium or duralumin would be easiest to work. A hole can be drilled and bored in the independent chuck to take the toolholder, then two cross-holes drilled. One is for a holding bolt, the other for a short plunger and, at the outer end when tapped, the locking screw. The toolholder can have a round central hole even if the bits are square, and a tapped hole for the toolholding screw. It may also be graduated to set in the block, which can be twisted on the slide which itself can be angled on the cross slide. Hence, all angles can be pre-set and duplicated. If desired, an angle-graduated plate with a tongue or stud in the T-slot, may be used between the slide and mounting block to facilitate setting.

For dealing with milling cutters and taps which must be sharp to cut cleanly without breakage, jigs are also essential. Suitable types are as at D and E. A saucer wheel or saw gummer may be used for milling cutters and a straight type with radiused edge for taps.

The jig for a milling cutter can be a plate on the angleplate on the vertical slide, with a spigot to take the cutter and clamp by a nut and a screw-n stop to locate the teeth from one another. Whenever possible sharpening should be done grinding the front edges of teeth, as this least changes the size and shape of a cutter.

The jig for taps consists of a baseplate carrying centres, one adjustable. As a carrier there of a collar with a stud sliding in a hole in the base, so the tap can be turned and set as required.
In any grinding where the work revolves, it is necessary to take account of the directions and rates of rotation of the grinding wheel and workpiece. It is otherwise where the work is flat or contoured by a shaped wheel and clamped stationary, or where it is traversed by a slide past the face or periphery of the wheel. Direction of rotation then has little significance, subject only to the cut being applied against the wheel, if there is any possibility of "gathering on" occurring. It simply means the feed is given from the appropriate side.

In cylindrical grinding with the work rotating, the same principle obtains—or should obtain—if possible. It does so in the case of a production grinder as at A1, where grinding wheel and workpiece turn in the same direction, forward to the operator as in ordinary turning. Peripheries of grinding wheel and work run in opposition with downward turning of the grinding wheel, for coolant and swarf to go down to the base of the machine.

In the normal set-up of a toolpost grinder the contrary can and often does occur as at A2. The grinding wheel runs downwards so grit and swarf and possibly sparks are not flung upwards, and the work revolves in the normal direction. This reduces the relative surface speed and admits of gathering on at times if the work when between centres, runs loose. The faster the lathe turns the greater is the loss of surface speed, and a trace of "pattern" may appear on the surface.

Reversing the lathe
Naturally for good results the effect must be minimised or overcome—which may be done in several ways. Without trouble the lathe may be run in the slowest backgear speed; and the largest grinding wheel that can be accommodated will be better than a small one, as having a higher surface speed for a given r.p.m. To reverse the lathe, and lacking any other solution, a pulley may be attached to the stud or quadrant wheel of the screwcutting train—though not, of course, running the leadscrew. Changing the grinder leads may be possible with attention to the upward fling of grit and swarf. Temporarily changing the lathe motor leads is another possibility. Obviously there is no problem where the lathe motor has a reversing switch—or for internal grinding where the normal direction of rotation is correct, as at A3.

Wheel Dressing
Dressing the wheel, too, has to be taken into consideration in achieving good results while eliminating risk. In cylindrical grinding the whole periphery of the grinding wheel should lie parallel to that of the workpiece: for if not, though the work may be performed, there is likely to be a trace of spiral on its surface. To ensure satisfaction following the set-up the wheel should be lightly dressed.

To dress the wheel periphery straight the diamond dresser can be mounted like a fixed flycutter tool in a mandrel, which can be mounted in the chuck. This is then held for the dresser to be horizontally with its tip touching the grinding wheel at the centre line. A thing to avoid in dressing is an upward tilt of the tool, as at B1, since movement may result in a dig-in which could be more or less disastrous. A downward tilt as at B2, may obtain, on occasion where the tool-mounting is fixed and the wheel traversed past it. But on a lathe where the wheel itself should be located at centre height, the horizontal mounting as at B3, is to be recommended.

To radius a wheel for grinding balls or grooves a holder which can be swung is required, and the arrangement can be as at C. The tool is clamped in the holder which can be turned in the bracket, held by a spigot in the chuck. Tool-setting can be as at D with the swinging holder in a V-block on packing on the surface plate, a reading being taken by indicator at Y, then allowance made for the distance from centre Z.

Over 260 hints and gadgets for improving workshop efficiency are contained in Aids to Workshop Practice, by C. T. Bower (Odhams. 18s.). Among the subjects dealt with are assembly methods, marking out, clamping, electrical work, power transmission and lathe work. Most of the ideas and devices are applicable to the requirements of both amateur and professional craftsmen, and though the emphasis is on metalwork, many of the methods can be adapted to woodwork and other allied crafts.—E.T.W.

23 OCTOBER 1958
By GEOMETER

Although it is possible to sharpen circular saws and cutters merely by grinding the front face of each tooth, and although this is the only method possible for some tools, a considerable amount of cutter grinding is nevertheless done on the clearance or relief angles of teeth.

It has the merit of sharpening the cutter, while at the same time bringing it circular. In a works, the machine employed is a universal grinder or a tool-and-cutter grinder. The exceptions to this method of grinding for sharpening are tools with complicated profiles, like taps and circular gear cutters. To sharpen these the only practicable method is to grind the front faces of the teeth. In the case of a tap, grinding the profile for sharpening, even if possible, would reduce the diameter and the thread produced would be too tight.

But for a circular saw, a slitting cutter, or a roller mill, the loss of diameter is of no importance. Grinding on the top face or clearance angle of each tooth has the advantage of bringing the cutter circular, so that in use the work is evenly spread over all the teeth. In some instances if the cutter is not carefully ground or the mandrel on which it is mounted wobbles this does not occur. Then there is a type of rhythmic cutting with vibration, and the finished surface is irregular or full of chatter marks.

The principle of grinding on the clearance angles of teeth is as at A. A cup-type grinding wheel may be used and the cutter mounted on a mandrel, free to turn in bearings or a bracket. A support is arranged for the tooth being ground; and the cutter is simply held by hand to the support and traversed past the grinding wheel. When a tooth has been ground, the cutter is turned to the next one without altering the feed. Naturally, the height of the cutter and of its support are such that the required angle is ground on each tooth.

Where a grinder is not available, a lathe can be used on this principle, running the grinding wheel on a block bolted to the lathe bed. For the cutter, a simple mandrel can be attached to the vertical slide which will provide the means of height adjustment. Cut can be put on from the leadscrew feed to the saddle, while traverse will be from the cross feed.

An endmill may be sharpened in this fashion, as at B, showing a method of mounting a small mill by its parallel shank in a simple jig.

Support strip on a block bolted to the lathe bed. For the cutter, a simple mandrel can be attached to the vertical slide which will provide the means of height adjustment. Cut can be put on from the leadscrew feed to the saddle, while traverse will be from the cross feed.

A lawnmower rotor or a wide roller mill, can be sharpened on lathe set-ups. With any spiral tooth cutter, either it or the grinding wheel must be traversed, while the cutter is kept down to the support strip so that it turns slightly in grinding a tooth.

To grind a lawnmower rotor, one end of the spindle can be held in the chuck, the other supported by the tailstock. Using a portable grinder the support strip must be arranged on the vertical slide when a lathe is used. Such a jig may be made by boring a hole for the mill shank in a block of material like aluminium, and fixing a support strip by screws. A collar each side of the block locates the mill, while permitting rotation from tooth to tooth. For a larger shell mill, as at C, a mandrel must be provided to mount in the jig, though the principle is the same.

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THE manner in which components or material may be broken or torn without intention, is closely related to ways in which material may be deliberately sheared in workshop operations. The principle of each operation is very similar—advance by degrees to arrive at an end otherwise unattainable; advance in the one case of a defect or crack through a component or material, and in the other of tools like scissors, snips, chisels, or shearing punches.

Usually, of course, workshop processes are accepted without reflection, or quickly dismissed as “obvious”—though the reason may not be immediately clear. If, for instance, one is chiselling a length of plate it will be found that, for a given blow, a cold chisel of moderate width will cut better and sink deeper than a broader one. Being longer the instantaneous cut of the latter meets greater resistance. Again, in the absence of a progressive cutting action, tools like scissors and snips could not be used. If the cutting edges came together immediately over the full length, they would meet too much resistance for hand tools.

This principle of progressive advance applies not only to actual cutting, but also to splitting, tearing and cracking. Relatively soft materials such as wood and paper, may be split or torn by running a fissure through them—where they could resist a total attack. In the case of hard materials which can be subject to cracking, surface finish can be a vital factor—glass is an outstanding example. Scratch the surface with a diamond or cutter and with a light tap or moderate bending a fissure can be run right through.

Although that is an extreme example it is not without parallel in engine or machine components. There the danger may be that a crack can develop from a surface defect, and y insidious advance creep through and weaken the material to the point where the remainder may suddenly break.

Circumstances leading to this are loading of parts by direct heavy tension, bending, shock or vibration—aided by any surface defect. Loading a part, as at A, gives tension one side of the centre line, compression the other, and with good design and finish the part will function without fail. But any groove or defect, as at B1, directs stress towards the centre line where there is less resistance. If the part is sufficiently loaded, a crack develops and runs through, as at B2. This may be done deliberately and quickly, as in the case of glass cutting, or when a groove is ground in hard tool steel for it to be broken in a vice from a hammer blow.

From this point of view, a high surface finish is desirable if not imperative in the case of highly stressed engine and machine parts—since ordinary machined surfaces contain irregularities from which a crack may develop, as at C. Grinding, lapping and polishing operations considerably increase resistance to crack formation from the smooth continuous surfaces presented, while burnishing and shot-peening have similar effects by closing the surfaces—the last often being employed for connecting rods in “hotted up” i.c. engines.

When a crack develops in sheet or plate material, it may often be arrested, as at D, its further progress being prevented by drilling a hole which directs stress from the advancing point round the smooth continuous surface.

From the aspect of progressive advance in workshop processes like punching, even where power is available, a shearing principle can reduce shock and admit of working to larger dimensions than would otherwise be the case. As an example, a circular flat punch, as at E, makes instantaneous contact with the material, shearing the whole perimeter of a blank at once, with considerable shock. By sloping the end, as at F, contact is made progressively from x round to y, and either shock is reduced, or it is possible to accommodate larger work.
CRACK DETECTION and PREVENTION

By GEOMETER

A PART from direct observation there are two simple ways in which cracks can be detected in components, depending on the size and type. One way is to “ring” the component with a tap from a hammer, the other to soak the component in warm oil such as thin lubricating oil or paraffin, remove and dry, and paint thickly with whitewash. When dry—and particularly if the component is warmed—the oil exudes and stains the surface along the line of the crack which otherwise might be virtually invisible.

The method is applicable to all sorts of components and engine parts. It is, perhaps, the best substitute for a proper magnetic crack test which is not always possible, and usually beyond amateur scope.

Not always apparent

In some instances, though cracks may be suspected they may not be readily apparent except under working conditions. This can be so with hot parts like exhaust manifolds, or where there is pressure as in lever type hydraulic shock absorbers. Evidence may be a trace of soot on a manifold, or persistent loss of shock absorber fluid. Warming the removed manifold with a blow-lamp may be helpful in opening up the crack; while for shock absorbers, the whitewash method is effective—paint scraped off, and the lever worked to create pressure. If stains appear, it means a new shock absorber.

Parts subjected to unusual strain should be inspected from time to time when convenient. These include steering arms on cars, which may have to be scraped and cleaned with emerycloth, and the front forks of cycles—where these join the internal head tube, and where breakage sometimes occurs.

Often, of course, cracks can be prevented by good design. Sheet metalwork which is subjected to strain and vibration can be very prone to cracking; and unless there is some support for a panel at a bracket, a crack may completely encircle a bolt, as at A. In these circumstances large washers can effectively distribute strain over a wide area. They may be round, oval or square.

Much can be done in design to distribute strain and increase the resistance of parts to cracking and failure, sometimes with less effort or weight than formerly. The edge of a panel, for example, may be stiffened by rolling over a wire, or simply by flanging—as at B1 and B2. Oddly perhaps, the latter construction is much stronger and less liable to cracking than the former when used for mudguards on vehicles.

Axles and crankshafts

Cantilever-type components like swivel axles, are smaller at the outer end than at the inner end, where the strain is greater. An overlap of crankpin and mainshaft, Z, on a crankshaft, as at C, greatly increases strength and allows the use of narrower webs. A radius at the junction of a diameter and a flange or web is always advantageous.

Where there is flexibility and insufficient support for a component, cracking can be a problem. This frequently occurs in the exhaust systems of vehicles, with the endplates of silencers breaking out. An effective way of overcoming it is to weld struts made from pieces of 1/4 in. rod from the body to inlet and outlet pipes, as at D, leaving sufficient clearance for applying clamps. The alternative would be some sort of large washer on the endplate, which might not always be effective.

The problem can be increased if the silencer has no supporting bracket. One can be provided, as at E, by welding a strip centrally under the silencer, and bolting it to flexible strips such as narrow belting, which transmit neither noise nor vibration.

Ordinary small pipes, of course, can be given an anti-strain or vibration coil, as at F, which is commonly used for petrol pipes—when for gravity feed, the coil should lie horizontally.
Avoiding assembly cracks

By GEOMETER

Besides the acquisition of positive knowledge and skill, a good part of most engineers' experience, if not training, is of a negative variety. Based on the elementary idea of avoiding immediate or subsequent trouble and expense it is none the less useful. From a limited point of view, knowing how to proceed may be quite sufficient—while circumstances remain the same; but in the wide sense they rarely do—and so may set a trap for the inexperienced, the unwary, the too bold, or those ready to take a chance.

As a simple instance, a sharp tap above a certain size may be used with a certain amount of abandon in material like brass or aluminium; but it is otherwise for one which is off-colour, used in a piece of tool steel. Experience would suggest contriving the circumstances before there is any problem, by ensuring the core hole is the proper size, and using good taper or second taps, with lubricant and care. The alternative may be starting again after removing a broken tap or obtaining another piece of material.

Unnecessary force

In ordinary assembly and dismantling where there should be least chance of error, damage can occur through strains or cracks arising from wrong or over-application of force. Use of a thick semi-soft joint on an oval flange, as at A, results in strain and bending of the flange, and can lead to actual breakage of a lug, though this may be only later should working strain or vibration be added. Thick joints resembling this are commonly used between carburetters and manifolds to provide insulation against heat; but they now consist of a piece of hard insulating material with a thin joint either side. It was not always so; and any other arrangement, as substitute or expedient, may well lead to breakage.

The forcible pulling up of joint faces when they do not meet squarely, as at B, is similarly to be avoided, and is a condition that may have to be dealt with in the case of an exhaust system and manifold. Even if a factoritively tight joint is obtained there is inevitably strain which, with vibration, may result in the pipe cracking below the flange or at the silencer. Before bolting, the faces should come up squarely by hand; and if they do not, the holding brackets should be slackened and adjusted, though the pipe may have to be removed and reset, heating to red first. Where there is a "built in

strain (and a welding torch is available), it can often be relieved by bolting up fairly hard in situ, then heating the pipe to red for a few inches, so that it can acquire a natural set.

Sometimes, driving keys in pulleys and wheels results in the cracking of bosses, and there may be several reasons—an inherently weak boss, the keyway in a weak part, an unsuitable key, or a poor fit of the boss on the shaft with constant working loose—when there is a strong temptation to use extra "beef" when driving the key in.

When a keyway is provided in a boss, as at C, in the absence of any strengthening hump (which may be advisable in design), it should preferably pass under a spoke, as at x for a little extra strength, rather than between spokes, as at y. The key should be gradually tapered and fit well into the boss, as a short steeply-tapered key may crack the front end of the boss.

Similar cracking of bosses can occur when a too tight bush is pressed or driven in, as at D, and when too much force is used for tightening a banjo union as at E—owing to the bursting effect of the thread. Used for petrol, such a union has a red fibre washer each side, and these can rarely successfully be used again. Also, at times, the banjo needs filing parallel.

Dismantling of taper-fitted parts generally demands pullers, which should be of correct type. Even where there are convenient studs or holes, a thread or groove on the boss, as at F, may indicate a puller to be fitted there, adjacent to the source of resistance.
Fitting

VALVE GUIDES

Tholgh valve guides may seem to be components of minor importance by comparison with others in four-stroke i.c. engines, their condition can nevertheless have a considerable influence on performance—when this is interpreted in terms of smooth, quiet running, lengthy periods between servicing, and moderate oil consumption. Of course not all faults attributable to valve guides are to be found in one engine, and not all arise directly with the guides. Engine types and valve gear types have effects, as also have materials and lubricants.

As a generalisation the guides of side valve engines are the most durable, usually being the longest and containing valves which receive a straight push from tappets. The guides of single cylinder o.h.v. engines are the least durable, their length restricted in layout, and carrying valves receiving a substantial side thrust from rockers moving through small arcs. For given capacity and r.p.m., side valve engines require springs less strong than o.h.v. types, there being less weight to deal with in the operating gear.

Typical faults arising with worn guides are oil leakage in the case of o.h.v. engines (this alone, or in the absence of correctly fitted seals, causing a heavy oil consumption), and rolling of the seals when valves do not seat squarely. This in turn, can lead to wide and badly shaped seats, and may help towards burning of valves in engines driven hard. Alternatively, or in addition, there may be considerable noise and carbon formation on valve stems and in the ends of the guides in the ports.

Normal valve guides are of two types—with or without a locating flange, this excluding the special Ford type split longitudinally, which has a flange. When there is a locating flange, it is always on the spring side of the guide, away from the port, and there is no doubt as to the direction in which such guides must be removed, or to what position the new ones must be brought. The situation is obvious from the supplied replacements; or if old guides are to be used as patterns for replacements, it can be ascertained by using a mirror and flashlight in the valve spring chamber of an engine still in the chassis.

For guides without flanges, there is the possibility of removing in either direction and also of locating at positions other than the original. Condition, shape and fitting of guides may provide information as to removal. Position can be checked with a depth gauge, as at A, depth in the port x, or distance from the end of the guide to the spring seat Y, any difference there may be in fitting between inlet and exhaust guides being noted.

As to condition, if the end of the guide in the port is burnt or scaled, it can be seen to offer resistance in removing towards the spring side. Ordinary carbon can be scraped off, of course. In the case of some exhaust guides, there may be relief or counterboring at the top end Z, so making the end faces thinner and more likely to break or burr if guides are tight. Scraping in their tops or using a suitable drill, can reveal this feature if it is choked with carbon.

A depth check can also be made on side valve engines to discover if the tappet screws need removing. Separate tappet blocks as on some engines, can be taken out.

Subject to such conditions, guides may be driven out towards the spring side with a stepped steel drift, as at B (fairly common for o.h.v. engines) or drawn towards the port side, as at C (frequently employed for side valve engines), when the bolt may have a circular nut instead of a shoulder.

New guides may be fitted similarly, but check for size against old ones individually. If an old guide is tight, a new one should not be larger; and may be brought to size, as at D, by mounting on a mandrel in the lathe, and reducing its diameter carefully with a Swiss file and micro-meter checks.
WITH heat taking an active part in bringing it about, a shrink fit can have certain advantages in component assembly over a normal interference fit, in which no account is taken of heat and it is assumed both components (the "shaft" and the "hole" as they may be conveniently termed) are at the same temperature.

Obviously, by varying the dimensions of shafts and holes, a range of interference is possible. This is aided by the fact that metals possess elasticity and compressibility, a fact which has long been covertly recognised in such terms as "light driving fit," "heavy driving fit," "press fit," etc.

The difference in dimensions between components providing these different fits may be quite small; so the limit is soon reached at which an excessive amount of force would be required in assembly. It is then that the shrink fit, if it is practicable, has advantages. Little physical force may be required for it; and components can be put together more firmly than they would by solely mechanical means, in which there would also be the risk of scoring or abrasion.

**Phenomenon of expansion**

The shrink fit functions, of course, on the dimensional difference between metals in the cold and hot states—a rod, as at A, lengthening as it is heated. Normally, such expansion passes unnoticed; but it becomes marked if a rod held in the vice is heated with a welding torch. It will stretch and bend away from the source of heat. The principle has a certain effect in hot-riveting, besides permitting improved swelling of the shank and facilitating formation of the head. Cooling, the rivet tends to contract lengthwise and draw the plates more firmly together—if the process is speedily performed.

It operates similarly in the case of "shaft and hole" as at B with the hole in a disc or collar too small to pass on to the shaft with both at the same temperature. But with the disc or collar heated, the shaft can enter easily, and the two lock together as their temperatures equalise. In some instances, a final tap or press may be necessary should a slight gap be left between the disc and shoulder.

With two metals having different rates of expansion, the larger rate being with that forming the "hole" perhaps subject to heat in normal working, a shrink fit may be virtually essential, as in the case of an aluminium alloy cylinder head fitted with bronze valve seat inserts. Then it is ad visable to arrange the dimensions so the inserts can only just be fitted (or with light force) when the head alone is heated. A steel mandrel carrying the insert, as at C, is needed for speedy work when the head has been heated in oil.

**Locating collar**

The efficacy of a shrink fit is such that it can be used on components in vital situations. The bearing of each rear axle shaft on one model of a well known make of car is located by a shrunk-on collar, as at D; and when bearing or oil seal has to be renewed, the collar must be cut through or turned off in a lathe. In assembling the new one, it is heated to dark blue (about 300 deg. C.), dropped and driven on. Another maker has an alternative thread and nut at the same position.

The ring gear of a car flywheel is usually shrunk on; and as at E, the seating may be behind a lip, showing a space W about 0.008 in. to a square gauge.

Removal is effected on a set-up as at F, supporting the ring gear on blocks XY, just clear of the water in which the flywheel is submerged, heating with a welding torch, and letting the flywheel drop out. To fit the new ring gear, it is expanded supported on hooks in engine oil (at 200 deg. C. or 392 deg. F., checked with thermometer Z), then lifted out and dropped—and tapped if necessary—on the flywheel.

**OVER 260 hints and gadgets for improving workshop efficiency are contained in Aids to Workshop Practice.** by C. T. Bower (Odhams, 18s.). Among the subjects dealt with are assembly methods, marking out, clamping, electrical work, power transmission and lathe work. Most of the ideas and devices are applicable to the requirements of both amateur and professional craftsmen, and though the emphasis is on metalwork, many of the methods can be adapted to woodwork and other allied crafts. - E. T. W.
Jig boring principles

BY GEOMETER

USED to its full extent with accessory equipment, the lathe is undoubtedly the most versatile of machine tools, and all types with rotating spindles owe something to it. Certainly each may perform some particular operation or group of operations faster and with greater facility than the lathe, as is the case with bench and pillar drills, milling machines, and universal and surface grinders. Various operations special to these machines can be performed reasonably efficiently on the lathe, given time, moderate dimensions in the work and some ingenuity in the set-up.

The same is true to a considerable extent of the jig-borer, which operates in the reverse way to a lathe, working with a single-point boring tool and with special emphasis on accuracy.

For a normal boring operation on a lathe, the work revolves mounted in the chuck or on the faceplate, and the single-point boring tool is set to cut and feed. For the corresponding operation on a jig-borer, the work is stationary on the machine table, while the single-point boring tool revolves and is fed.

The reason for this reversal is the nature of the work. In the main a jig consists of a built-up plate or cast box structure in which components can be placed, for drills, reamers, etc., having obtained the position of one hole (top left), the centre of another (bottom right) follows from lateral feed X and a vertical feed Y. Holes may be centre drilled, drilled, then bored from the chuck.

On a jig-borer, holes at right angles and other angles require the work to be mounted on fixed and adjustable angle plates. This principle may follow on the lathe, though some settings can be obtained by turning the slide, as at D, much easier than by the normal lathe principle. Radius machining, too, may sometimes be simpler as at E, on a saddle casting, if large.

traversing the saddle; and using a tool of reverse shape, a boss can be machined if required, as at B. Hole centres in plate material or castings may be located by marking off in the ordinary way; then the scribed lines can be set vertically and laterally to a needle point spinning truly in the chuck, as at C—the same as on a jig-borer—and noting the feedscrew readings. For the lathe setting, a needle can be soldered into a piece of brass rod. Having obtained the position of one hole (top left), the centre of another (bottom right) follows from lateral feed X and a vertical feed Y. Holes may be centre drilled, drilled, then bored from the chuck.
EMPLOYING the on a jig-boring principle, with the tool rotating and the work mounted on the vertical slide with longitudinal feed by means inevitably raises problems of setting and feeding the tool in use. For holes, it is a boring tool, of course, though parallel bosses and spigots are tackled by the same method.

It is not disputed, of course, that setting up can be done in the four-jaw chuck to virtual “spot on” accuracy—given a dial indicator, time and patience in ordinary use. But it is always noticeable on getting down to fine dimensions, that the mere pressure of the chuck jaws can have a marked effect. Slackening will set a marked wobble into the work; and the tightening of one without slackening the other can be quite sufficient to correct a wobble or start one.

In turning it may not be of great importance, because once a setting is obtained it is finished. But working with the tool rotating and needing to be set for each cut, it can present a problem towards the finish when there is no certainty as to depth of cut applied.

Fine radial feed or setting of tools can be obtained in either of two ways on the principle of the inclined plane, or on that of the eccentric. The inclined plane gives a small radial movement for a larger endwise one, and the eccentric provides a similar radial movement for considerable rotational displacement. First, however, there may be the problem of locating the work accurately by scribed lines to a truly-spinning needle which, to avoid the chuck jaw push-over effect, can be mounted in a holder as at A. The holder is held in the chuck and the needle-soldered in a hole in the central rod set true at the tip by adjustments to four small screws.

The inclined plane method of tool feed can be arranged as at B, using an angle plate on a faceplate. The fixed block is bolted to provide the guide and reference base for the toolholder, which is kept pressed up to it and unclamped, and moved endwise for setting cut. Inclination can be according to needs; but about 1-1/2deg. will give a feed of 1/40, increasing diameter by about 0.001 in. for 0.020 in. endwise movement.

**Eccentric feed**

Eccentric feed for a tool can be provided as at C. The body is circular to hold in the chuck and has a few thou eccentricity in the bore, while the taper-ended toolholder is fitted in a ring which can be turned in the body with the draw bolt slackened. Setting up adjustment can be made locating the toolholder in the ring, and final fine cuts obtained turning the ring in the body. With a four-jaw chuck, roughing cuts can be applied by adjusting the jaws.

The alternative is as at D, with a circular plate located on an eccentric spigot in the spindle bore, and clamped back to the faceplate. The toolholder is held by studs and nuts to the plate, with major adjustment made through slots. The spigot can be turned eccentrically by mounting the plug in the spindle with a strip of shimstock one side.

To set tools initially, an indicator can be mounted as at E, on the base to push across the lathe bed, picking up the reading from a mandrel turned to required diameter X, or using a bridge gauge as at F, a slip gauge Y, of radius dimension, will give the reading for the tool tip.
Locating HOLE POSITIONS

WHEN the lathe is used on a jig-boring principle, spinning the boring tool in the work clamped to the vertical slide, there are several possible ways of locating the positions of holes.

Given that the centre distances of the furthest holes are within the range of movement of the vertical slide and cross slide, and that these slides have accurate micrometer collars, the jig-boring principle can be continued even to the locating of holes. That is, having settled the position of one hole by any method, the positions of others can be obtained by appropriate feeds on the screws—afterwards clamping the vertical slide and cross slide.

Where centres of holes are beyond the movement of slides, or where feedscrews are without micrometer collars or insufficiently accurate, other methods are necessary.

If it is simply range that is lacking, or if feedscrews are inaccurate overall but sufficiently accurate locally, the principle of setting to marked-off centres can be employed. Cross lines will locate each hole-centre on the work, and can be set to a spinning needle-point by reference to the micrometer collars. Naturally, this involves somewhat more preparation of the work than where locating can be done from feedscrews and collars; but it is straightforward, and with care accuracy should be equal to that of the marking-off.

If, however, it is impossible to rely on the feedscrews, then the toolmaker's button method is essential, using a dial indicator for the actual setting. Accuracy in locating the hole positions will then depend on the precision with which the buttons are set on the work. This can be done in the normal way with micrometers, vernier gauges, block or end gauges, before coming to the lathe.

Each button is as at A, a short, parallel, thick-walled sleeve with a truly square end abutting to the face of the work—which, of course, must be flat. The bore is clearance for the holding screw; and the hole in the work having been approximately located, drilled and tapped, and the button fitted with washer and screw, the button can then be adjusted for position and held by tightening the screw.

Where there are two buttons, as at B, measurement V over them, gives the centres of the holes. The work can then be adjusted on the vertical slide, or by the feed screws, for the indicator to show a steady reading when its lever arm is turned round a button. With the hole finished, the procedure is repeated for the second one—and for any more there may be. A small mirror is useful for checking the setting-up reading, at positions where the indicator is upsidedown or facing backwards.

When holes conflict

When two button-located holes come close together, the second button if fitted with the first, may prove an obstruction for tool or swarf, as the first hole is bored. In these cases, fitting the second button afterwards is possible, using a plug in the finished hole, as at C, when measurement W over plug and button will locate the centre of the second hole.

The procedure may involve removing the work for setting the button, and this can be avoided by employing a prepared gauge, as at D. Such a gauge can be made from flat bar, drilling and boring or reaming a central hole, mounting by this bore on a spigot on the faceplate, clamping, then turning the ends to radius—when any error of measurement will be halved at the functional centres.

Having bored the first hole, a reading is taken over the plug by dial indicator, as dimension X. Then feed gives a similar reading over the gauge, as dimension Y. The work is initially set, of course, so the hole centres lie on the line of feed.

Alternatively, as at E, a second hole at centres Z may be located by removing a gauge block of the same thickness, Z1, from between a stop and the work, then moving this to the stop.

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