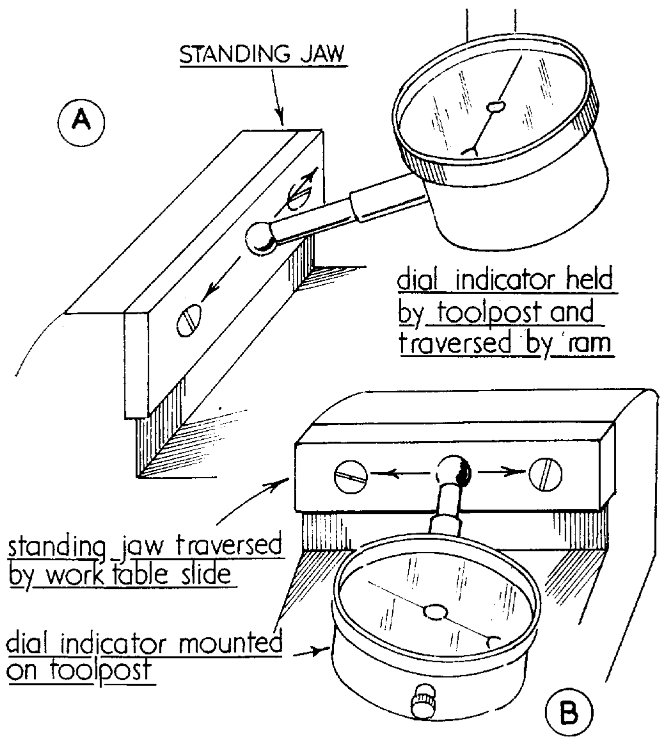
CHAPTER 9

Some Representative Machine Operations

AS HAS ALREADY been said, it is manifestly impossible to detail the procedure for every possible machining operation that can be performed in the shaping machine. In this chapter, therefore, it is proposed to deal with some operations that are representative of the many machining techniques that may be employed.

As much of the work undertaken involves the use of the machine

Fig. 1 Checking the Vice



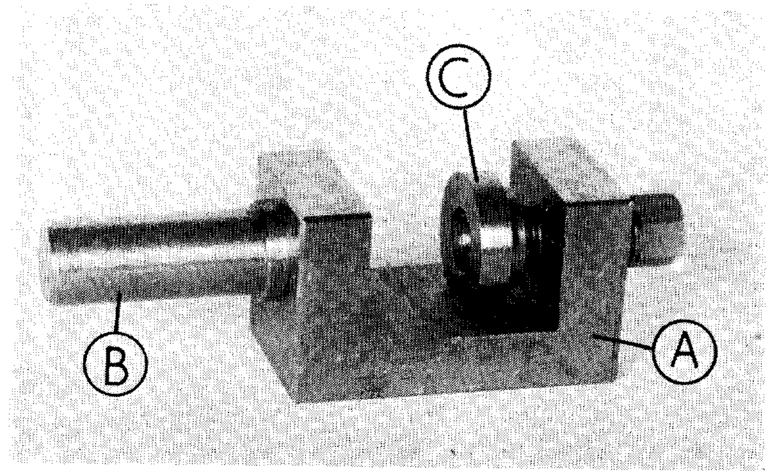


Fig. 2 Dial Indicator Clamp

vice, it is of the utmost importance to ensure that this fitment is set accurately in relation to the ram. When the vice assembly is of the type fitted to the Acorn Tools shaper, and has a tenon formed on its base to assist in rapid accurate replacement when needed, the makers sometimes leave the engraving of the zero lines on the graduated base to the eventual user of the shaping machine.

Setting the Machine Vice

The checking and setting is carried out with a dial test indicator applied to the standing jaw of the vice, the indicator itself being mounted on the shaping machine ram. In one place the foot of the indicator is passed across the face of the vice jaw by moving the ram by hand; in the other the ram remains stationary whilst the work table cross slide is operated again by hand, to provide the necessary movement of the vice jaw past the indicator foot. These procedures are illustrated diagrammatically in Fig. 1.

The dial indicator can most conveniently be attached to the toolpost or even, by means of a simple and easily made clamp, directly to the tool itself. A typical clamp of this kind is illustrated in Fig. 2. Its make-up will be evident from this illustration. The body (A) is fitted with a spigot (B) and a clamp screw (C). The spigot serves as a support for any ancillary fittings needed to secure the dial indicator itself. The parts are easily made from the details given in Fig. 3.

An alternative means of mounting the dial indicator is depicted in Fig. 4. Here the "Eclipse" magnetic base is seen supporting the

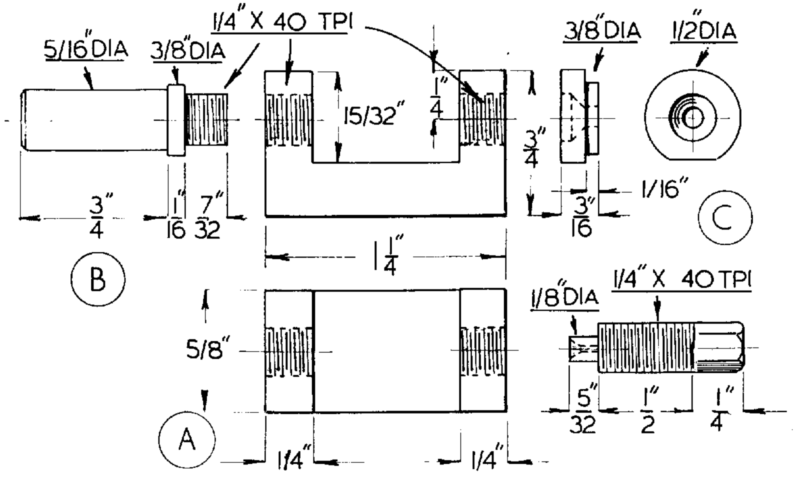


Fig. 3 Details of the Clamp

instrument which is being used to carry out the setting of the machine vice illustrated at (A) in Fig. 1. The magnetic base is a device provided with a powerful magnet system that can be switched on and off by means of the button seen in Fig. 5 at the centre of the base itself. The "Eclipse" equipment is perhaps too costly, and may be overlarge, for use on the smaller shaping machines in which we are primarily concerned. However, one of the powerful pot magnets, also made by "Eclipse", is quite suitable as an inexpensive substitute for the larger magnetic base. These magnets have a tapped hole in their upper surface, the author's example is threaded No. O.B.A., and into this hole can be set a spindle of the correct size to accommodate the clamp fittings commonly supplied for use with a dial indicator. As has been said, the magnets are very powerful. The largest being only 1 in. diameter, they take up little room so can be used on quite a small flat surface. A typical indicator mounting using a pot magnet is illustrated in Fig. 6. Having considered the matter of setting the machine vice accurately we may now proceed to the description of various machining operations.

Squaring the Ends of Shafts

It is often necessary to machine flat surfaces on the end of a shaft either to allow a spanner to be used on it or to provide a seating for a handle with which to turn the shaft. The work is held in the vice, having been first set level on parallels if necessary. Two dimensions need to be maintained; these are, first, the length of the flat

surfaces and secondly the measurement across the square itself.

Provided some form of stop can be contrived, the index on the table feed screw can be used to preserve uniformity in the machined length. If not the shaft should be coated with blue marking fluid and marked off to show the limits of the machining. The set up is illustrated in Fig. 7. The amount of down feed needed to cut the finished squre to the right size is put on by the tool slide feed screw. This amount is calculated from the formula $t = \frac{D - A}{2}$

Where D is the diameter of the shaft and A is the dimension of the finished square as shown in the diagram Fig. 8. If the shaft is large it is unlikely that the machining of any one flat surface can be performed at a single cut. Two or more passes will normally be required to complete one flat. After the first flat surface has been shaped the shaft can be turned and set in the correct position for machining the next flat by means of set square applied to the first flat. This procedure is followed until all the work has been completed.

Machining the Ends of Shafts

One has sometimes to shape the ends of a shaft in order to form a

Fig. 4
Using the Eclipse Magnetic Base

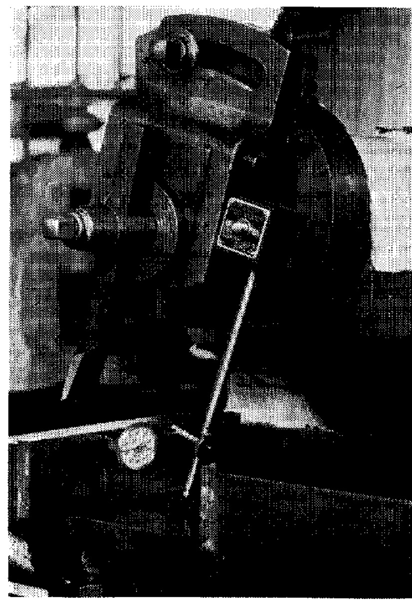
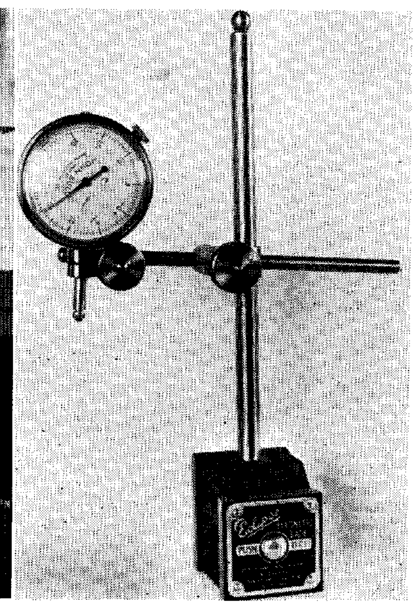
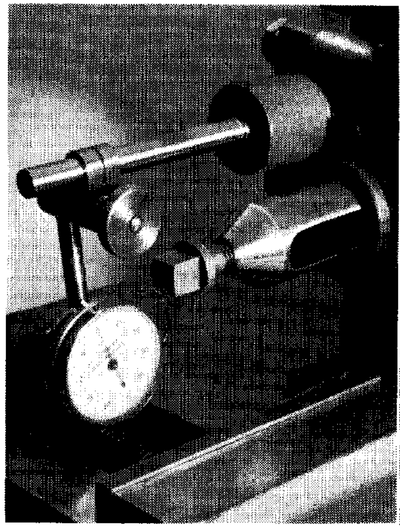
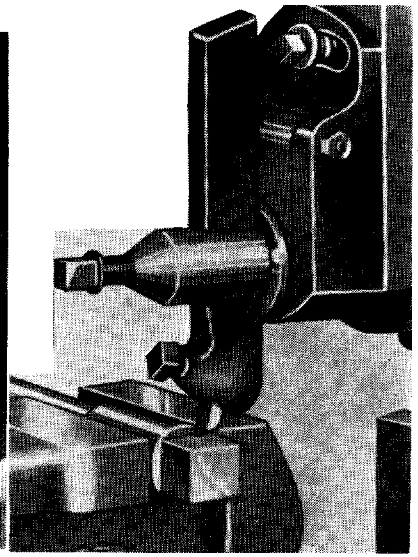


Fig. 5
The Eclipse Magnetic Base







dog that will fit into a corresponding slot in some other components.

An example in point is depicted diagrammatically in Fig.9. If the male component is very short it may be set up in the vice, gripped in an accurate V-block to ensure that it is upright, and machined with what amounts to a parting tool and so can cut on both side faces.

Some shaping machines have provision for mounting the vice on

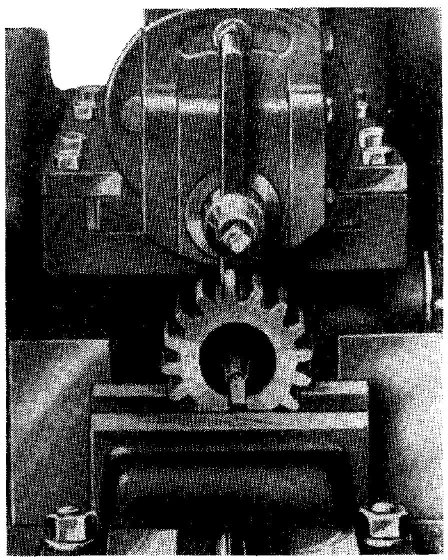


Fig. 6 Indicator mounting using a pot magnet

Fig. 7 Set up for machining squares on shafts

Fig. 10 Cutting a key in a gearwheel

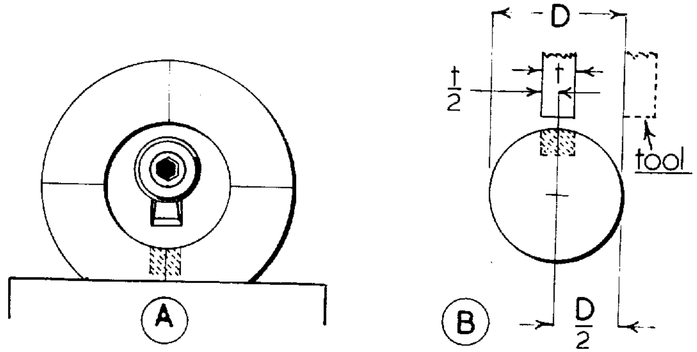


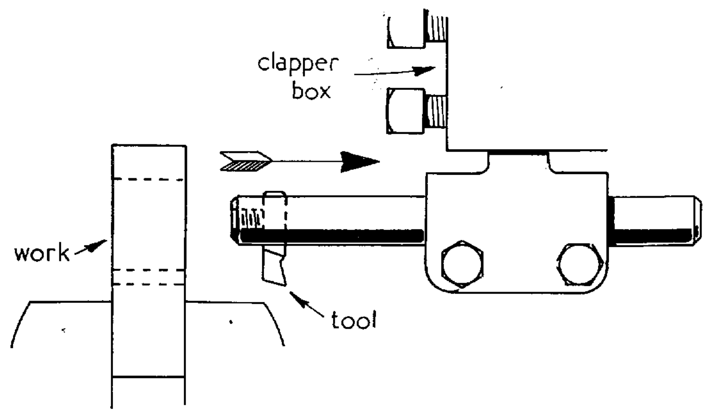
Fig. 11 (A) Setting the keyway cutter
(B) Centring the keyway cutter

the side of the work table, the Acorn Tools shaper for example has this facility. So when the work is over long it may need holding in a side mounted vice.

If the dimensions $\frac{D-t}{2}$ shown in Fig. 9 are maintained the dog will be formed centrally at the end of the shaft. When actually carrying out machining of this character, however, the author, for the most part, leaves an extra 0.010 in. on each side of the dog to be finally removed with a final cut controlled by tool slide feed screw.

When much material needs removal a pair of roughing out tools, one right-hand and the other left-hand, will have to be used before the tool actually depicted in Fig. 9 is brought into play.

Fig. 10A Set up for cutting an internal keyway



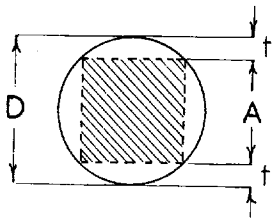


Fig. 8 Diagram to show amount of down feed

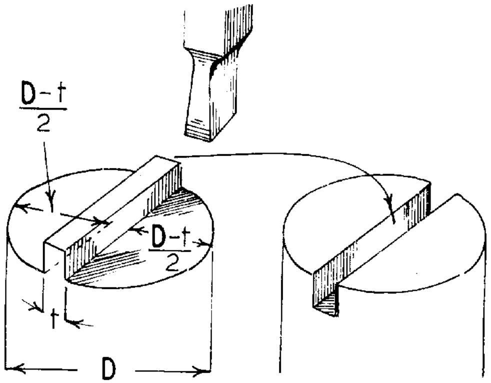


Fig. 9 Diagram to show side feed required to produce a tongue on the end of the shaft

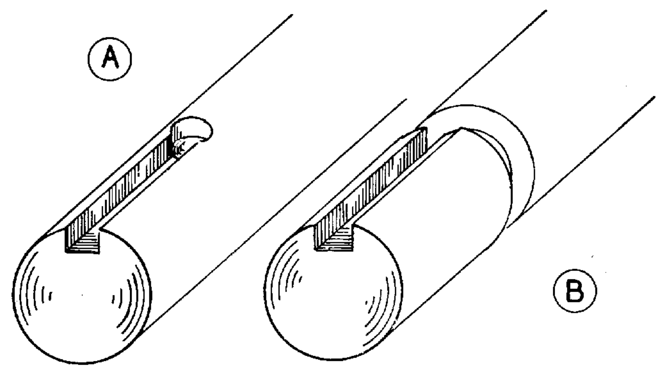
Cutting Keyways

The shaper can be used for the cutting of keyways, both internal and external. The operation illustrated in Fig. 10 is the cutting of a keyway in a small gearwheel. The tool is shown being *pushed through* the work, whereas the author prefers to *pull it* through, because in this way there can be no possibility of a "dig-in". This arrangement is depicted diagrammatically in the illustration Fig. 10A.

Small keyways are cut by a tool ground to the width of the actual keyway required and fed into the work to the correct depth by the tool slide. In a light machine a wide keyway would need to be formed in two or more cuts.

It is always essential to make sure that the keyway is machined centrally in the work. While this proviso is not difficult to maintain when external keyways are involved, it is not so simple to set the tool centrally when cutting an internal keyway. When this process

Fig. 12 Run-outs for external keyways



is being carried out the keyway must first be marked off. If this work is performed accurately the tool can be aligned with the lines of the marking off once the work itself has been set truly in the vice. The procedure is illustrated in Fig. 11 at (A).

It is well to scribe centre lines on the work itself. A surface gauge or a square mounted on the vice can then be used to ensure that the work is then secured in the vice accurately. When cutting external keyways the tool can be centred by means of a reading taken with the cross feed index dial. The required reading is obtained from the calculation depicted in the diagram Fig. 11 at (B).

Assuming that the tool has been aligned with the work as shown by its dotted outline, in order to place the toolpoint centrally over the work it must be moved for a distance $\frac{D}{2} + \frac{t}{2}$. Let us suppose a keyway $\frac{1}{8}$ in. width has to be cut with a tool of similar width in a shaft $\frac{1}{2}$ in. dia. then

$$\frac{D}{2} + \frac{t}{2} = \frac{0.5''}{2} + \frac{0.125''}{2}$$
$$= 0.250'' + 0.062''$$
$$= 0.312''$$

This movement is imparted by the work table feed screw, as has been said, and is measured by its index dial which is first set at zero after the side of the tool has been aligned with the work itself in the manner already described.

After the tool has been centralised it is brought into contact with the work, the index collar on the tool slide is then set at zero so that the amount of down feed required to machine the keyway to full depth can be read off directly.

When internal keyways are being cut, the tool, for the most part, has a clear passage through the work. Where external keyways are concerned this facility is not always available: it is therefore necessary to provide a run out for the tool point, either by drilling a shallow hole in the work as depicted at (A) in Fig. 12 or by machining an undercut in the shaft as illustrated at (B). The drilled hole should be slightly larger than the width of the keyway and somewhat deeper than its depth. The ram must be set both for position and stroke to make sure that the point of the tool cannot reach beyond the half-diameter of the clearance hole.

Cutting Racks

An operation for which the shaping machine is very suitable is the cutting of teeth on a rack. A rack may be defined as a gear wheel

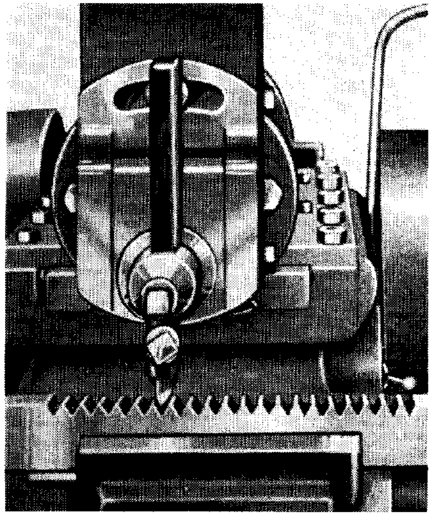


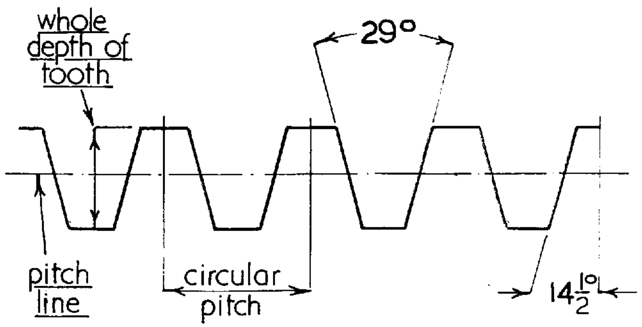
Fig. 13 Machining a Rack

of infinitely large circumference having a tooth pitch line that is for all intents and purposes, flat. Racks are used, in conjunction with gears of a variety of diameter to provide movement to parts of scientific instruments, cameras and the like.

In order to cut a rack in the shaping machine a blank is first prepared and machined in the vice as illustrated in Fig. 13. The work needs to be flat and mounted in a level manner so that each tooth in the rack can be cut to a uniform size.

Two distinct measurements govern the size of the finished rack tooth which, in contradistinction to teeth in a gear wheel, is straight sided and has an included angle of 29 degrees. The measurements concerned are:

Fig. 14 Proportions of a Rack



(*a*) The distance between the centres of one tooth and the tooth adjacent to it, called the circular pitch.

(*b*) The depth of the teeth themselves called the whole depth of tooth.

These details are represented diagrammatically in Fig. 14.

When cutting a rack in the shaping machine, circular pitch is controlled by the work table feed screw, the distances being read off on the feed screw index dial.

The whole depth of tooth, that is the amount of tool down feed required to produce it is read off from the tool slide feedscrew index dial.

In both cases the dials should be set to zero after each measurement has been made, otherwise "error may creep in" if one attempts to add successive measurements together.

The figures required for the maching of a rack are for the most part obtainable from tables, providing, of course, that the pitch of the gear, with which the rack is to be made, can be recognised.

Measuring the distance from the centre of one tooth to the next on the pitch line needs special equipment not generally available in the small workshop. However, for all practical purposes this lack is of little moment since a simple calculation will furnish the figure for circumferential pitch we require.

It is assumed that the gear to mate with the rack is available for measurement. This being so it can be used to find the circumferential pitch of its teeth by measuring its outside diameter and employing the figure obtained in the following formula:

$$\frac{OD}{0.3183 \times N + 2}$$

where OD is the outside diameter of the gear and N is the number of teeth in the gear. To take a concrete example, let us suppose that a gear having 30 teeth and an overall diameter of 2 in. is involved. Then:

$$\frac{2}{0.3183 \times (30 + 2)}$$

$$= \frac{2}{0.3183 \times 32}$$

$$= \frac{2}{10.186}$$

$$= 0.189'' \text{ Circular Pitch}$$

This is the amount the work must be moved between the cutting

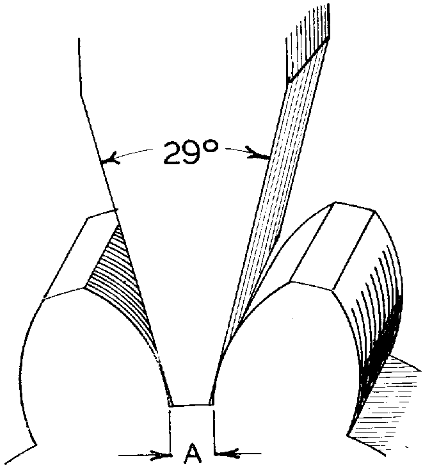


Fig. 15 **Using the gearwheel as a template**

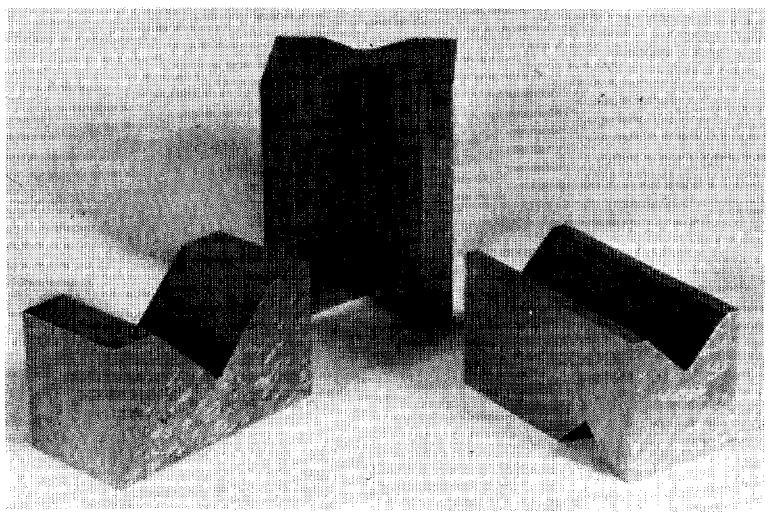
of successive rack teeth. Having found this figure the whole depth of the teeth can be calculated.

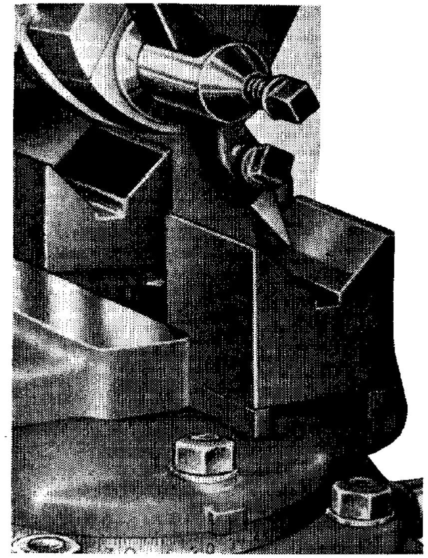
Now the whole depth of tooth is given by:

$$\text{Circular Pitch} \times 0.6866$$
$$\text{so } 0.189 \times 0.6866$$
$$= 0.130''$$

this being the amount the tool must be fed into the work by the tool slide feed screw.

Fig. 16 **Group of V-blocks**





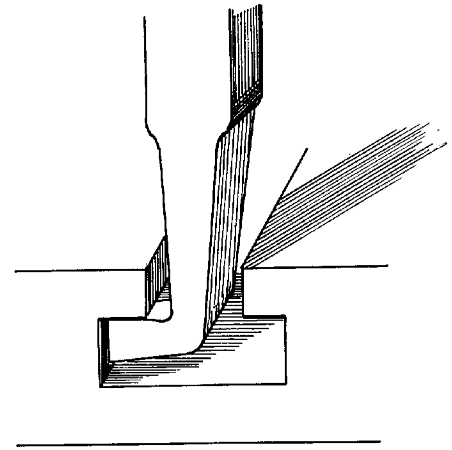


Fig. 18—Machining T-slots

Fig. 17—Machining V-blocks

What of the tool itself. We have already seen that a rack tooth is straight sided and that it has an included angle of 29 degrees so, provided that this angle is maintained when grinding it, a suitable tool for cutting the required rack can be produced. We are left, however, with the problem of how thick to make the tool. For all practical purposes this matter can be resolved if the mating gear wheel is used as a template and the tool ground so that its point width (A) coincides with that of the base of the gap between the gear teeth as depicted in Fig. 15. The included angle of 29 degrees shown in the diagram must, of course, be maintained.

Cutting Gear Teeth

This is work that can be carried out in the shaping machine but involves the use of a dividing head whose cost could hardly be justified unless much work needing such equipment was contemplated. In any case the class of gear cutting usually undertaken in the small workshop is best carried out in the lathe.

V-Blocks

One of the more common operations for which the shaper is suitable is the machining of V-blocks either singly or in pairs. Readers will not need reminding that V-blocks are essential equipment for many purposes around the workshop so the ability to make them for oneself is of some advantage. A group of special blocks

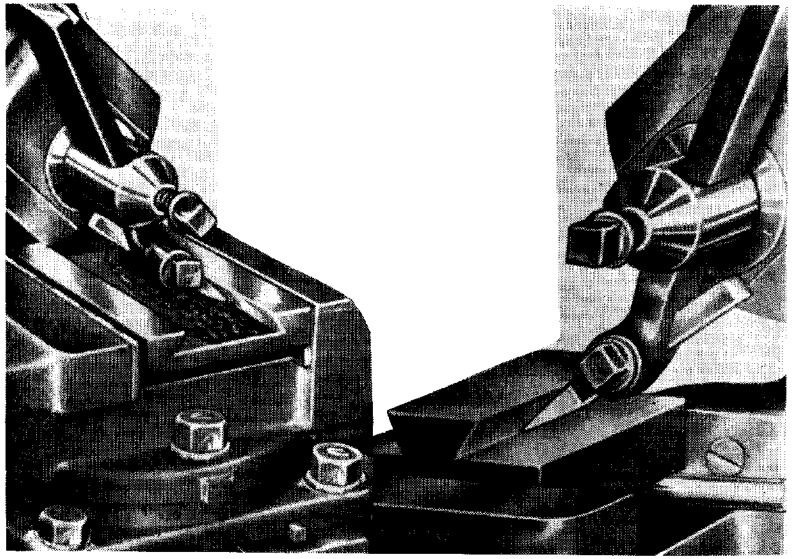


Fig. 20 Machining Dovetails **Fig. 19 Machining Dovetails**

made by the author are seen in the illustration Fig. 16, whilst the set-up may be seen in Fig. 17. This view depicts the blocks being machined in pairs. As will be seen, the tool slide has been set over at an angle to the vertical. This angle is of course half the included angle of the finished block, usually 90 degrees, so the tool slide needs to be set at 45 degrees each side of the vertical. The clapper box, however does not require to be swivelled as no overhung surface is involved in the operation.

When making V-blocks one may, with advantage first mark them out in order to show the extent of the machining. Then, if the block is large, surplus material can be removed with a hacksaw, leaving the balance to be cleaned up in the shaping machine. Some workers prefer to provide a "run-out" for the tool at the bottom of the Vee. This is a practice with many advantages. The run-out need only be narrow, say $\frac{1}{16}$ in. wide, and can easily be made by a parting tool before the final cuts are given to the surface of the Vee itself. The automatic down-feed fitted by the author to the shaping machine in his workshop is a piece of equipment that materially assists in the machining of components such as V-blocks.

Machining T-slots

The amateur worker is sometimes called upon to form T-slots in various pieces of equipment. While the process is, perhaps, more comfortably performed by a milling operation when apparatus for the process is available, T-slots can be machined in the shaping machine.

The slot is shaped in three separate stages. First a slot is made using a parting tool fed in vertically. In a small shaper this is work that needs to be carried out in stages with the clapper box free to lift on the return stroke of the ram.

The wings of the T-slot are cut with the cranked tool seen in the illustration Fig. 18. The tool is used with the clapper box locked, so by turning it round in the toolpost, the tool can be employed to form either the right or left-hand wing since it will cut equally well on the back stroke when reversed.

The size of the cranked tool must, of course, be tailored to allow it to pass into the slot made initially in the work. The tool is then fed sideways till the wing is fully formed; this procedure may also need to be carried out in stages.

Shaping Machine Slides

One of the advantages to be had from the shaper is the facility with which it may be used to plane the slides of various machine components. Readers will be familiar with the cross-section of the common machine slide; these take the form of dovetails, one fitting within the other. The set-up for machining the dovetails is illustrated in Fig. 19 and Fig. 20.

The tool slide is set over to the angle required and the clapper box is swivelled or tilted in the direction of the angle of the surface being machined. This will ensure that the tool cannot jam on the idle stroke. The shape of the tool needed will be apparent from the illustrations.