

in the slotting machine that two modifications had to be made in holders, the same cutters being applicable.

The Capstan-rest Chasing Lathes designed by the writer's firm have now become much used, and as a large amount of their work is produced from black bars of iron, steel, or other metals, each of which has to be finished at its extremities and cut or parted off, it was found advisable to make one special tool-holder, Figs. 14 to 17, page 268, for carrying tools of the correct sections to produce the desired shapes for the ends. The tedious and unreliable process of turning the end with hand-turning tools is thus avoided. Each cutter is of absolutely the same section throughout its entire length, and the re-sharpening is done by grinding the end of the cutter only, so that it can only produce the same standard form as long as it lasts, that is to say till it is ground too short to be used any longer. The parting off might have been accomplished by the swivel tool-holder, but a special form, Figs. 18 to 20, is found to be more convenient in parting off close up to the chuck or lathe spindle.

To produce a maximum amount of cutting in a minimum space of time, there are two main points which must be carefully attended to. These seem to be applicable to all cutters for cutting metals, whether they happen to be those fixed rigidly in tool-boxes, as in turning lathes, planers, shapers, slotters, etc., or those which cut while they revolve, as in milling-cutters, twist-drills, boring-bits, etc.

These two important points are;—

First, the cutting angle, or angle of the cutting surface, Fig. 21, page 268, i. e. that surface which removes the shavings of metal, and upon which the pressure of the cut comes, as shown by the arrow.

Secondly, the clearance angle, or angle of the clearance surface, i. e. that surface which passes over the surface of the metal that has been cut, and does not come in contact with the metal at all.

To produce the best results, and to ensure the utmost simplicity, it is important that these two angles be correctly constructed in the first instance. The best measure for both angles has been arrived at from actual practice and a series of experiments. When once obtained and started with, they should not alter by use, but should always remain constant, if the greatest amount of cutting efficiency is to be attained. When aided by a mechanical system of re-grinding, and the use of standard angle-gauges, Figs. 22 and 23, page 268, there is no difficulty in maintaining the exact angles. The only changes which take place are that the cutters in tool-holders become gradually shorter by grinding, and that milling cutters during a long period of time become very gradually smaller in diameter, by the process of re-sharpening them on a fine emery-wheel. In the case of the tool-holders, as already explained, the cutting angle is maintained by the system of re-grinding, and the tool-holder itself always maintains the clearance angle. The system is thus simplified, as will be clearly understood when it is remembered that each one of the tool-holder cutters, no matter of what description, is ground on its end only. Thus the section is never altered, no smutting or alteration in form is necessitated, and consequently no repairing has to be done in the smith's shops.

The objects aimed at have been.—

1st. To produce the highest class of workmanship, by providing the best known form of cutters, carefully made, and capable of having their cutting edges accurately re-ground, so that the surfaces of the machined work may be produced direct from the cutters so highly finished that no hand-work could possibly improve them. Most of the turning of wrought iron, for instance, may be so perfectly finished that there is no necessity to polish it by means of emery or emery-cloth.

2nd. To make all the cutters so free from complication, and simple to keep in order, that no difficulty or error may occur in re-grinding them.

3rd. Since finely-polished surfaces cannot be obtained without the most perfect cutting edges, to make all cutters not only of the best steel, but with their cutting edges most accurately and carefully ground up, in almost all cases by mechanical means. The durability of the cutters, from their construction and high class of material, is very great, and they are thus capable of removing a great weight of metal in a given time.

The grinding or re-sharpening of all cutting edges is reduced to the greatest simplicity; and only three descriptions of machines are requisite for this purpose. They are all arranged to grind mechanically; that is to say, the cutters while being ground are carried and pressed on the grindstone or emery-wheel by mechanism. The requisite forms and angles are also

obtained by mechanism, it being found in practice that sufficient accuracy cannot be secured by hand-grinding.

The machines are as follows:—

1st. A grindstone with slide-rest, for grinding all the cutters used in tool holders.

2nd. A twist-drill grinder; this also is by preference a grindstone, with mechanism for holding and guiding the twist-drills. A machine with an emery-wheel in place of the stone is also used for the grinding of twist-drills, with much the same mechanism for carrying the drills. In practice however the stone grinds about double the number of drills per hour, and with less risk of drawing the temper. Both stone and emery-wheel are run at a high speed, and used with water.

3rd. A small but very complete machine, one of which is exhibited, for re-grinding milling-cutters. In this case gritstone does not answer, and the grinding wheels are obliged to be of emery or corundum. They are very small in diameter, and many of them are exceedingly thin, and so delicate in form that if made of gritstone they would rapidly lose their shapes. They are run at a high speed, 3000 ft. per min., and are turned into form while revolving by means of a diamond.

A milling-cutter will work for a day, and in many cases for two days, before showing signs of distress. Before the cutting edges are visibly blunted, but as soon as the sense of touch indicates that their keenness is diminished,* the cutter should be put into this machine; and the probability is that not more than one 1000th in. need be ground off each tooth, before it is restored again to a cutting edge almost as fine as that of a wood chisel. Each cutting edge, or in other words each tooth of the milling-cutting, is only passed rapidly once or twice under the revolving wheel, which is itself of very fine emery. It can therefore be readily understood how delicate an operation this is, and why emery alone will answer for it.

In order to maintain the correct forms and angles of all cutters for tool-holders, sheet-steel angle-gauges, Fig. 22, page 268, are provided, and the process of grinding is thus reduced to a complete and exceedingly simple system. In well-regulated shops, a young man is selected to work each machine for cutter grinding, and in practice each man so engaged can keep a works employing 150 men (exclusive of moulders or boiler makers) well supplied with all the necessary cutting tools from day to day. A very great saving is thus effected, as no machine need ever stand idle for want of cutters, and no repairing of tools in the smithy is wanted.

Take for instance an engineering works employing 250 men. The requisite number of improved grinding machines, with special mechanical appliances, is as follows:—

Two patent grindstones for re-sharpening cutters mechanically.

One patent twist-drill grinder for re-sharpening twist-drills mechanically.

One improved cutter-grinder with small emery-wheel, for re-sharpening the cutters used in milling machines.

To follow the system out satisfactorily, the man working the grindstone goes round to each machine every morning, collects together those cutters which have been blunted by use the previous day, carries them to his grindstone, re-sharpens them, and distributes them out again to each machine;—which is thus kept well stocked with an ample number of cutters, always ready for immediate use.

The cutters for tool-holders do not require any repairing in the smithy; consequently that operation, which is costly in so many ways, is avoided, and jobbing or tool smiths with their strikers are almost entirely dispensed with.

For re-hardening the cutters, a rule is made that when the grinder meets with cutters which are not as hard at their cutting points as they ought to be, he puts them on one side, and periodically, say once every fortnight, he sends the lot into the smithy for the end of each to be re-tempered. This is a very inexpensive operation, the time occupied being about two hours per fortnight. They are placed in a small oven by dozens and very slowly heated up to a dull red; the end of each cutter is then plunged into a perforated iron box immersed in water till the bottom is covered to the required depth for hardening the cutter up to the proper distance from its point. The cutters are left standing in a nearly vertical position in the box of water, until they have gradually cooled down sufficiently to be removed. They are then sent to the grindstone, re-ground, and given out with the other cutters to be used again in the

* The sense of touch, in passing the finger over the cutting edges, conveys the idea of slight bluntness better than it can be detected by the eye.