MILLING PRACTICE

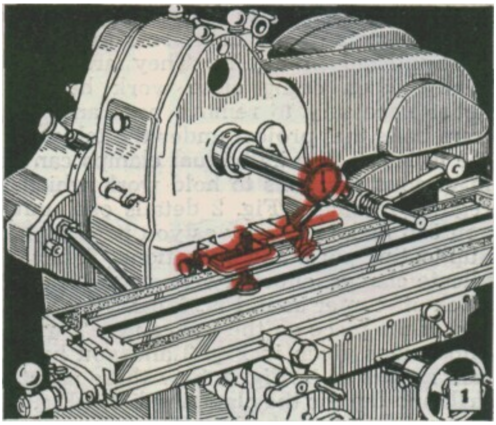
By H. J. Chamberland

PRODUCING accurate work efficiently with a horizontal-spindle milling machine requires accessories that clamp and support the work rigidly on the machine table. These are necessary to resist the machining forces caused by the milling cutter removing material from the work, as these forces create vibration which results in chatter, the worst enemy of machining.

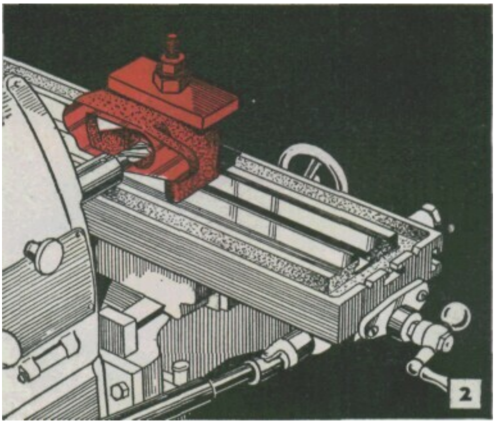
Maximum rigidity is attained when the table and the cutter are as close to the frame of the machine as possible. Before clamping the work to the table, the arbor, which is the "heart" of the milling machine, should be tested for runout with a dial indicator fastened to the table as in Fig. 1. Runout, which is the difference in parallelism between the arbor and the table and ways, should not exceed .002 in. A runout of .005 or .006 in. increases with higher spindle speed and, if permitted to exist, will ruin the arbor and its support bearing, shorten cutter life and result in poor work. Arbor runout is due to various causes, such as a bent arbor, resulting from taking excessively deep cuts or too fast a feed, wear in the arbor-support bearing and burrs on the arbor shank or in the tapered bore of the spindle. When making a cutter assembly, the arbor support should be positioned before tightening the arbor nut. If the arbor was true when tested with the dial indicator and the cutter is untrue after assembly, check between the collars for chips or dirt. If the cutter runs out radially, its bore is larger than the diameter of the arbor. The bearing in the arm support must be kept well-lubricated. When the arbor is removed, it should be cleaned thoroughly and when not in use it should be wrapped in cloth and placed in a drawer or cabinet.

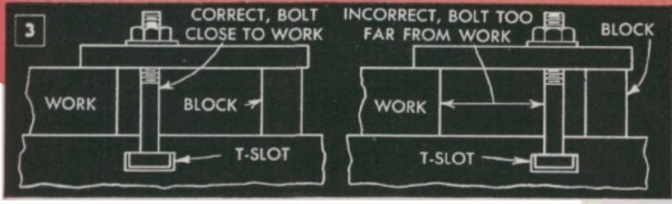
Accessories for clamping the work consist of simple T-slot bolts and strap clamps, as in Figs. 5 and 6; a milling-machine vise, Fig. 8, or the more complicated indexing equipment shown in Figs. 11 and 12. The correct and incorrect locations of the T-slot bolt in relation to the work are shown in Fig. 3. The casting being machined internally with an end mill in Fig. 2 presents no clamping problem, as the flat surfaces of the casting rest on the table and the T-slot bolt projects through a hole in the work. The comparatively larger casting in Fig. 5, also being machined internally, is clamped at each end with a T-slot bolt and blocks. Milling forces in this case are much less than in Fig. 6 where they are increased by the wider cut being taken with a shell end mill. Where a number of different machining operations are to be done, the clamping naturally should be sufficient to take care of the heaviest load. An irregularly shaped casting, such as the one shown in Fig. 7, must be blocked at the bottom to align the work accurately and prevent distortion due to clamping. Machining forces are reduced to a minimum when the milling machine is used, as in Fig. 4, to lay out and center-drill holes that are to be drilled and bored later. Nevertheless, the high degree of accuracy involved still makes clamping a major factor.

The milling vise, shown in use for contour milling, Fig. 8, offers an efficient method of holding some types of work. The base of the vise is bolted to the milling-ma-



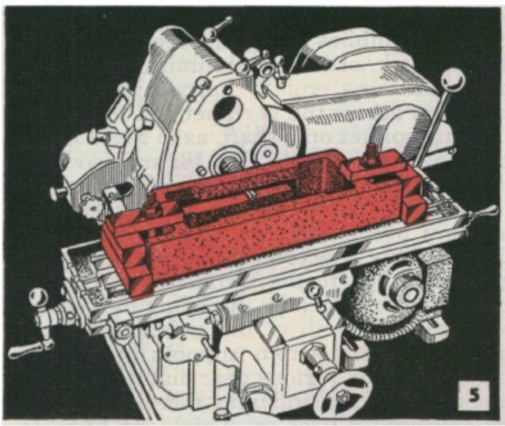
Above, a dial indicator it used to lest accuracy of milling-machine arbor. Below, only one T-slot bolt is needed to hold small casting in place on table

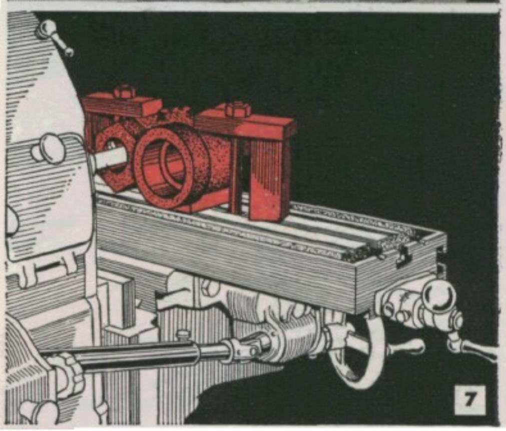




chine table and the work is held between the vise jaws. Many such vises are equipped with a graduated swivel base which permits the work to be set at any angle to the table ways.

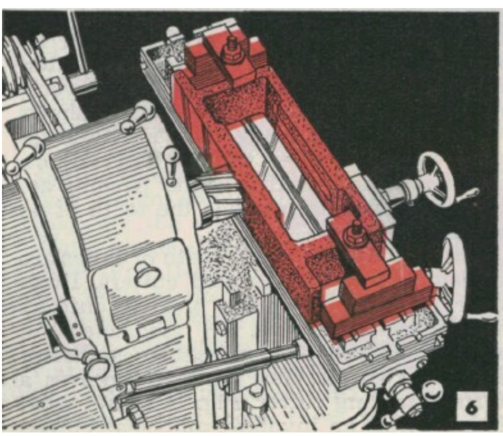
Two types of indexing equipment are in general use. These are the rotary indexing table, Fig. 11, and indexing heads, or centers, Figs. 9 and 13. The rotary indexing table is used for cutting straight or circular slots and grooves in flat work, usually circular in shape. The base of the indexing table is bolted to the milling-machine table and the work is clamped to the indexing table, which can be rotated and locked

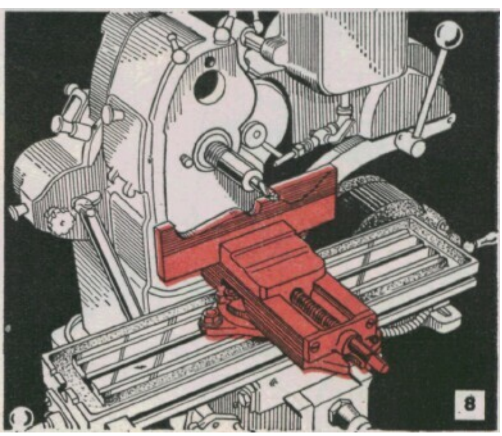


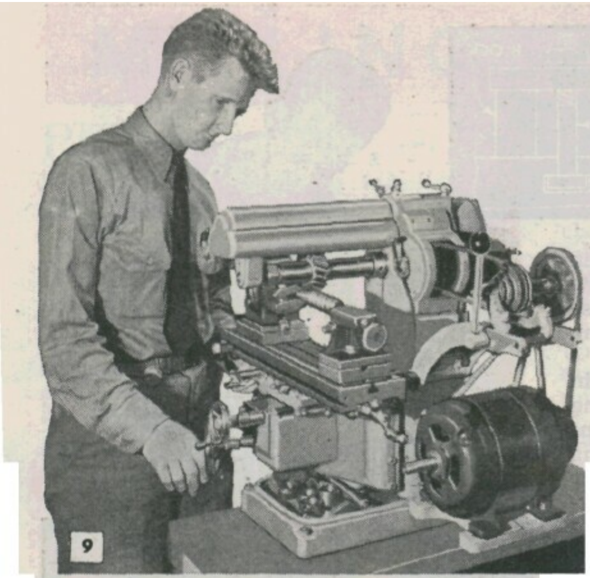


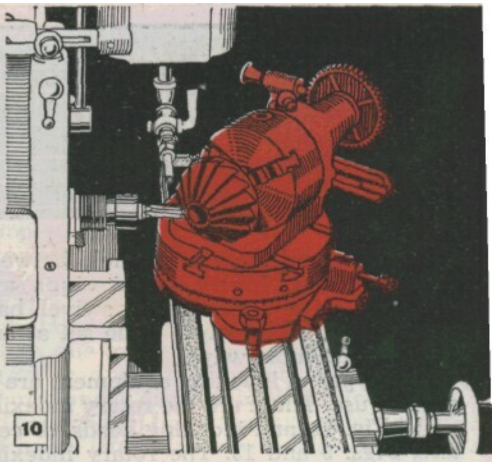
Large castings, as shown above and below, must be clamped down at each end. See Fig. 3 for the correct position of T-slot bolt in relation to the workpiece

Above, irregularly shaped work is blocked at bottom, Below, milling-machine vise, which is bolted to top of table, is used to hold work for contour milling

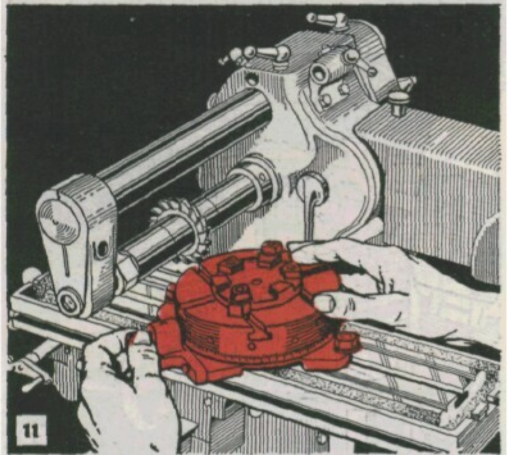




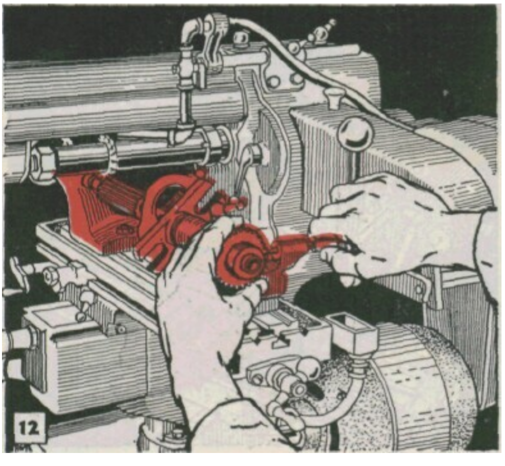




Accurate spacing for milling the teeth of an angular cutter is accomplished by mounting the work in a chuck fastened to an indexing center which, in turn, is bolted to an indexing table. Angular cutter is then heat-treated and ground



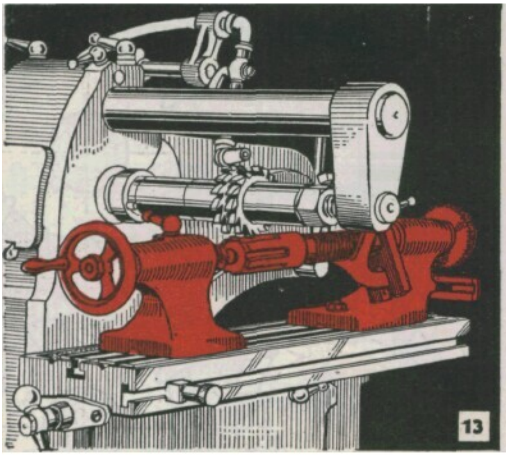
Above, work is clamped to a rotary indexing table which is bolted to milling machine. Below, gear is used to position work held between indexing centers



in place at the desired position. Indexing centers, which resemble the head and tailstock assemblies of a lathe, are used to position work, ordinarily cylindrical in form, for machining equally spaced grooves or surfaces across the periphery of the work. Milling splines on a shaft, as in Fig. 13, and making a gear, as in Fig. 18, are good examples. The method of indexing or positioning the work varies with the type of centers used. With the centers shown in Fig. 12, this is accomplished by rotating a gear fastened to the spindle of the headstock indexing center. A sliding pin, which engages the teeth of the gear, locks it in position. The lockpin support bracket is adjustable for various gear diameters, thus making accurate indexing merely a matter of selecting a gear on which the number of teeth is divisible by the number of spacings required on the work. The tailstock indexing center has a handwheel for adjusting its center longitudinally.

Angular indexing is accomplished by mounting a headstock indexing center, equipped with a chuck to hold the work, on a rotary indexing table. Fig. 10 shows this type of setup being used. Here the rotary table provides the angular adjustment and the indexing center permits accurate spacing to produce the teeth of an angular cutter.

On a production basis, teeth or flutes are milled with special-formed cutters. However, as an ample supply of these cuttters would be expensive, an assortment of standard cutters is, in most cases, sufficient for small shops. Gear cutting requires a formed milling cutter. Fig. 14 shows what is known as an involute spur-gear cutter.



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Milling spline on shaft with side milling cutters. Shaft held between indexing centers is rotated the required amount and locked in position for each cut

Eight different forms of these cutters comprise a set that will handle gear-cutting jobs within the ranges indicated in Fig. 16. These cutters are designed so their forms are correct for the lower numbers of teeth in each range, but if extreme accuracy is desired in the higher range, intermediate-numbered cutters, such as 1½, 2½, 3½, etc., should be used.

Therefore, knowing the exact diameter and number of teeth required for a gear, the mill operator can readily select a cutter of the correct diametral pitch for the job. The exact diameter of a gear is neither the outside diameter of the gear blank nor the diameter at the bottom of the teeth. Instead, it is the pitch diameter, indicated in Fig. 17 as P.D. Circumference of this diameter is an imaginary line known as the pitch circle. To find the diametral pitch of a given gear, simply divide the number of teeth by the pitch diameter. The diametral pitch is not an actual dimension but the ratio between the number of teeth in a gear and its pitch diameter. For example, a four-diametral-pitch gear has four times as many teeth as it has inches of pitch diameter. The two details of Fig. 15 show the actual sizes of gear teeth of five and ten diametral pitch.

For accurate work, gear cutters must be sharp. Frequent sharpening by removing only a slight amount of metal is better than allowing the cutter to become so dulled that a single sharpening will depreciate it from 10 to 15 percent. In sharpening, only the faces of the cutter teeth are ground. This must be done on a machine equipped with a dish-type grinding wheel and a sliding toolholder that will permit cutter movement as indicated in Fig. 19. Gear cutters having radial faces, Fig. 20, upper

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INVOLUTE GEAR-CUTTER

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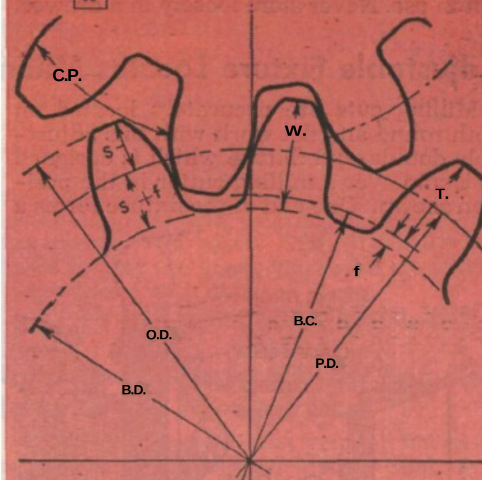
10 DIAMETRAL PITCH
0.3142 CIRCULAR PITCH

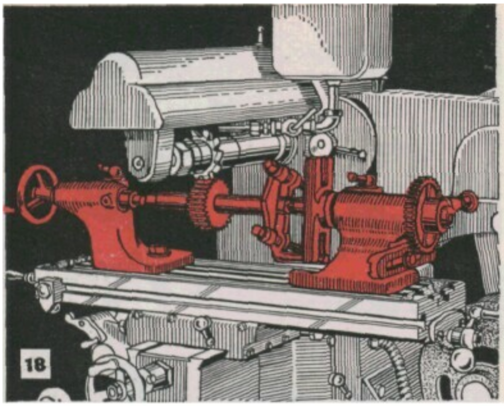
5 DIAMETRAL PITCH
0.6283 CIRCULAR PITCH

16 SIZE OF CUTTER	GEAR-CUTTING RANGE
No. 1 will cut gears from	135 teeth to a rack
No. 2 will cut gears from	55 teeth to 134 teeth
No. 3 will cut gears from	35 teeth to 54 teeth
No. 4 will cut gears from	26 teeth to 34 teeth
No. 5 will cut gears from	21 teeth to 25 teeth
No. 6 will cut gears from	17 teeth to 20 teeth
No. 7 will cut gears from	14 teeth to 16 teeth
No. 8 will cut gears from	12 teeth to 13 teeth

17 GEAR-TOOTH NOMENCLATURE

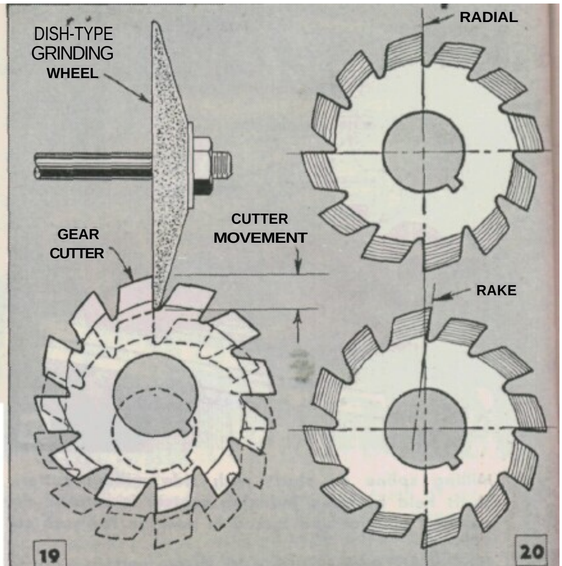


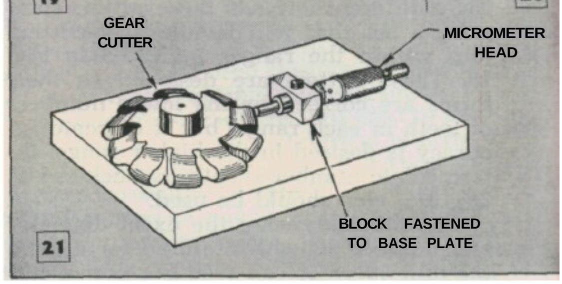
O.D.——OUTSIDE DIAMETER
P.D.——PITCH DIAMETER
B.C.——BASE CIRCLE
B.D.——BOTTOM DIAMETER
C.P.——CIRCULAR PITCH
W——WHOLE DEPTH OF TOOTH
T——WORKING DEPTH OF TOOTH
f——CLEARANCE
S——ADDENDUM
S+f——DEDENDUM



Typical setup for making gears with milling machine

detail, must always be sharpened radially. Gear cutters with rake—faces back of center—as in Fig. 20, lower detail, must be ground to the rake angle stamped on the side of the cutter. After sharpening, the cutter should be checked for uniform depth of cut. A suitable fixture for checking this can be made as shown in Fig. 21. In use, the cutter is rotated and each tooth checked with the micrometer head. A variation of .001 in. is permissible between the extreme high and low teeth. Gear cutters, when properly sharpened, will produce duplicate work throughout their entire lives. Place gear cutters on individual racks when not in use. Never store loosely in a drawer.





Adjustable Fixture Locates Milling Cuts on Round and Flat Work

Milling cuts are accurately located on both round and flat work with this adjustable double-end fixture which is designed to clamp over a milling cutter in the position shown. One end of the fixture forms a vee to take round work while the other end contains a spring-loaded pointer for locating the cut on flat surfaces. Using the fixture for centering the cutter over a line scribed on the work, is merely a case of advancing the work until the line and the pointer coincide. This automatically centers the cutter over the line. When a keyway is to be cut in round work, the fixture is turned end-for-end and the work is positioned to cradle in the vee formed by the ends of the fixture. Construction is apparent from the drawing. Dowel guide pins and clamping screws are fitted in each end of the fixture which is made from two pieces of square bar stock beveled at the ends. The pointer, crosspinned by the dowel, passes through the exact center of a collar which is held by spring tension against the end of the fixture.

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