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# MILLING PRACTICE SERIES

## *Book Two*

## THE MILLING MACHINE and ITS ATTACHMENTS

KEARNEY & TRECKER
MILWAUKEE

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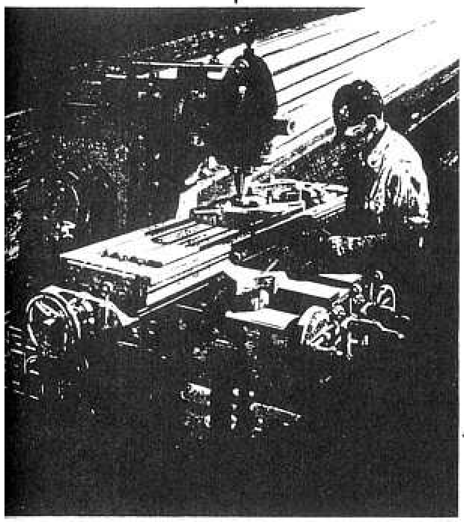

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# CONTENTS



*Chapter One*

# KNEE-TYPE MILLING MACHINES

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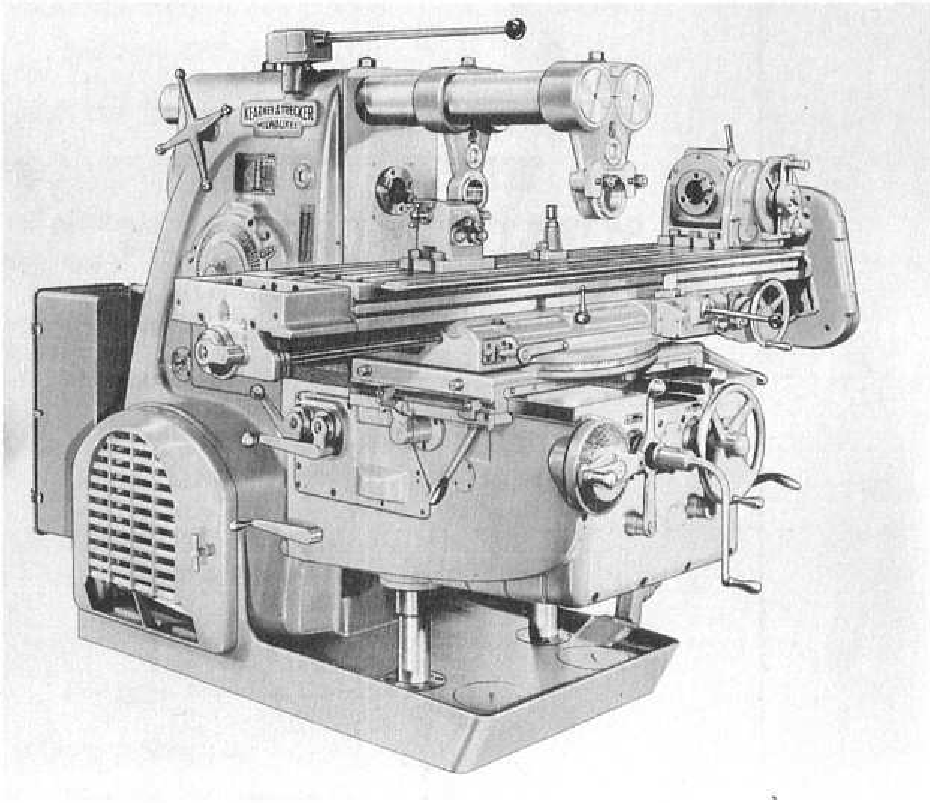

*Fig. 1. TF Series Model 315 universal machine equipped with conventional lead attachment, Model K dividing head, center rest and tailstock.*



MODERN milling machines are precise, powerful tools and form an important branch of the machine tool family. Research and development programs are constantly improving machine design and techniques used in milling.

Machine tools use a variety of methods in removing material from the workpiece. For example — on a lathe the work revolves while the tool is fed into it; in the case of a planer, the tool is stationary while the workpiece is moved into it; in the milling process, a power driven, rotating multi-tooth tool is used to remove material from a workpiece which is fed into the cutter.

Frequently the question arises as to the variety of milling machines used in modern shop practice. Numerous variations of a few standard types make exact classification impossible, but the list should include hand, bench, knee, bed, manufacturing, thread, planer, cam, profile, bridge, and rail, as well as many special purpose machines.

This book is directed to a study of the knee-type and bed-type milling machines, attachments, and accessories.

Knee-type milling machines are divided into three classes, plain horizontal, universal horizontal, and vertical. Most widely used of all milling machines is the horizontal knee-type shown in Fig. 1 on the opposite page. The term horizontal knee-type is derived from its major distinguishing characteristics, the knee and the horizontal spindle.

The machine shown in the illustration is a No. 2 universal horizontal milling machine. Relative size of knee-type machines is customarily designated by number, beginning with No. 1, the smallest, and ranging in size up to No. 5, the largest. Power available for the machines varies with size from 3 to 50 horsepower.

## HORIZONTAL MILLING MACHINES

In the succeeding paragraphs the horizontal milling machine is discussed unit for unit as it is constructed and assembled. Plain and universal horizontal milling machines are similar with one exception. Universal machines are equipped with a swivel block to permit angular positioning of the machine table while the plain machine does not have this feature. Basically, the design is much the same for both horizontal and vertical knee-type machines except for location of the spindle axis. Construction of the horizontal machine should be studied carefully so that it may be compared with the vertical machine discussed in the following chapter.

*Fig. 2. The column — foundation of a milling machine*



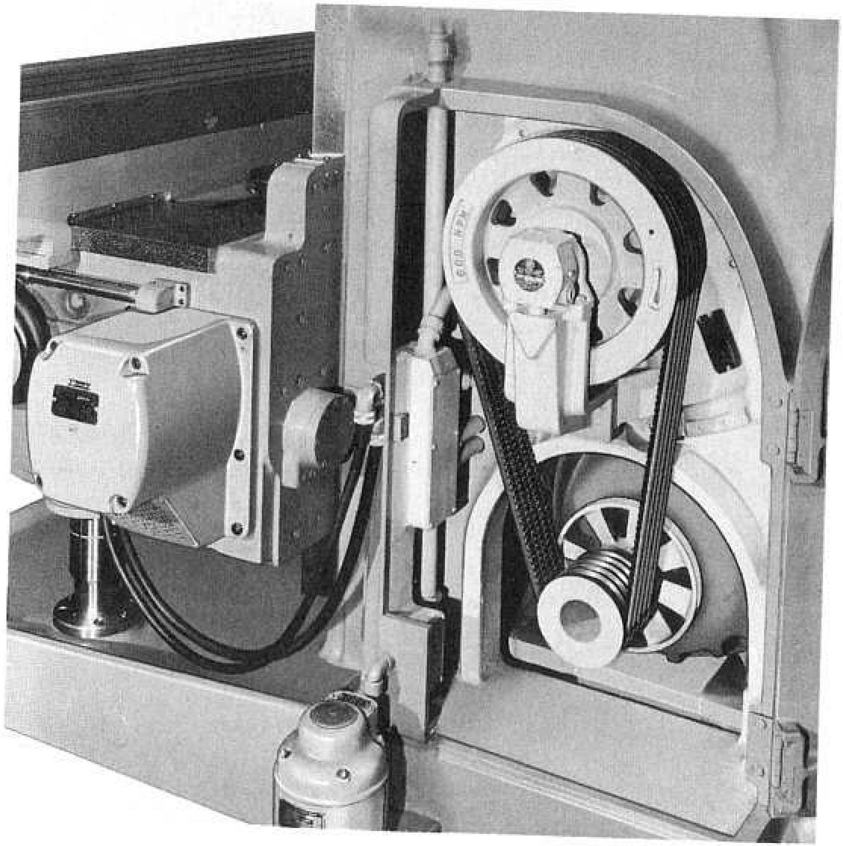

*Fig. 3. Power is transmitted from the drive pulley through V-belts to the main drive clutch*

## COLUMN

Backbone and foundation of the knee-type milling machine is the column, Fig. 2, which houses the electric drive motor, the spindle speed change box, the spindle, and the overarms. Column and base are cast in one piece and machined on the bottom to allow the machine to set level when resting on a flat surface.

In the base of the column is a compartment for the cross-mounted electric drive motor. Multiple V-belts connect the drive motor pulley with the main drive pulley. Power is transmitted from the main drive pulley to the speed box on the left side of the machine through the main drive clutch. This clutch is a single plate, dry disc unit. The drive assembly in Fig. 3 shows the drive motor, V-belts, and the single plate disc clutch.

The mechanism of the speed selector dial, Fig. 4, controls the spindle speed through a train of gears between the drive clutch and the spindle. A wide selection of speeds is available to meet the common requirements of general manufacturing, toolroom, and experimental operation.

Overarms, whose principal functions are to provide maximum support for the arbor and to prevent vibration, fit into twin bores at the top of the column.

Two separate reservoirs are located in the column — one in the base for coolant, the other directly above the rear of the motor compartment for lubricant. Lubricant is automatically circulated under pressure, distributing a constant flood of oil over all gears, shafts, and bearings in the column. When coolant is required for a milling operation, it is mechanically pumped through pipes to outlet nozzles above the cutters.

The column face is a wide, strongly reinforced surface which furnishes a support for the knee, saddle, and table. Its precision is fundamental to accurate alignment of the overarm bores, spindle bore, and knee-column relationship.

**KNEE**

The knee is assembled to the column as shown in Fig. 5. A gib at the rear of the left column dovetail is necessary to adjust knee movement over the column face. It holds the knee to the column and assists the enclosed elevating

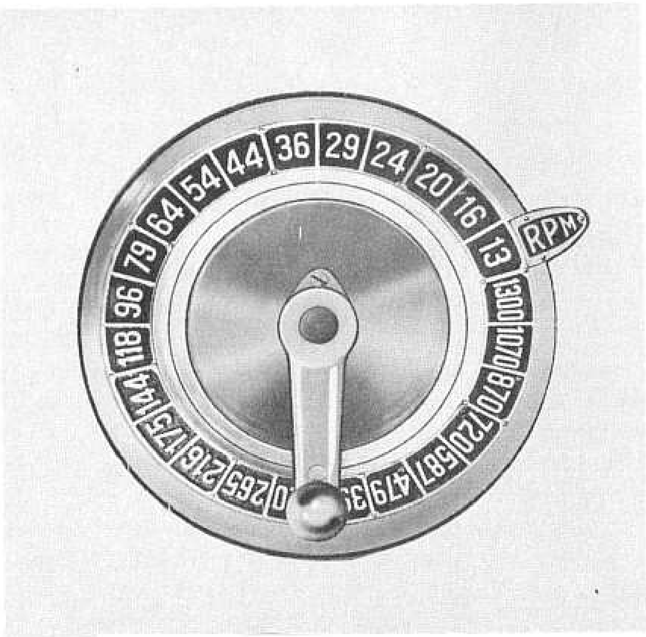


*Fig. 4. Spindle speed selector dial and lever*



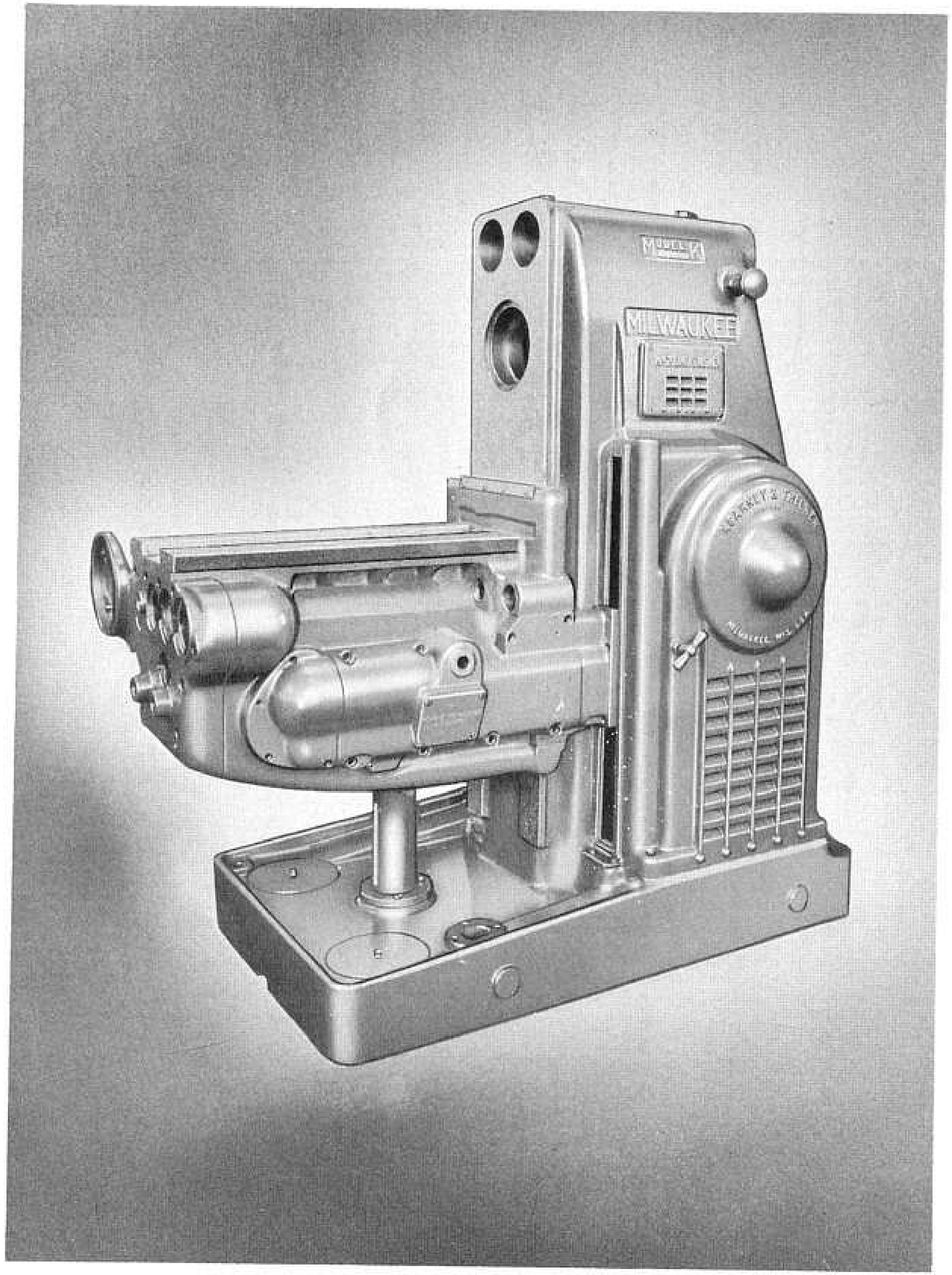


*Fig. 5. Knee mounted on column face supported by elevating screw*

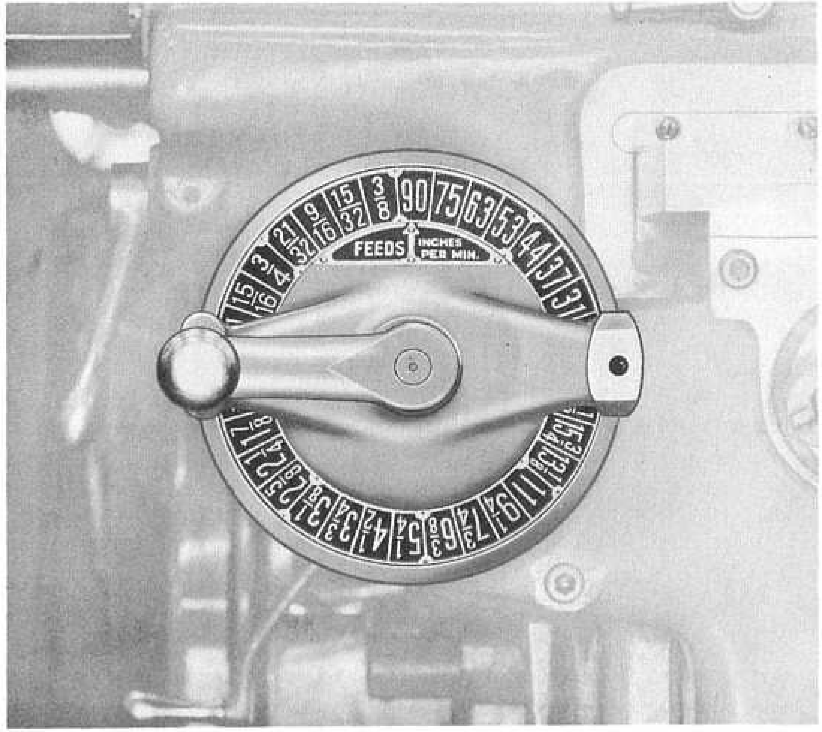


*Fig. 6. Feed rate selector dial and lever*

screw in supporting the knee. A knee gib clamp is provided to lock the knee in any required location.

Power to the knee from the drive pulley is transmitted by a spline shaft and gear drive through the feed and rapid traverse bracket on the right side of the knee. By means of a feed distribution box equipped with hand and power controls, vertical and cross movements of the table are possible. Various feeds can be chosen with the feed selector dial, Fig. 6, to meet operating conditions.

The knee has a separate, fully enclosed, lubrication system. A gear driven pump supplies forced lubrication to the knee mechanisms immediately when power is applied.

**UNIVERSAL SADDLE**

This unit, mounted on the knee in Fig. 7, makes possible positioning the table at an angle with the column face. It is not used on plain machines. Angular positioning of the table on universal machines is accomplished by hand. The table may be set at a maximum of 47 degrees either right or left of its



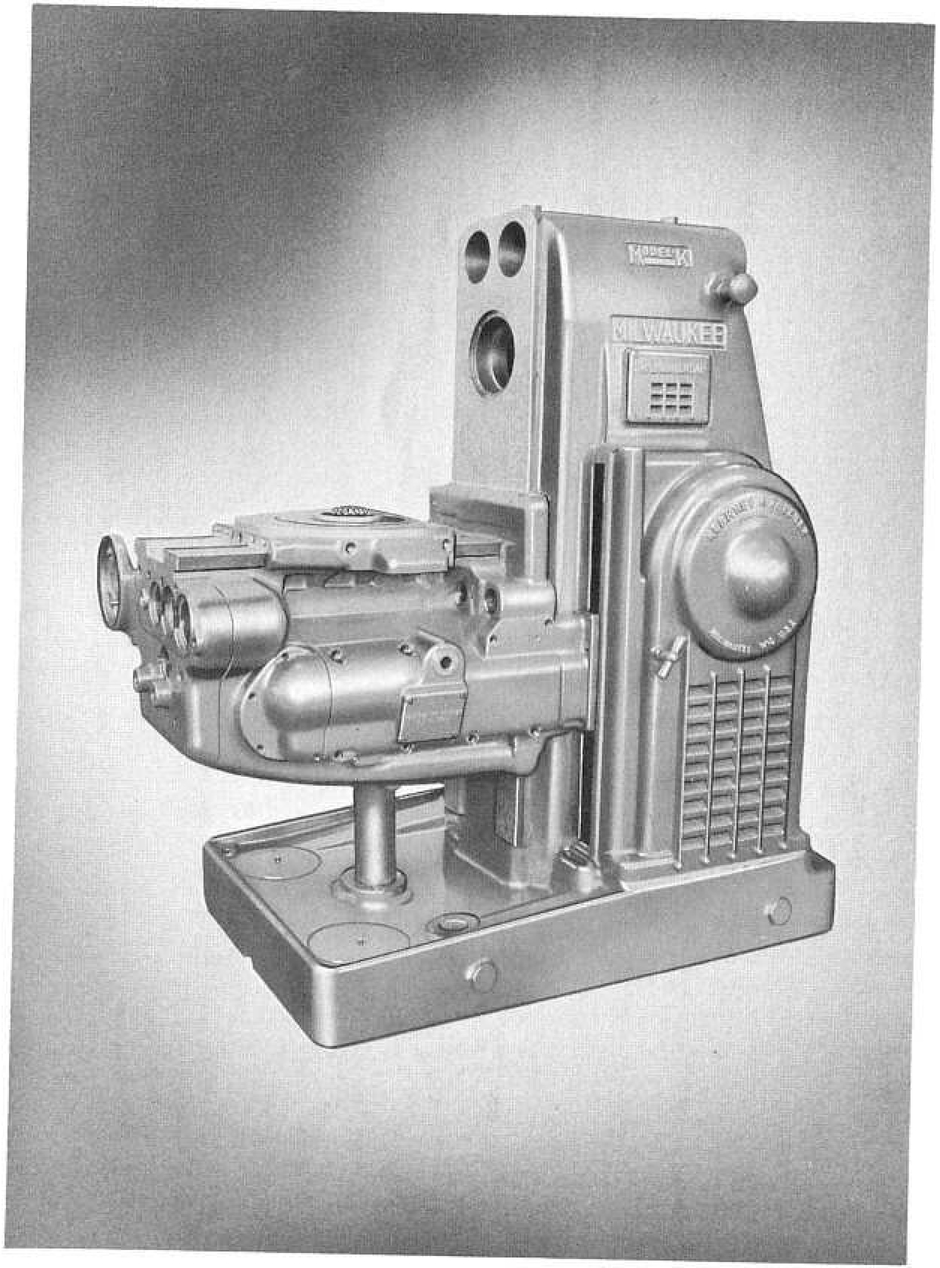


*Fig. 7. Universal saddle mounted on knee*

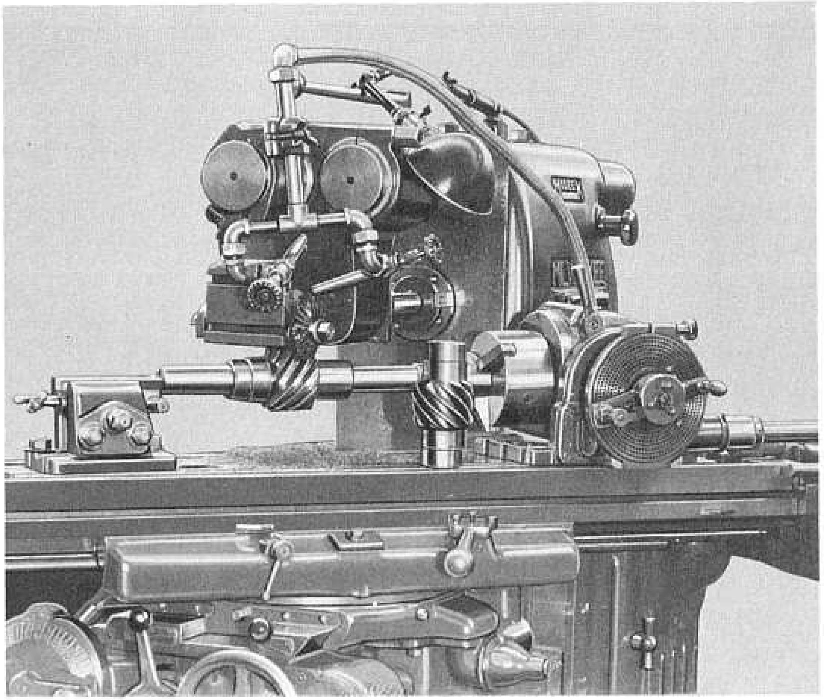

*Fig. 8 Universal machine table set at 45° to mill worm*

normal position parallel to the column face. Five clamp screws are provided to lock the table at the angle desired.

In shop practice, the universal horizontal milling machine is necessary for many tool room operations which include the milling of spiral flutes in cutting tools, gear teeth, and similar operations, Fig. 8.

**SADDLE**

In plain machines the saddle is mounted directly on the knee; universal swivel block is mounted on the universal saddle, Fig. 9. Saddle gibs are used for adjusting the sliding fit between the saddle and knee ways. A saddle gib clamp is furnished to permit locking the swivel block in any position with respect to the knee.

Power is transmitted to the saddle through spline shaft and gear drive from the knee distribution box. The saddle contains the table screw nut, table screw drive gears for longitudinal table movement, and the table directional control mechanism.

A separate lubricating reservoir is located in the front of the saddle. It provides a wick oil feed to the saddle mechanism and the sliding-way bearing surfaces of the saddle, knee, and table.



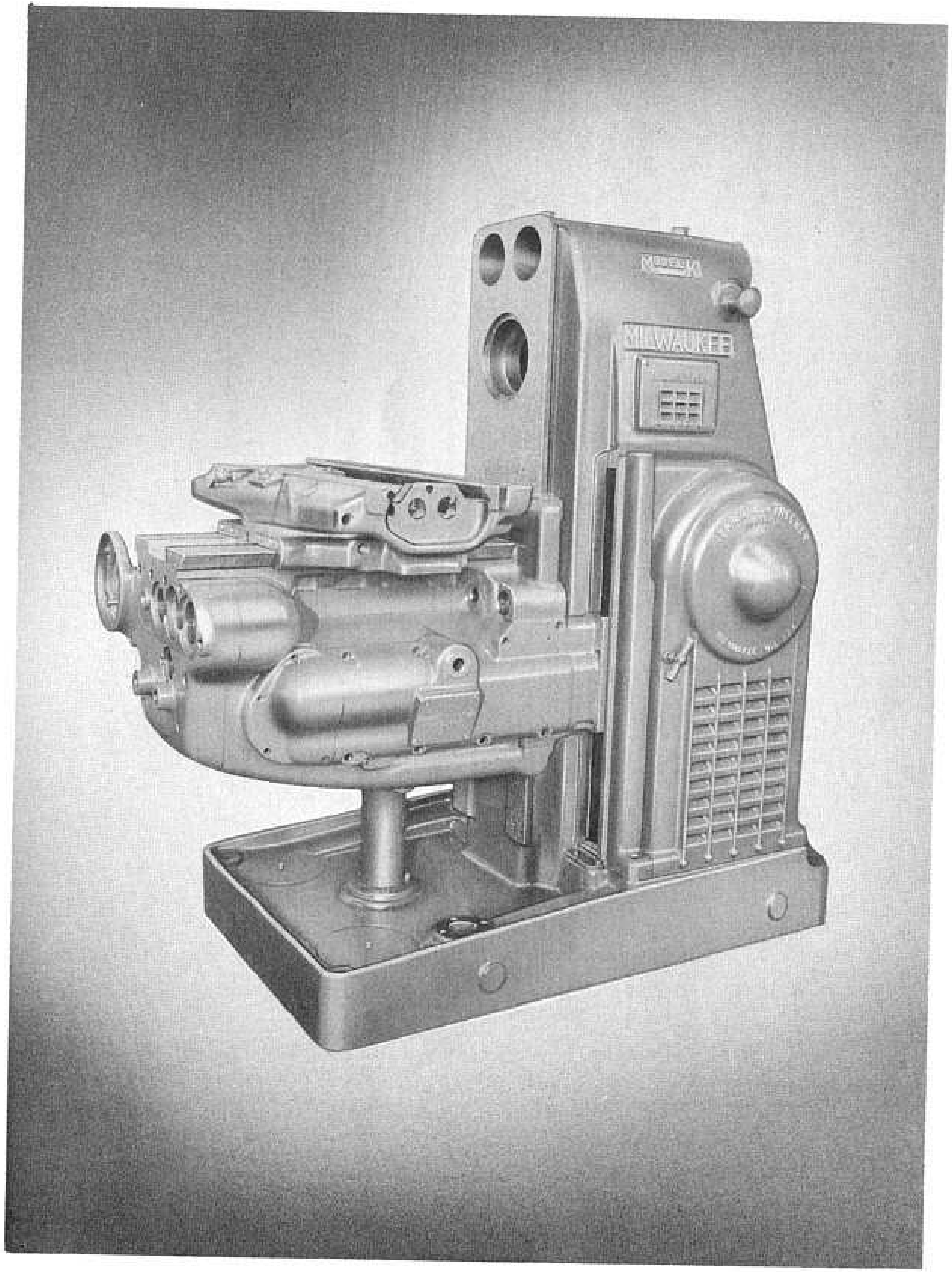


*Fig. 9. Universal swivel block mounted on universal saddle*

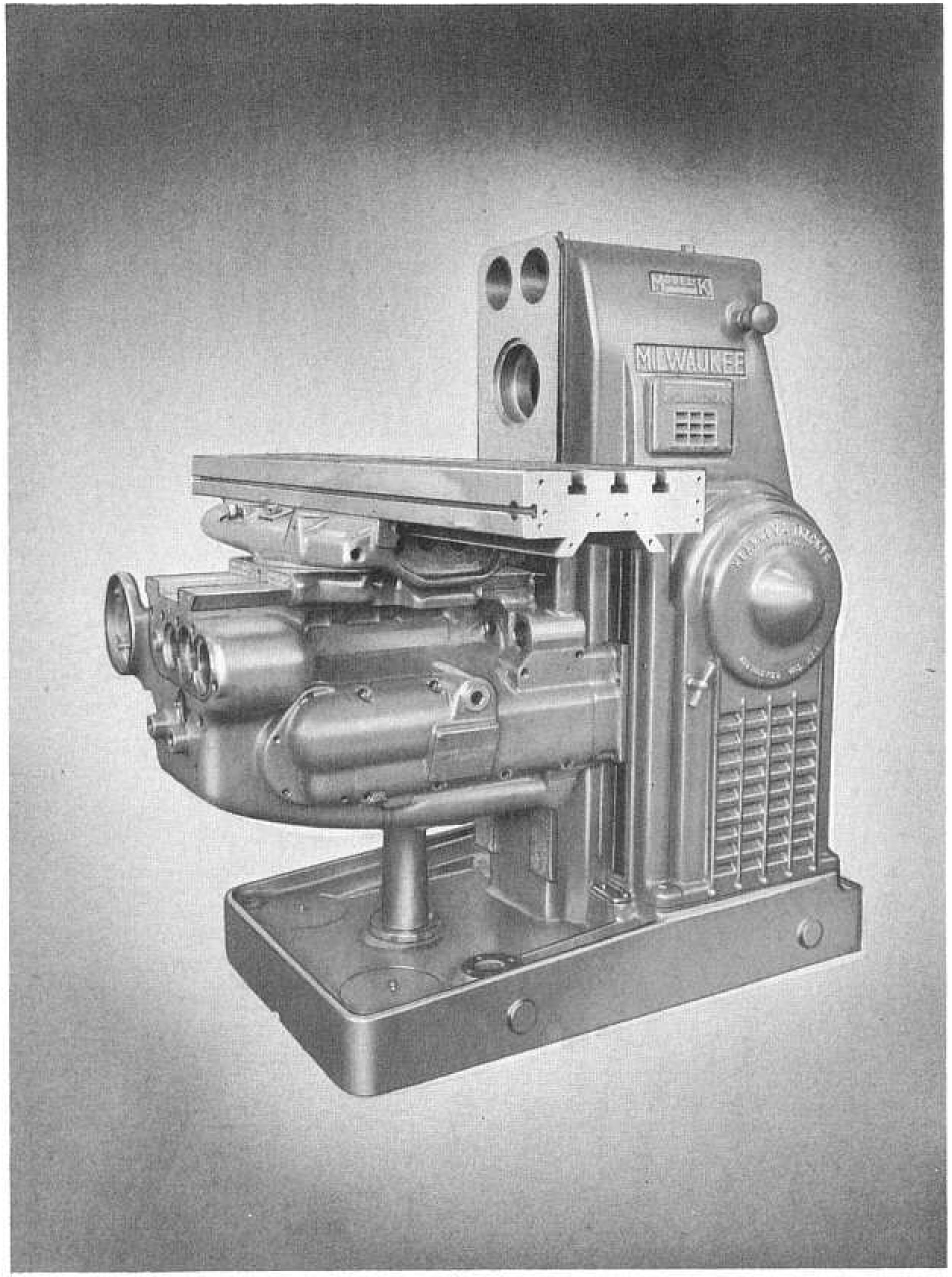


*Fig. 10. Table mounted on universal swivel block*



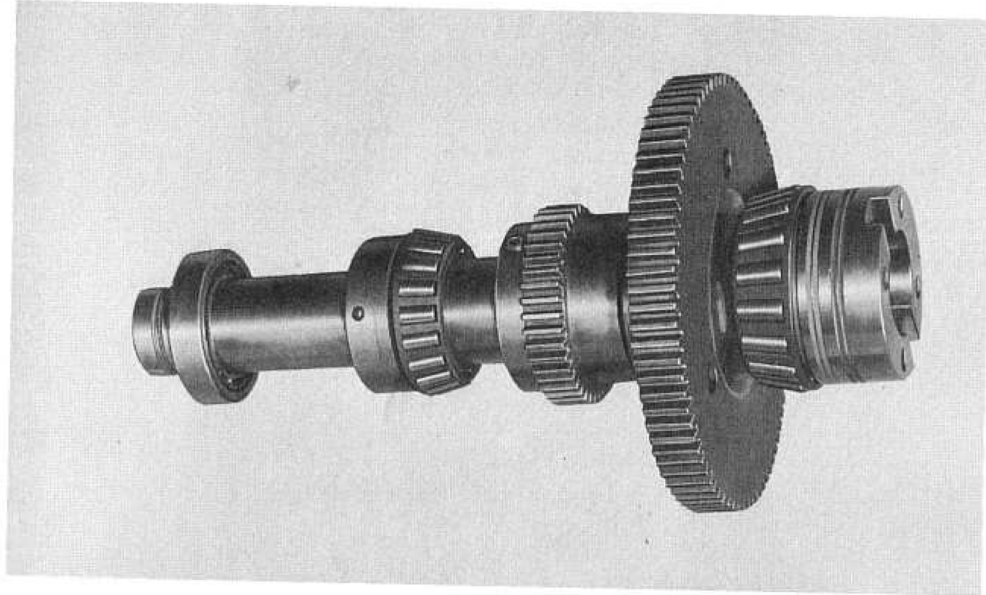

*Fig. 11. Three bearing spindle*

**TABLE**

The table, Fig. 10, moves longitudinally over the broad, accurately machined and hand scraped ways on the top of the saddle. This longitudinal movement, together with the cross movement of the saddle on the knee and the vertical movement of the knee over the column face constitute the three dimensional movements built into knee-type milling machines. With these movements, a wide range of setups may be made.

Screened coolant openings are provided on three sides of the table. The coolant returns to the reservoir in the base of the machine through channels in the saddle and a telescoping tube at the side of the saddle.

**SPINDLES**

Spindles, Fig. 11, are gear driven shafts. They are made of heat treated alloy steel, ground to a smooth finish to insure accurate alignment with respect to the table top. Spindle drive keys are fastened in slots in the spindle nose and provide a positive drive for arbors. Arbors are held in the spindle by means of an arbor draw-in rod.

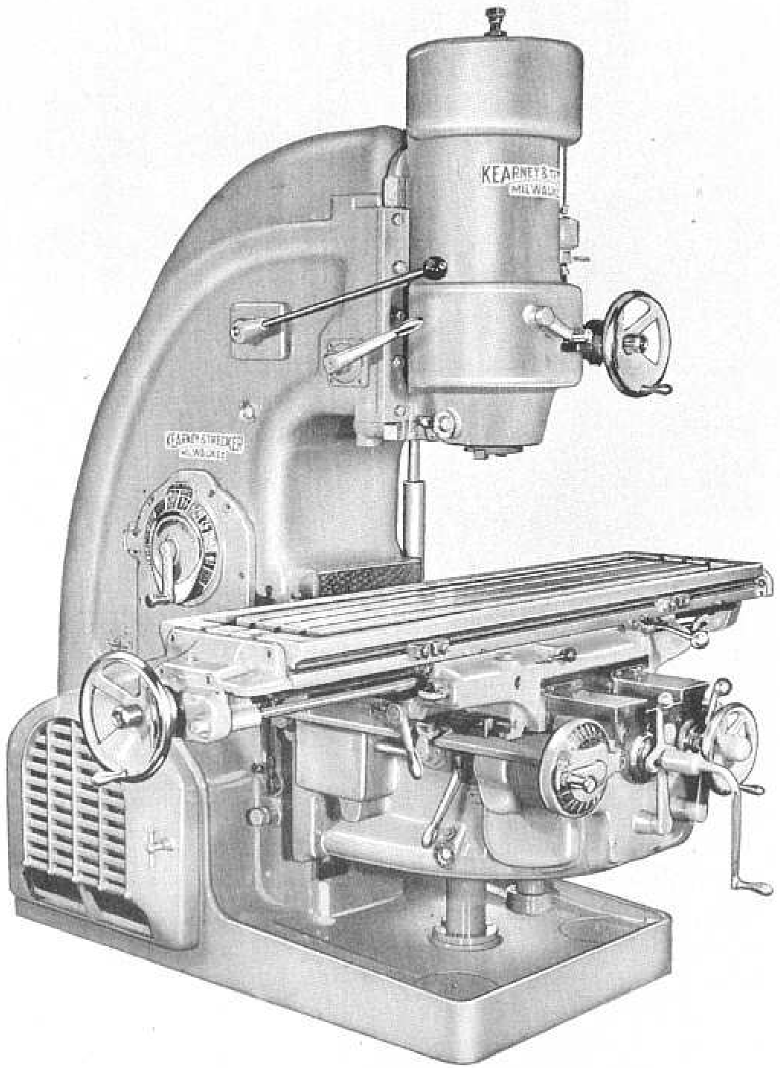

*Fig. 12. Number 2, Model K, sliding head vertical milling machine*



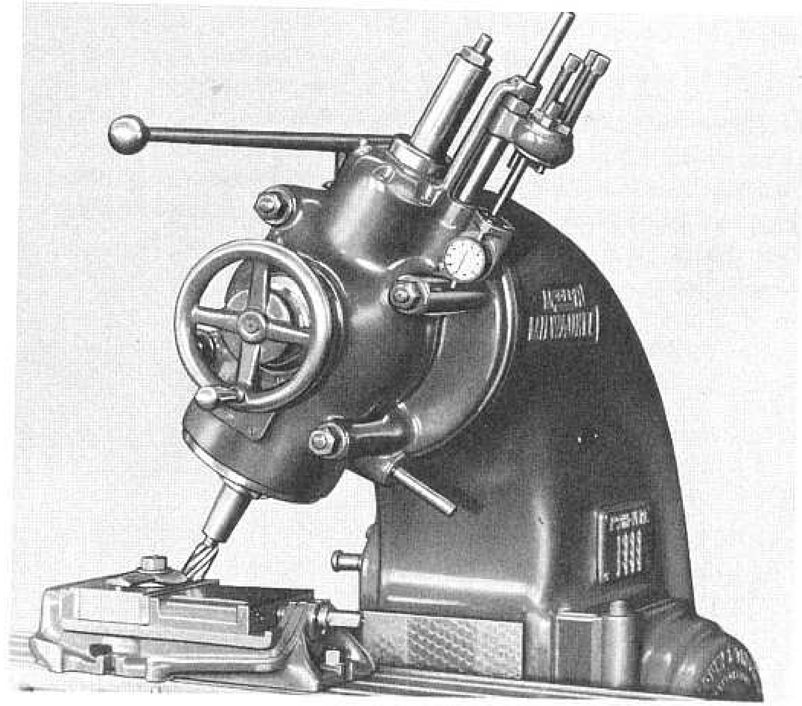

*Fig. 13. Angular milling operation on swivel head machine*

## VERTICAL KNEE-TYPE MILLING MACHINE

The vertical knee-type machine differs from the horizontal only in the position of its spindle. In some vertical spindle machines, Fig. 12, the sliding vertical head can be moved up and down by hand or power. In other models, Fig. 13, angular positioning of the head is possible.

A four-position stop, together with an indicator, increases the usefulness of this type of machine for step milling operations. The head is locked in position by means of a gib clamp on the left side of the vertical head. A power feed lever and handwheel are located on the right side and the front of the head respectively. A graduated dial on the head handwheel makes possible a precise vertical adjustment of the spindle.

Vertical machines, by reason of the vertical spindle, permit a different approach to the milling process and accommodate many jobs unsuited to horizontal machines.

## APPLICATION OF KNEE-TYPE MACHINE

Knee-type milling machines are the most versatile of all milling machines, in fact of all machine tools. In milling practice they are economical and efficient. Their design and construction features permit quick establishment of the proper relationship between cutter and workpiece. They are well suited for application where frequent changes to different sizes and kinds of jobs are required. Because of their versatility, a minimum amount of time is lost in setup changes since the units, spindle, table, saddle and knee, can be operated independently or simultaneously.



*Chapter Two*

# BED-TYPE MILLING MACHINES

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*Fig. 14. Simplex bed-type milling machine*



BED-TYPE milling machines, Fig. 14, are basically designed for high production milling, and their construction places greater emphasis on rigidity than on versatility. The term "bed-type" is derived from the large foundation casting, Fig. 15, which is the principal support for all assembled units. These machines are built to withstand both heavy and light milling cuts alike and to produce accurate work under all circumstances.

In size, bed-type milling machines are not designated by number, but rather are classified as small, medium, or large according to their physical size and rated horsepower capacity. A small model may use a 5 horsepower motor while larger machines use 15 or more horsepower.

Because of their ready adaptation to production milling, bed-type machines may be seen with one or two (infrequently more) spindles. Respectively, these are known as Simplex and Duplex models, and from the viewpoint of design, they are fundamentally the same.

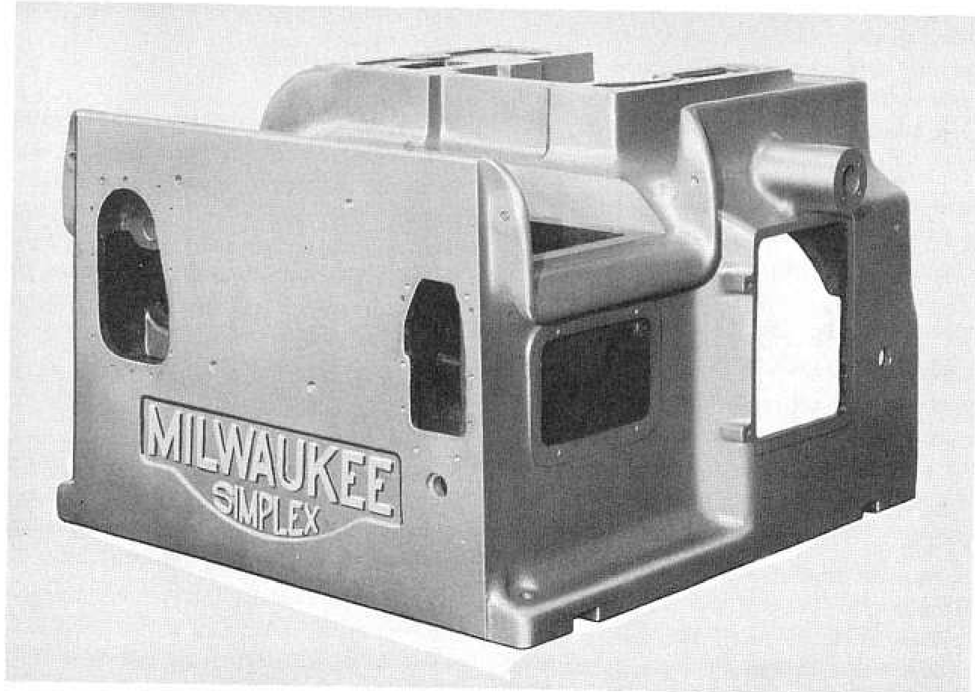


*Fig. 15. Foundation casting of bed-type milling machine*

## SIMPLEX MILLING MACHINE

Most common among bed-type milling machines is the Simplex or single spindle model, Fig. 14. Its principal construction units are the bed, saddle, table, uprights, and spindle block.

### BED

The bed, Fig. 15, is a rugged, one piece box section casting, with heavy internal walls. At the rear of the bed is a compartment for the electric drive motor. Power is transmitted from the motor to the hydraulically operated main drive clutch by means of multiple V-belts. Pick-off gears in the speed box regulate the spindle speed and transmit power from the main drive clutch to the spindle. A shaft from the main drive clutch to the feed change gear box transmits power to the saddle gears which govern longitudinal table feed.

Contained in the drive pulley housing are two pumps, one for the hydraulic oil pressure and the other for automatic lubrication for the entire machine. Oil in the bed reservoir is used for lubrication and also for the hydraulic table clutch and spindle control mechanisms.

A second reservoir in the bed is for coolant. Machines which are intended to work with coolant are equipped with an external coolant pump, piping, and coolant troughs.

Speeds and feeds in bed-type machines are chosen by pick-off gears, rather than by dial selection. These gears are mounted by hand to splined shafts in the feed and speed boxes. This manual system of feed and speed control is in keeping with production milling practice where such changes are relatively infrequent. Charts showing proper combinations of gears for various speeds are located adjacent to the feed and speed boxes.

### SADDLE

In bed-type machines, the saddle is permanently attached to the bed. It contains the hydraulic mechanism which provides automatic table movement control, the table lead screw, and the adjustable nut to eliminate backlash in the table screw. This last feature permits climb milling operation and is not ordinarily found on knee-type machines. In ordinary horizontal bed-type machines the saddle has no cross movement.

### TABLE

As in knee-type machines, the saddle has wide, hand scraped bearing surfaces for accurate assembly and table travel. The table itself has a ground top surface containing three or five deep T-slots, depending on table width, and numerous stop holes to facilitate job setup.

Longitudinal table travel is the only power feed movement on bed-type machines. There is no cross or vertical movement affecting the table position although horizontal spindle quill and vertical spindle block adjustment compensate for the lack of these movements. An outstanding production feature of these machines is the automatic cycle of table movements which will be discussed at some length in a following chapter.




*Fig. 16. Spindle upright unit*

### UPRIGHTS

The assembly for spindle block support includes two rugged, reinforced, semi-steel uprights, Fig. 16, bridged with an equally durable support casting. The complete unit is doweled and securely bolted to the bed, thus providing a rigid mount for the spindle block.

A handwheel or handcrank is provided at the right side of the uprights for horizontal spindle quill or vertical spindle block adjustment together with clamp nuts to lock the spindle block or quill in position. These adjustments of the spindle together with the longitudinal travel of the table permit cutters to be properly located with respect to workpieces and the milling operations to be performed. Bores in the spindle block are for the overarms which, as we have seen in knee-type machines, serve to support the arbor-cutter setup rigidly.

### SPINDLE BLOCK

This unit, Fig. 17, is compactly assembled and arranged to slide on accurately scraped surfaces between the uprights, thus making vertical spindle adjustment possible. The spindle itself, mounted in a quill, is capable of horizontal adjustment in and out of the spindle block.

## DUPLEX MILLING MACHINE

As pointed out previously, the term "Duplex" conveys the meaning of "two" and as applied to these machines it means "having two opposed spindles." In comparing the Duplex, Fig. 18, with the Simplex, we need but remember this one fact, for it is the distinguishing characteristic of the Duplex machine.

The opportunity to utilize two spindles simultaneously, although each is separately driven and controlled, naturally increases a machine's productive capacity, for it becomes possible to take two cuts on either identical or dissimilar workpieces, or even a roughing cut with one cutter and a finishing cut with the other.

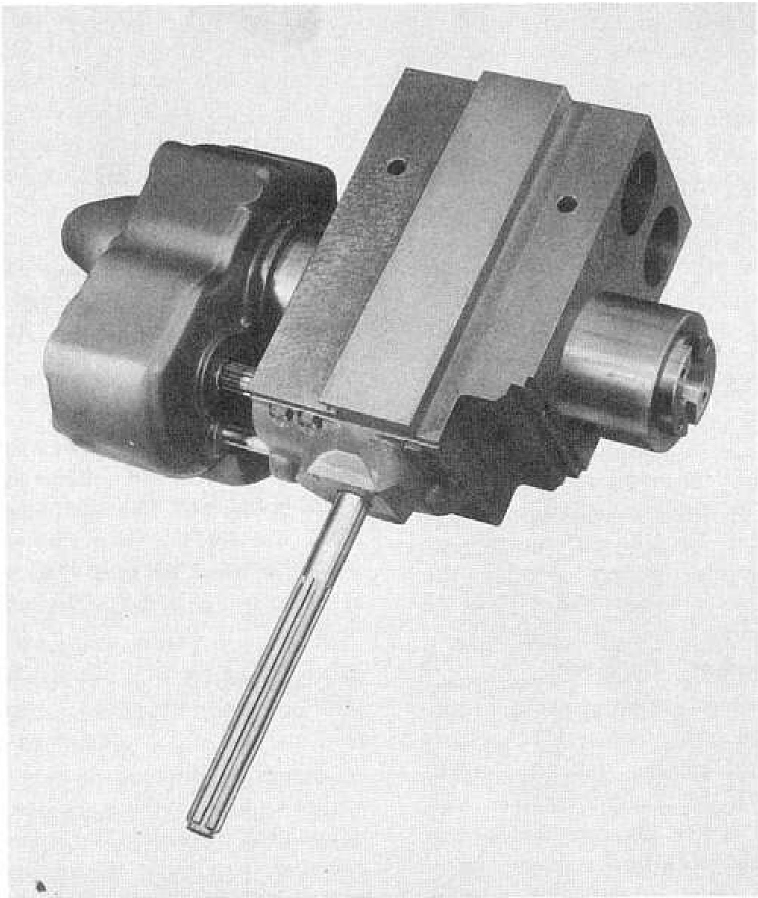

*Fig. 17. Bed-type milling machine spindle block*

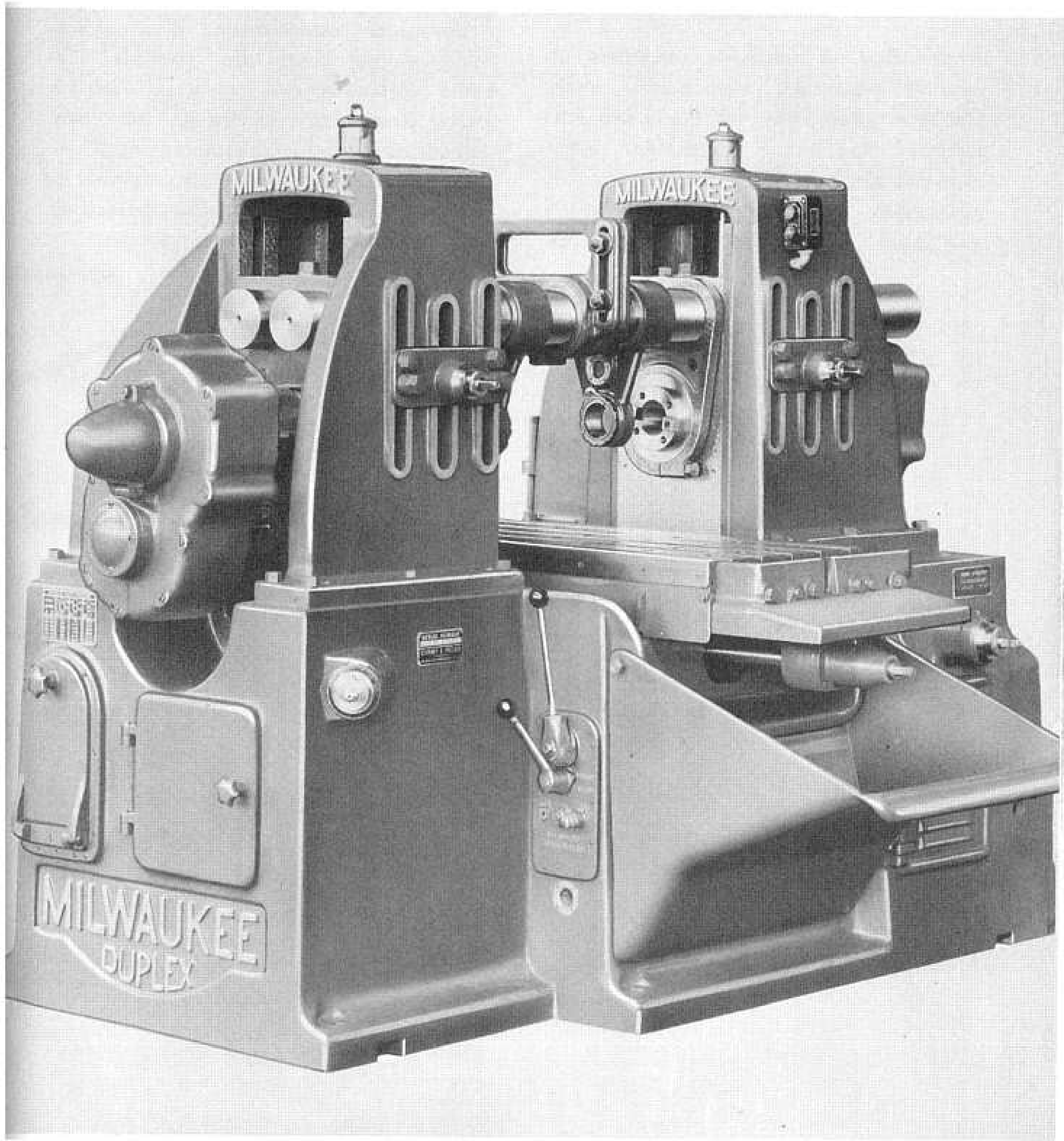


*Fig. 18. Duplex bed-type milling machine*

## APPLICATION OF BED-TYPE MACHINES

Application of bed-type machines is usually associated with heavy workpieces or production milling. Long production runs with infrequent setup changes are best suited to this type of equipment. There is no need for quick and easy adjustments of the cutter to the workpiece as is provided in the knee-type machines.

Numerous adaptations of standard bed-type machines are possible. In some cases special uprights support cutter heads, the spindles of which are driven by individual motors. Application or design of such machines is beyond the scope of this discussion and will be reviewed in a later volume.



# *Chapter Three*

# CUTTER DRIVING ATTACHMENTS

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A MILLING machine attachment is a supplementary device which, when applied to a standard machine—either knee or bed-type, increases the scope of work that can be done. Attachments often enable milling operations to be performed more economically even though, in some cases, they transform the milling machine into a special machine tool such as a slotter or thread miller.

Attachments may be classified according to two general types: 1) cutter driving and 2) work holding. In the first group are included the vertical, universal, slotting, thread, and rack milling attachments while the plain vise, swivel vise, rack vise, rotary table, dividing head, universal chucks, and special fixtures are work holding attachments.

## VERTICAL MILLING ATTACHMENTS

A certain amount of work in any shop is expedited through the use of a vertical milling machine. Very often the volume of such work does not warrant the installation of a vertical machine. A vertical attachment which transforms the more common horizontal into a vertical machine is an economical solution to this problem. In shops having both types of machines, the vertical attachment adds much to the versatility of the equipment and often eliminates the need for additional machines.

## SWIVEL HEAD ATTACHMENT

One of the most widely used vertical attachments is shown in Fig. 20. Gears

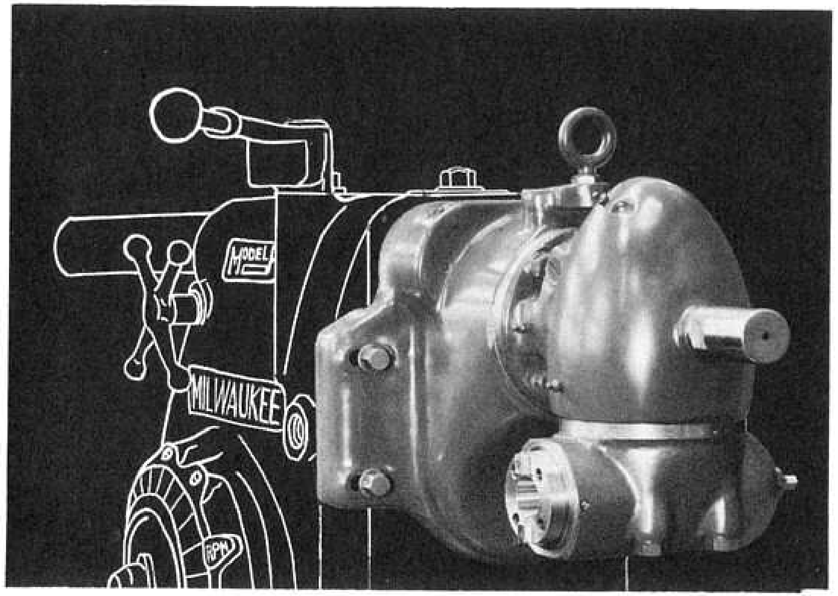


***Fig. 19. Universal milling attachment***



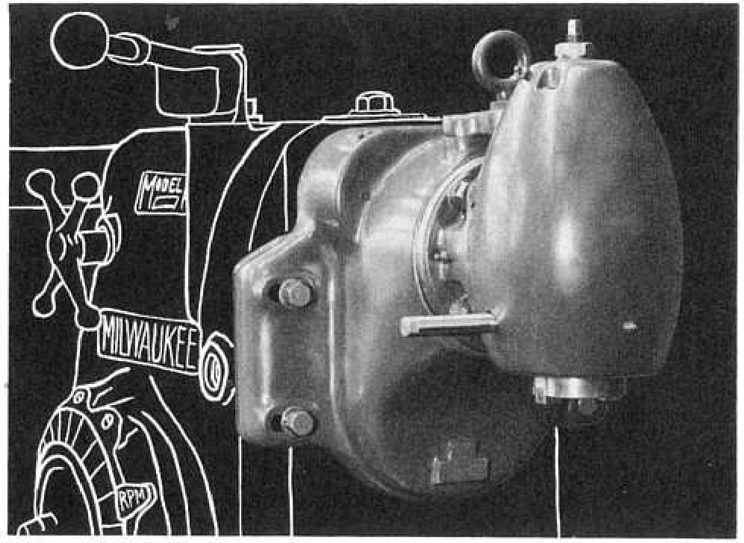


***Fig. 20. Swivel head attachment***

attached to the horizontal spindle of the machine drive the vertical spindle of the attachment while the attachment itself is securely gibbed to the column face and supported by the overarms. The spindle housing is graduated the full 360 degrees and the spindle can be set at any angle and clamped in position.

Machine spindle speed and attachment spindle speed are in 1 to 1 ratio, a convenience which permits easy selection of the proper speed for the cutter and workpiece material.

## UNIVERSAL ATTACHMENT

A universal milling attachment, Fig. 19, can be adjusted in both the horizontal and vertical planes. It has two graduated bases at right angles to each other which can be swiveled through 360 degrees, enabling the setup of a compound angle relationship between the cutter and workpiece. The machine spindle is the source of power for the attachment which is solidly gibbed to the front of the column and is supported by the twin overarms. This type of attachment is particularly useful in die, jig, or fixture milling.

## HIGH SPEED MILLING ATTACHMENTS

High speed adjustable universal milling attachments, Fig. 21, have two bases graduated through 360 degrees to permit compound angle setting of the cutter. The entire unit is mounted on the double overarms of the machine and is capable of lateral adjustment

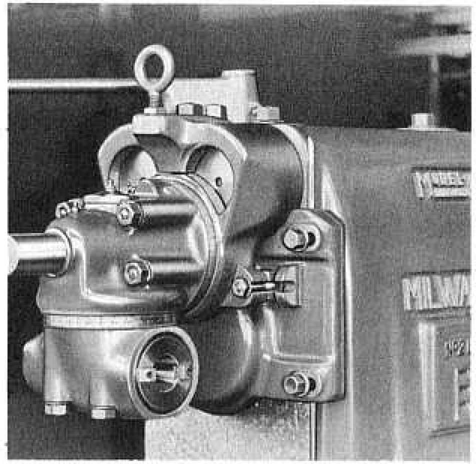

*Fig. 21. High speed universal milling attachment*

along the overarms. Spindle speeds of these attachments are approximately one and one-half times the machine spindle speeds. Generally these attachments are used with small cutters on light or medium operations and for this reason are of light, though strong, construction. When used in conjunction with swivel vises, dividing heads, or rotary tables, the versatility of both the attachment and machine itself is increased to a marked extent.

## ROTARY MILLING HEAD

The extremely versatile Tri-D rotary milling head will produce almost any geometric shape in metal, employing straight lines, radii or angles, using only simple arithmetic. This attachment, readily adaptable to horizontal column machines, is power driven from the machine spindle or can be driven by an individual power source.

## SLOTTING ATTACHMENT

For occasional slotting operations on keyways, internal gears, and for similar machining requirements, a slotting attachment, Fig. 23, can be applied to a standard horizontal knee type milling machine. The attachment is supported on the overarms and is rigidly secured to the column face. The ram (which replaces the spindle on this attachment) is driven with a pin and shoe from the machine spindle producing a sliding movement. The end of the ram is equipped with hardened steel V-jaws to hold the cutting tool firmly.

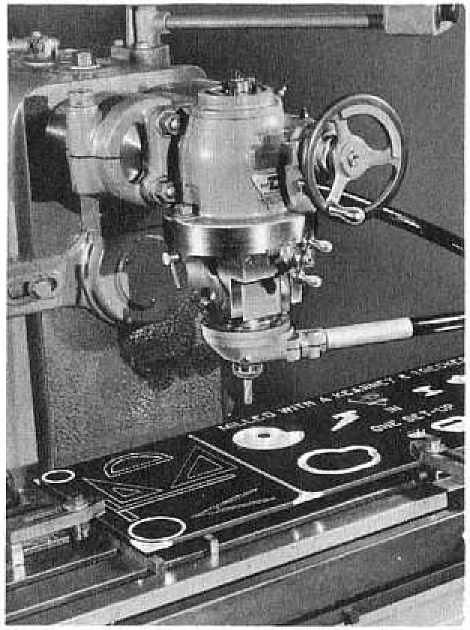

*Fig. 22. Tri-D milling head on plain machine.*



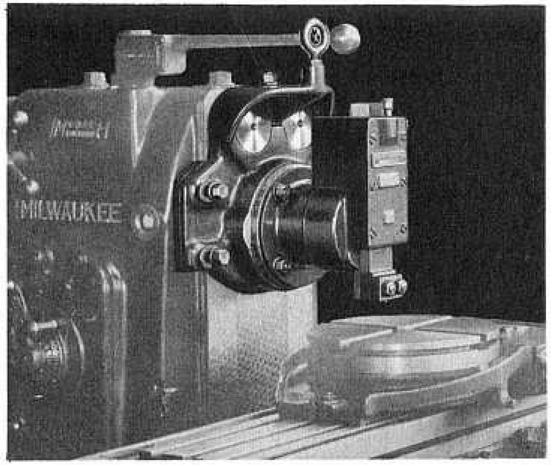


*Fig. 23. Slotting attachment*

The number of ram strokes per minute is the same as the rpm of the machine spindle. The base of the slotting attachment is graduated through 360 degrees, permitting angular positioning in a vertical plane. There are many applications of this attachment with the rotary table and dividing head. The ram can be set at any angle for horizontal or angular machining of slots, keyways, or splines. A typical application of this attachment with a rotary table is shown in Fig. 24.

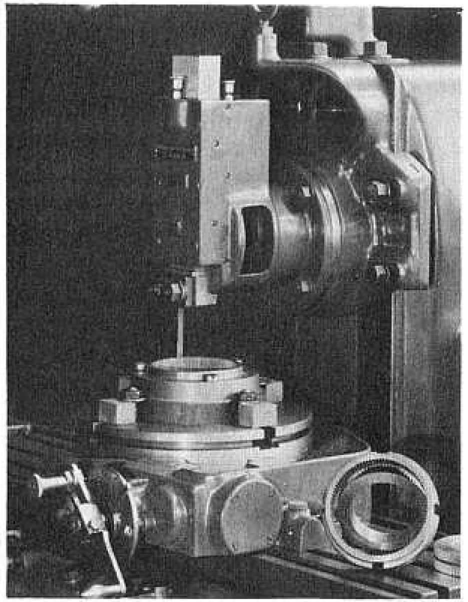

*Fig. 24. Slotting attachment machining serrations in workpiece*

## THREAD MILLING ATTACHMENT

Like other cutter driving attachments we have seen, the thread milling attachment Fig. 25, also is mounted on the overarms and clamped to the column face by a support bracket. It is used chiefly on universal milling machines and its spindle rotates at right angles to the machine spindle.

With this attachment, it is possible to mill all of the regular forms of threads (see Fig. 8) that can be produced on a standard thread milling machine. Innumerable special odd threads can be made when a low lead attachment is employed to rotate the workpiece through the dividing head spindle.

The thread milling attachment is found chiefly in tool rooms and experimental laboratories or in tool shops where thread work is relatively infrequent.

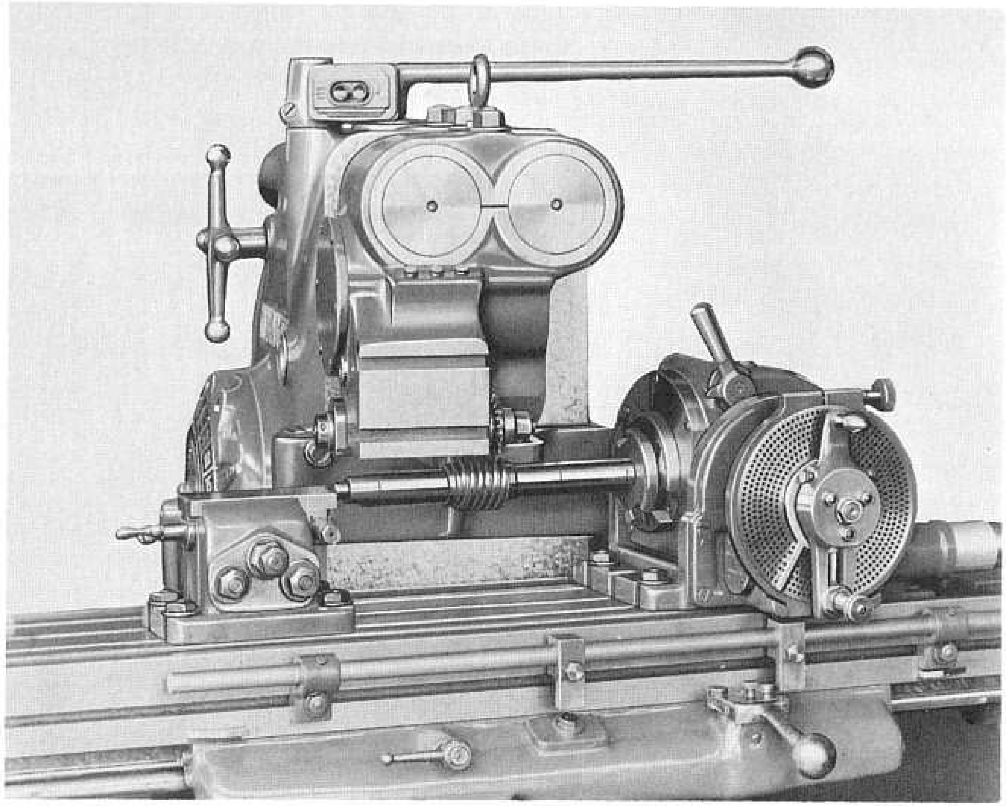

***Fig. 25. Thread milling attachment***



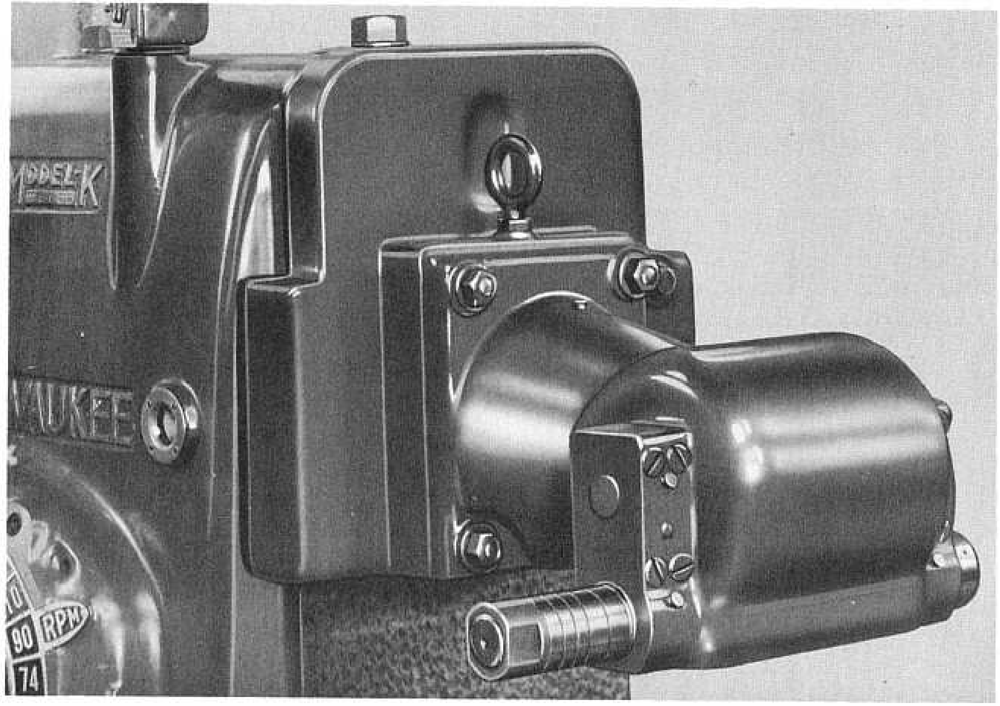

***Fig. 26. Rack milling attachment***

## RACK MILLING ATTACHMENT

As the name implies, this attachment Fig. 26, is primarily designed for milling racks. However, since it is far from a single purpose unit, it can be used for a number of other operations such as sawing off stock or cross milling on long workpieces. It permits the milling of long work—near the center—on the ends—in fact at any location with the added advantage that the workpiece can be rigidly clamped and supported throughout the entire length of the table by means of a rack vise.

The rack milling attachment is mounted on the overarms and gibbed

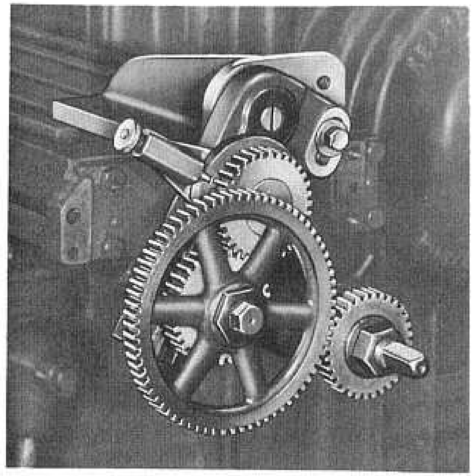

***Fig. 27. Rack indexing attachment***

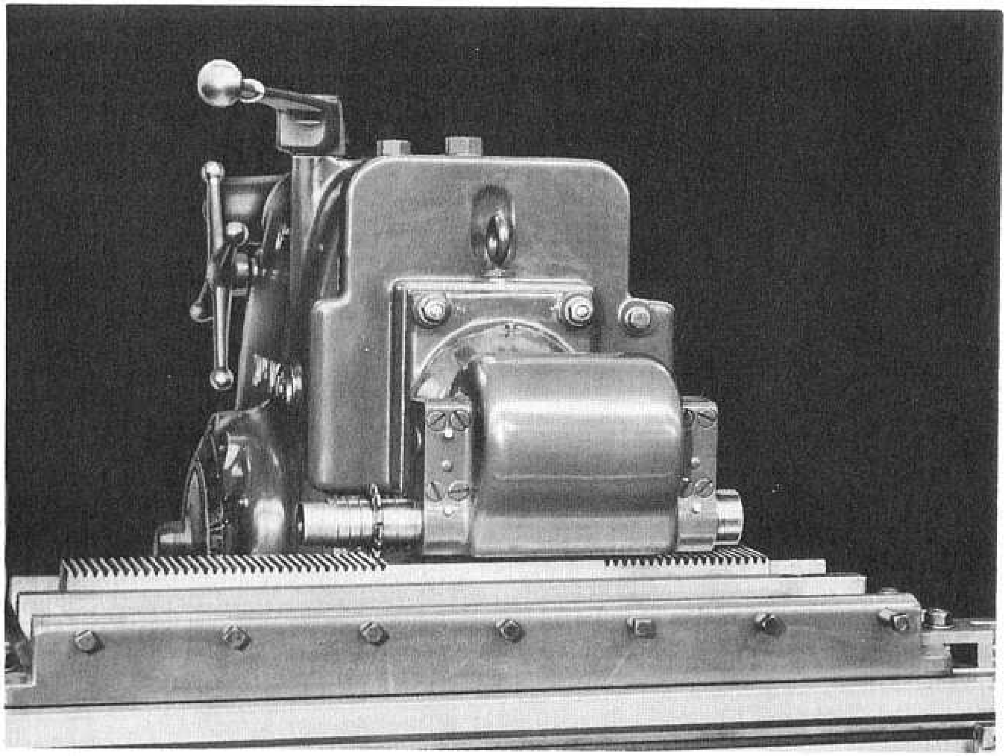

*Fig. 28. Milling rack teeth using rack milling attachment*

solidly to the column face of the machine. As in the thread milling attachment, the spindle (with integral arbor) is at right angles to the machine spindle and parallel to the top of the table.

Milling racks is a relatively simple operation and the table feed dial can be used for indexing the table. To facilitate indexing and to eliminate possible errors in dial readings a rack indexing attachment Fig. 27, can be attached to the table screw. This unit consists of several interchangeable gears which provide, when properly selected, the correct spacing required in the indexing operations. Fig. 28 illustrates a typical application of the rack milling attachment.



# *Chapter Four*

## WORK HOLDING ATTACHMENTS

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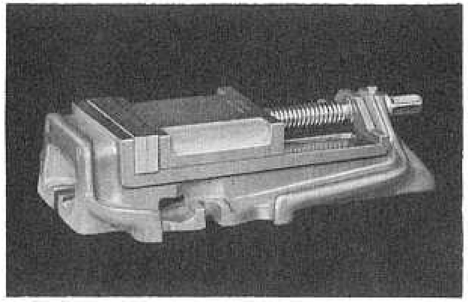

Fig. 29. Plain vise

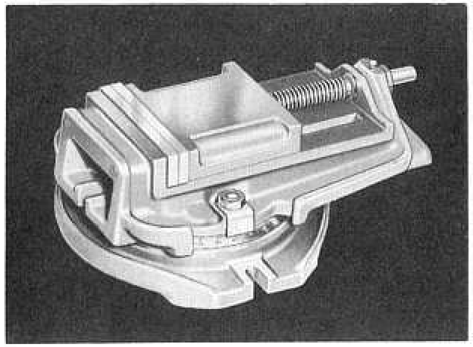

Fig. 30. Swivel vise

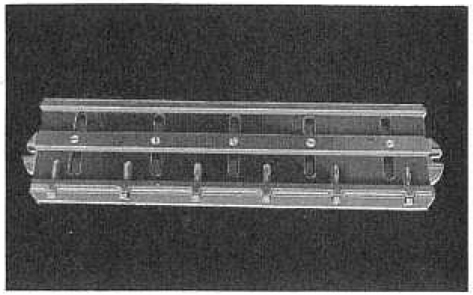

Fig. 31. Rack vise

## PLAIN VISE

THE most common of all work holding devices is the plain vise, Fig. 29, and probably because of its wide usage, it does not always receive the consideration it should as an accurate holding attachment. The vise has hardened and ground steel jaws, very accurately assembled, so that when the vise is bolted to the machine table these jaws will be either exactly parallel or at right angles to the table T-slots, depending upon the position of the vise body. Fixture keys fastened to the bottom of the vise locate the attachment precisely parallel or at right angles to the table centerline.

## SWIVEL VISE

The swivel vise, Fig. 30, is identical to the plain type with the exception of its swivel base which is graduated around its entire circumference in degrees. Thus the vise jaws may be set at any desired angle in a horizontal plane, permitting a precise angular relationship between cutter and workpiece. Typical of plain and swivel vise applications are Fig. 32 and 33.

## RACK VISE

The rack vise, Fig. 31, is an accurately made holding device for long workpieces that require a long clamping jaw to secure them firmly in lengthwise position on the milling machine table. The rack vise often is employed for production purposes so that many smaller, regularly shaped workpieces



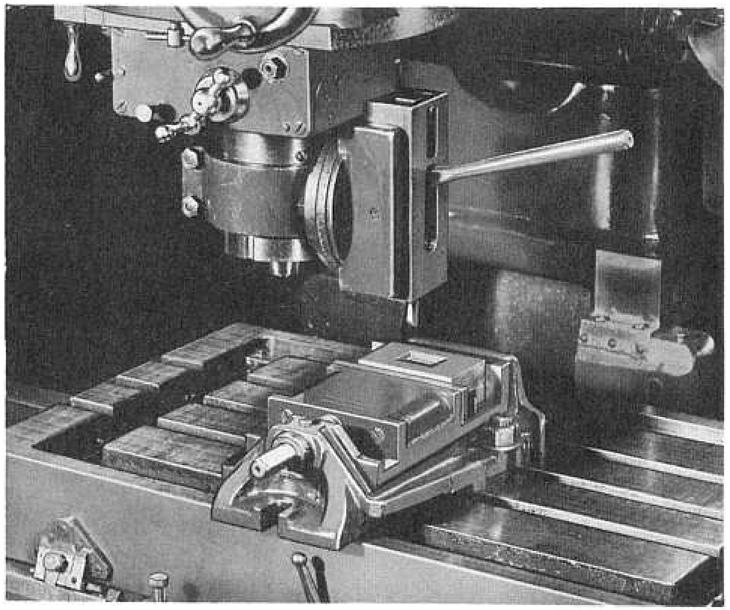

Fig. 32. Typical application of a plain vise

can be set up at one time over the length of its jaws. In construction, the rack vise is similar to the plain type with the exception that it has several equally spaced clamping screws rather than one. This arrangement produces an equalized clamping pressure over the full length of the jaws.

When tightening the vise jaw on the work, the operator should make certain 1) that the work is properly held and 2) that the vise jaw is reasonably tight. It is not necessary to use hammers on the vise handle to tighten the vise jaw properly. Such abuse injures the screw in the movable jaw of the vise, will destroy its accuracy, and puts undue strains on the entire vise.

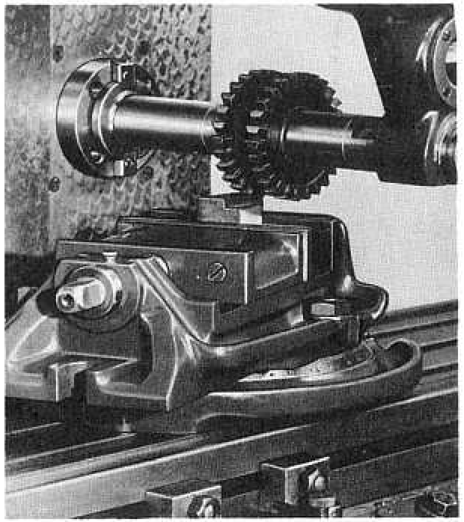

Fig. 33. Typical swivel vise application

## UNIVERSAL CHUCK

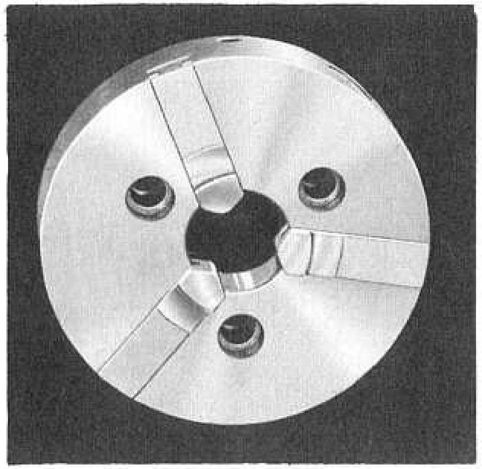

*Fig. 34. 3 jaw universal chuck*

The universal chuck, Fig. 34, is a precision holding device frequently used in milling operations to hold cylindrical workpieces.

Its principal construction elements are the chuck body, scroll, and jaws. Chuck bodies are semi-steel and all working parts are of heat-treated alloy steels. The jaws are reversible, enabling them to grip internally or externally. All three jaws are adjusted through a single pinion in mesh with the scroll.

The universal chuck may be employed in several ways in the milling process. It may be mounted to the machine spindle or dividing head spindle, Fig. 35 and 36.

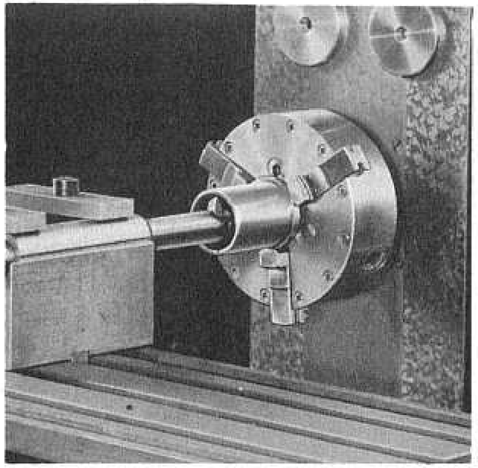

*Fig. 35. Chuck bolted to spindle nose for boring operation*

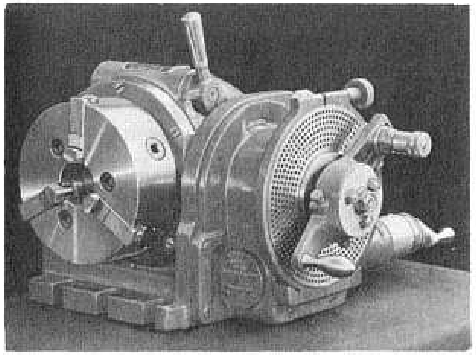

*Fig. 36. Chuck mounted on dividing head spindle*



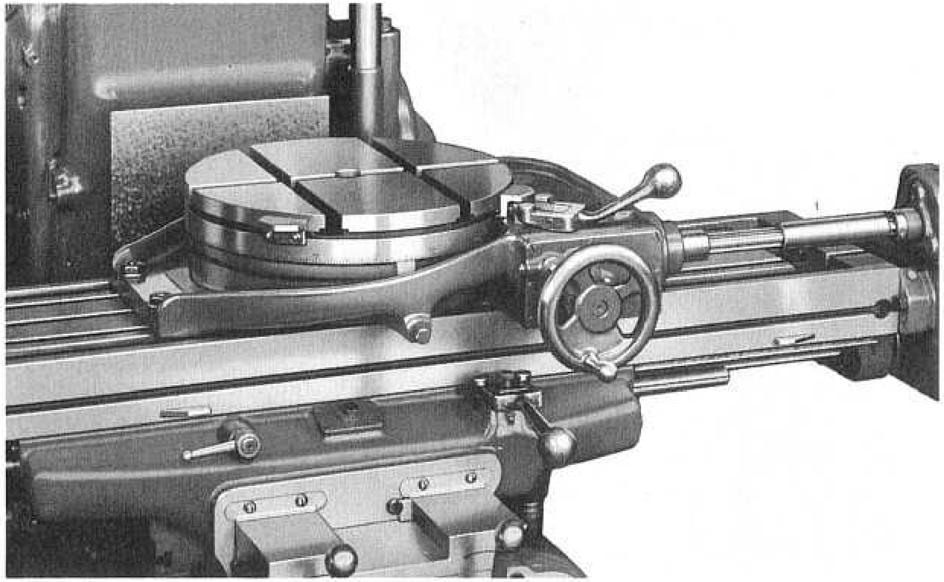

*Fig. 37. Rotary table*

## ROTARY TABLE

The rotary table, Fig. 37, as a work holding attachment is bolted to the milling machine table. Its base is graduated through 360 degrees, allowing the workpiece to be rotated in a complete circle. In conjunction with this rotary movement, an indexing unit, Fig. 38, can be applied to divide accurately, to space holes, flanges, gear teeth, slots, and to perform circular milling operations.

Rotary tables may be either hand operated or power driven models. The latter receives its power from the auxiliary table shaft through a drive bracket attached to the machine table. The

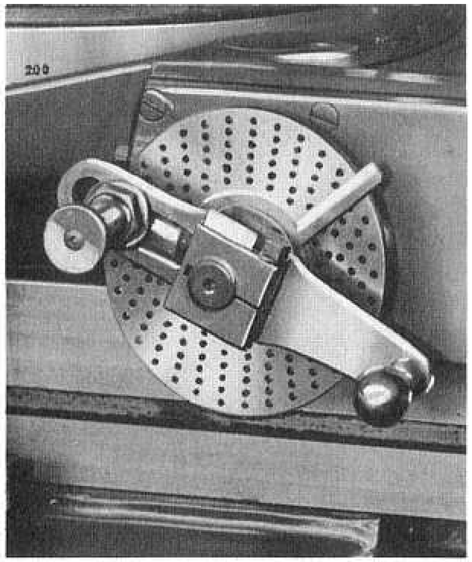

*Fig. 38. Rotary table indexing plate*

power feed mechanism permits circular milling in many types of operations. When rotated by power, the feed rate at the periphery of the rotary table corresponds to the selected feed on the feed dial of the machine. A typical application of a power feed rotary table is shown in Fig. 39.

## DIVIDING HEAD

The universal dividing head, Fig. 40, is one of the most interesting and important of all attachments. With it, numerous operations such as milling flutes, spirals, threads, and cams can be quickly and accurately completed.

Theoretically, the dividing head may

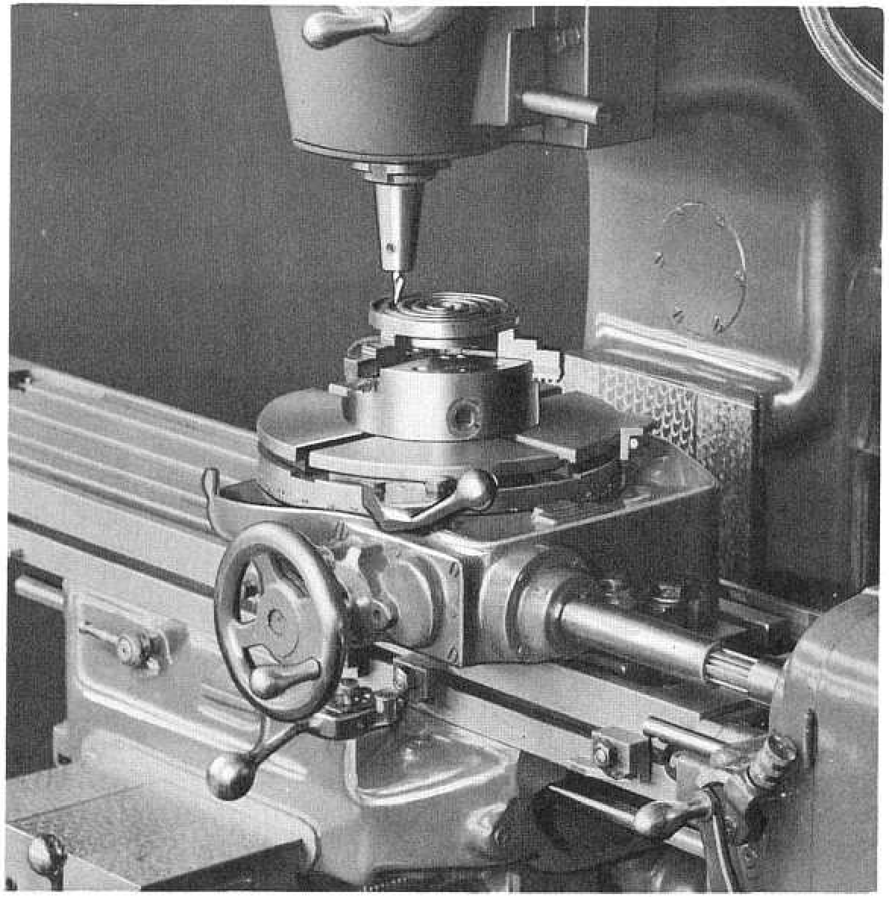

***Fig. 39. Power driven rotary table on vertical machine milling scroll in workpiece***



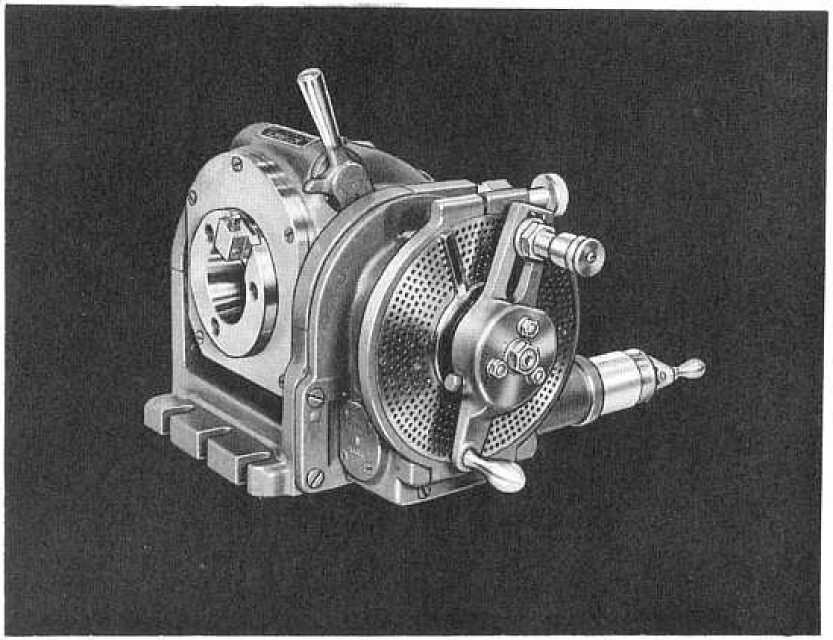

***Fig. 40. Model K universal dividing head***

be defined as a mechanical device used to divide a circle accurately into any number of equal divisions. In actual practice, however, its uses extend to milling applications far more complex than the mere division of a circle.

The fundamental units of the dividing head are the spindle, index crank, and index plate. By means of 5 to 1 ratio hypoid gearing (five turns of crank equal one complete revolution of the spindle) the relation between spindle and crank has been greatly simplified. The indexing accuracy of this dividing head is well within one minute of arc —the equivalent of 1/21,600 part of a circle.

The index plate of the dividing head contains seven circular rows of equally spaced holes. Its function is to provide the operator with ample opportunities for meeting the division or indexing requirements of his work. The index crank is equipped with a plunger pin which engages the particular holes selected to obtain the proper division. Sector fingers are used to space or mark properly the distance the crank is to be turned between divisions. Thus the operator does not have to count holes each time a division is to be made.

When operated by power, the dividing head is driven from the machine's table lead screw by means of either a low or conventional lead attachment. Power operation is usually needed in order to obtain the proper lead in

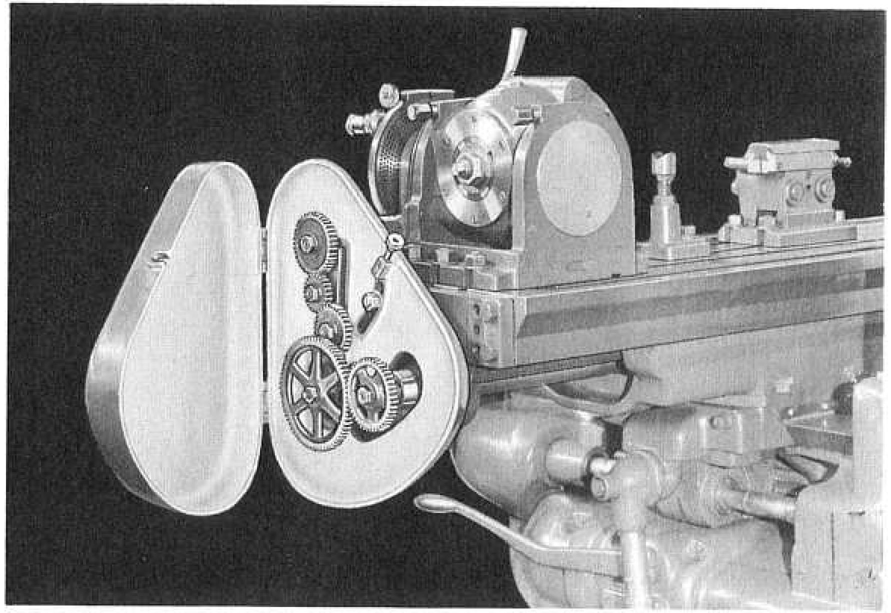

*Fig. 41. Conventional lead attachment*

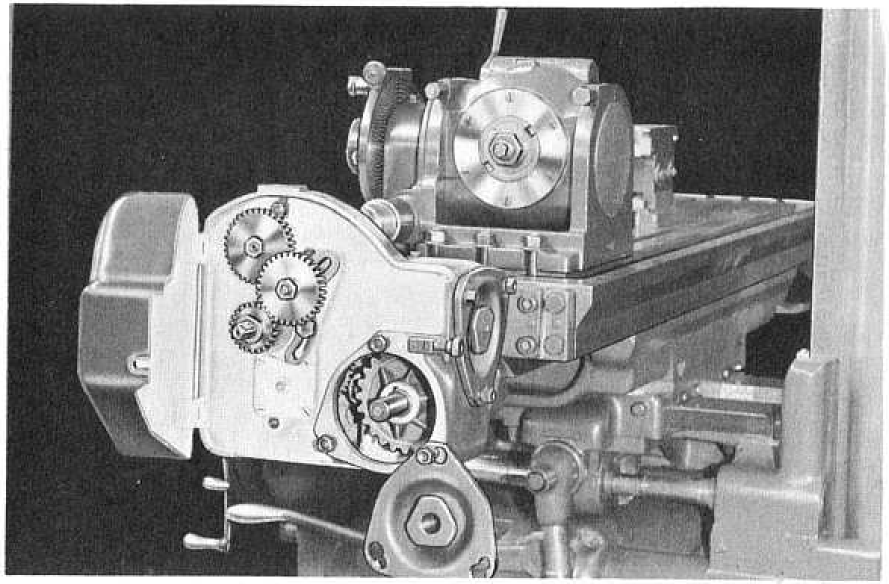

*Fig. 42. Low lead attachment*



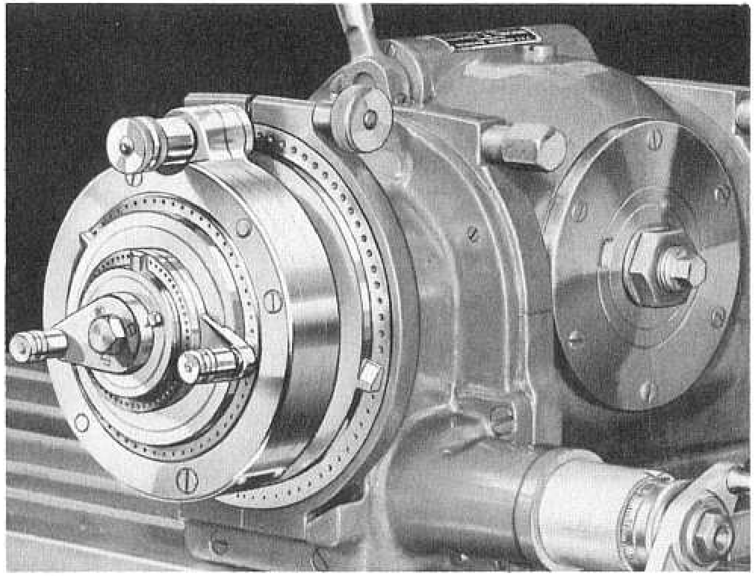

*Fig. 43. Astronomical dividing head attachment*

feeding the workpiece when milling a spiral. Lead may be defined as the distance the table travels while the workpiece, revolving with the dividing head spindle, makes one complete revolution. The conventional and low lead attachments, Fig. 41 and 42 respectively, consist of gearing combinations which provide the various leads that may be needed. A conventional lead attachment supplies leads from 0.670 to 149 inches, while more than 40,000 leads from 0.0219 to 2918.4 inches are obtainable through the wider range of the low lead attachment.

Contributing much to the development of more accurate milling methods is the astronomical divider, Fig. 43, a precision instrument designed for the purpose of dividing a circle into precise increments beyond those obtainable by ordinary means.

This attachment, usable only with the 5 to 1 ratio hypoid dividing head, enables a circle to be divided into 1,296,000 divisions by the simplest of indexing methods. The divider has three separate index plates, each with a single row of holes and plunger pin. The large plate has 72 holes, each representing one degree (five turns of crank for 360 degrees). The intermediate and smallest plates have 60 holes each, with each hole representing ONE minute of arc and ONE second of arc, respectively. For example, to space 5 degrees, 17 minutes, and 32 seconds, one merely has to move the small

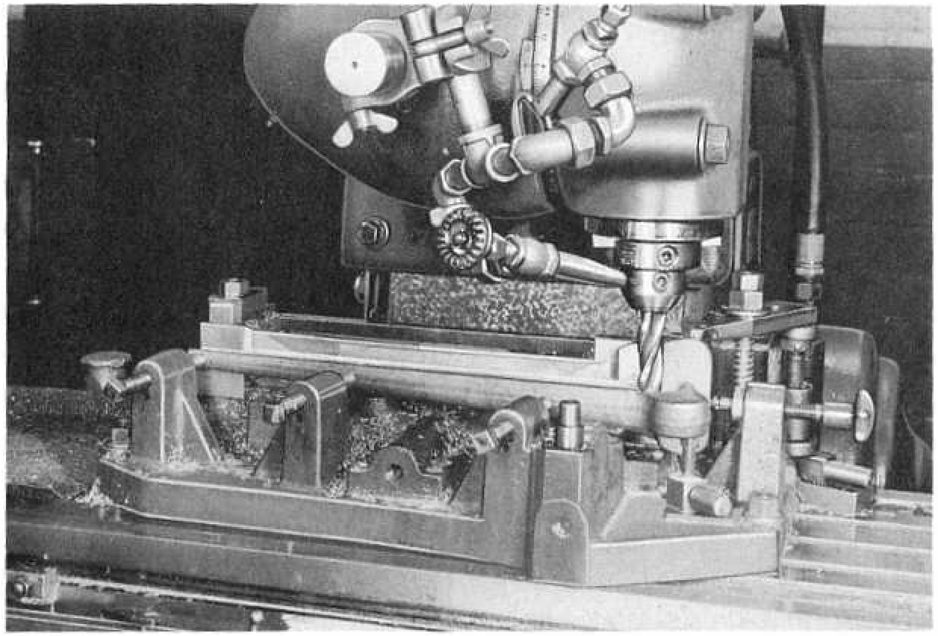

*Fig. 44. Typical milling fixture*

plunger 32 holes, the middle plunger 17 holes, and the largest 5 holes. Thus the time consuming task of indexing to degrees, minutes, and seconds, with its numerous possibilities of error, is reduced to the simplest of operations.

## FIXTURES

Very often it is impossible to accommodate workpieces in a conventional work holding attachment and it becomes necessary to use a special device known as a milling fixture. Fig. 44 is typical of fixtures which are widely used in milling operations on all sizes and types of machines. Primary purpose of the fixture is to hold the workpiece securely in a fixed location. Chief disadvantage of a special fixture is that it will usually be applicable to only one workpiece for one operation.

In review of milling machine attachments, their construction and place in the milling process, the points to remember about all of them are 1) their precision manufacture and the care needed to maintain this quality; 2) their usefulness in converting the standard machine to one with broader range of application; and 3) their easy adaptation to operations outside the field of milling such as drilling, boring, turning, and slotting.



# *Chapter Five*

# MILLING MACHINE ARBORS

★

KEARNEY & TRECKER MILWAUKEE

SINCE arbors have the purpose of holding and driving cutters, their precision and trueness greatly influence the accuracy and economy with which milling operations can be performed. The arbor is a precision tool as much as any fine measuring instrument or indicator and must be treated accordingly.

Prior to 1927 milling machine spindles were not governed by any taper standards and arbors, likewise, were not uniform. However, in that year the National Machine Tool Builders' Association adopted a standard tapered spindle end having a taper of 3½" per foot. In addition, a uniform numbering system for national standard tapered arbors was approved whereby the following specifications were listed in sequence: taper size, diameter, style, length from shoulder to nut, and size of bearing. For example, Arbor No. 41¼A16-3 indicates an arbor with a No. 40 standard taper, 1¼" in diameter, Style A, length 16" from shoulder to nut with a No. 3 bearing. Likewise, a 51½B24-4 arbor has a No. 50 standard taper, is 1½" in diameter, Style B, length 24" from shoulder to nut with a No. 4 bearing.

Arbors are made in three styles, namely, A, B, and C, Fig. 45. Each has a particular application in the milling process and the operator must determine from the job at hand which to

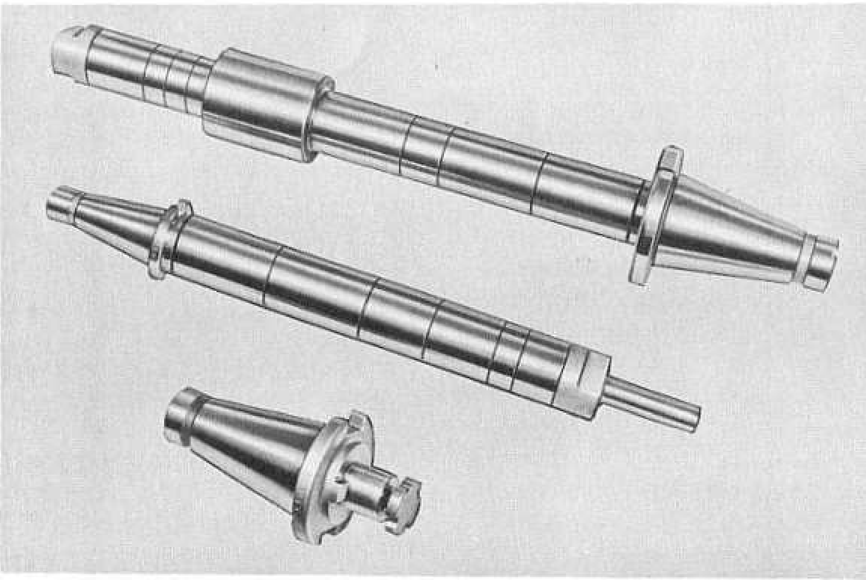

*Fig. 45. Style A (middle), B (top), and C (bottom) arbors*



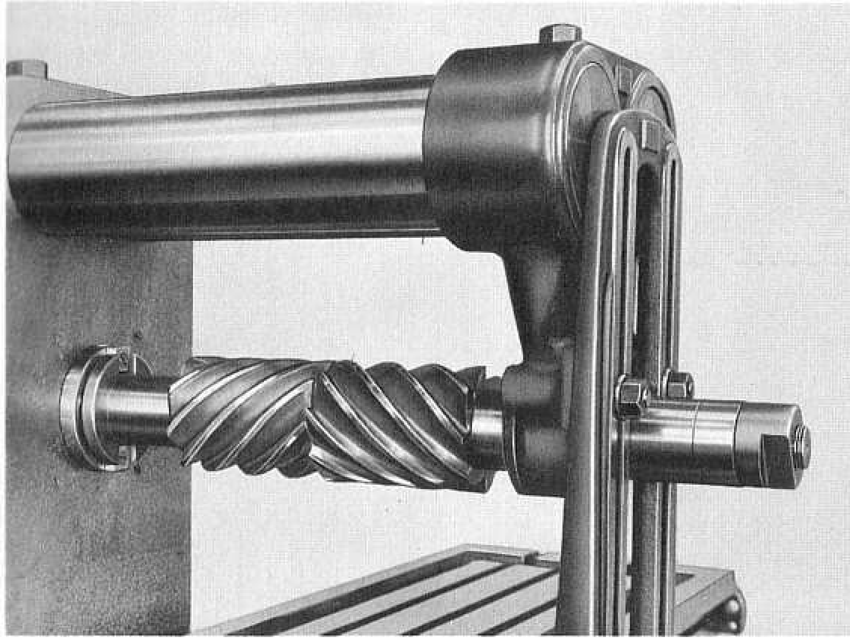

*Fig. 46. Style B arbor supported by outer arbor support and adjustable arm brace*

use. A word here, too, about collet holders: A collet holder is a form of sleeve bushing for reducing the size of the tapered hole in the machine spindle so that cutters with smaller tapered shanks (end mill cutters notably) can be inserted directly into the spindle. Thus a collet holder takes the place of an arbor in this respect.

Arbors and collet holders are firmly held in the milling machine spindle by means of an arbor draw-in rod which can be locked under heavy pressure. Driving contact is made by means of two drive keys on the spindle nose which fit into corresponding slots on the arbor flanges.

On Style A and B arbors, milling cutters are positioned by means of spacing collars. The cutter assembly is keyed to the arbor and locked securely through an end nut which exerts pressure against the arbor shoulder. The arbor-cutter assembly is supported and strengthened at the outer end by means of an outer arbor support adjustable arm brace, Fig. 46, as the setup may demand. These supports, mounted from the overarms, provide the necessary rigidity for accuracy and economy in milling operations. Style C arbors, being of the stub type, do not require this support.

## STYLE A ARBOR

The Style A arbor, Fig. 47, is characterized by the small pilot end. The arbor support, mounted on the overarms, supports the Style A arbor at this pilot end which becomes a journal running in the bronze bearing of the arbor support, Fig. 48. Style A arbors, when supported at the pilot end by arbor supports flush with the bottom of the arbor, permit use of small diameter cutters with sufficient clearance of the support to pass over fixtures, vises, and workpieces. Bearings can be applied to Style A arbors permitting the use of an intermediate or outer arbor support for larger cutters and heavier cuts.

## STYLE B ARBOR

The Style B arbor, Fig. 49, is used wherever heavy cuts are made and the milling operation does not require maximum support clearance. This arbor is characterized by a uniform diameter throughout its length. Proper arbor supports can be placed at any position along the arbor, and consequently, close to the cutters for maximum rigidity.

On medium and heavy cuts it is advisable to use both the intermediate and outer arbor supports. These should always be mounted as close to the cutters as possible. Additional setup rigidity is obtained by using, wherever possible, the adjustable arm brace, Fig. 46. This is bolted to the outer arbor support, thereby tying the knee and overarms together.

## STYLE C ARBOR

The Style C arbor, Fig. 50, is used for holding the smaller sizes of shell end mill and face milling cutters, Fig. 51, too small to be bolted directly to the spindle nose.

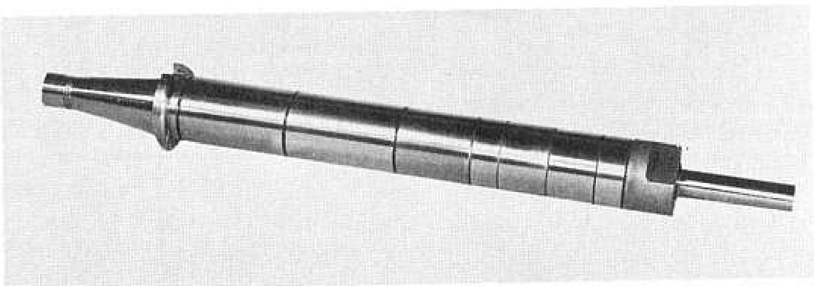

*Fig. 47. Style A arbor*



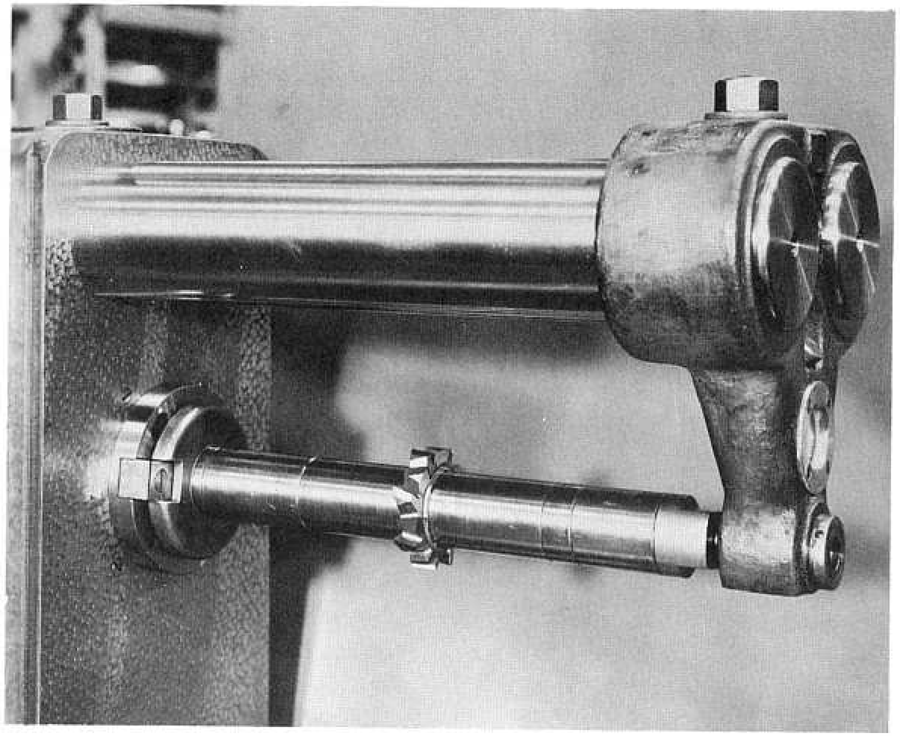

*Fig. 48. Style A arbor with style A arbor support*

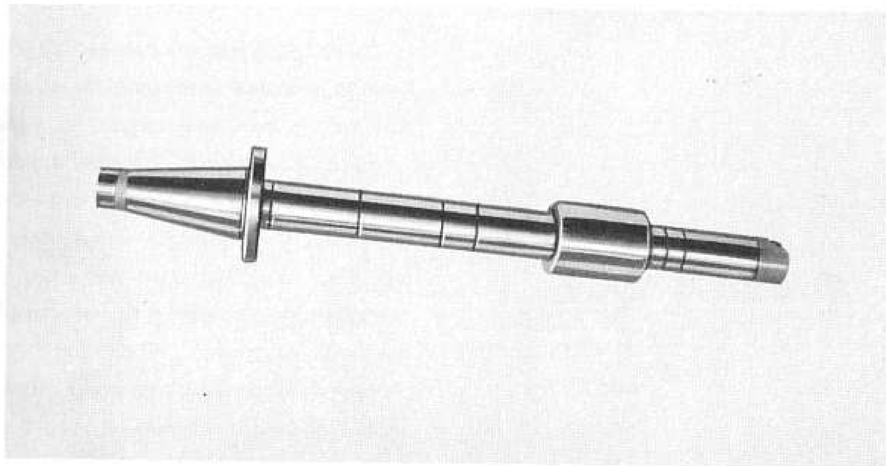

*Fig. 49. Style B arbor with arbor bearing*

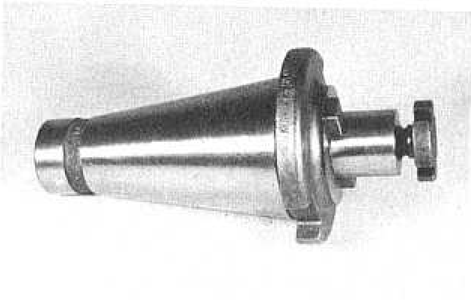

*Fig. 50. Style C arbor*

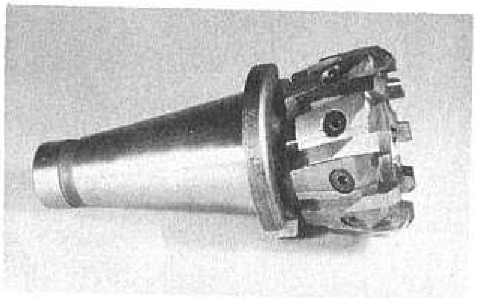

*Fig. 51. Face milling cutter mounted on style C arbor*

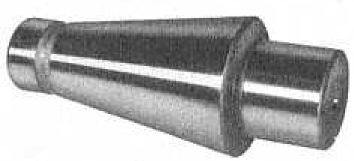

*Fig. 52. Centering plug*

## CENTERING PLUG

Centering plugs shown in Fig. 52, are used for centering cutters which bolt directly to the spindle nose. Large diameter face milling cutters, which center on the outer diameter of the spindle, are more easily mounted and have added support when used with a centering plug. Also, this unit affords protection to the spindle taper from chips and grit.

## COLLET HOLDERS

A collet holder is a form of sleeve bushing for reducing the size of the tapered hole in the machine spindle so that cutters with smaller tapered shanks (Morse and B & S tapers) can be inserted directly into the spindle. Thus a collet holder takes the place of an arbor in this respect.

Collet holders are of three types: one that is inserted and requires removing the holder from the spindle in order to change cutters, Fig. 53; the second is an extended type which permits changing cutters without removal from the spindle, Fig. 54; and the third is a spring collet holder, Fig. 55, used for various diameter collets for holding straight shank drills, reamers, and end mills. A cap nut forces a spring collet into the taper seat of the holder, locking the tool firmly into position.

## ADAPTERS

Adapters are used to change the taper of the spindle much as the collet holder does. A spindle taper adapter is bolted directly to the spindle nose and makes it possible to use No. 40 taper arbors on a machine with a regular No. 50 taper spindle.

A QUICK CHANGE adapter permits changing Style C arbors and all types of collet holders without disturbing the draw-in rod. With this adapter, mounted on a standard spindle nose, arbors and collet holders can be mounted or released with a half turn of a locking nut. They are available with either a No. 40 or No. 50 national standard outside taper.

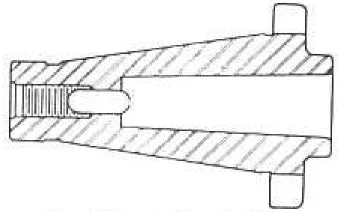

*Fig. 53. Collet holder*

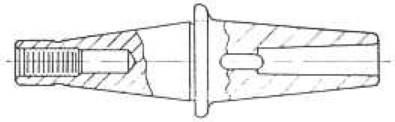

*Fig. 54. Extended collet holder*

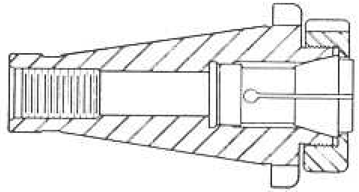

*Fig. 55. Spring collet holder*

*Chapter Six*

# MILLING CUTTERS

★

KEARNEY & TRECKER
MILWAUKEE

THE milling process in its various aspects is accomplished generally with such cutters as are shown in Fig. 56. One of the outstanding characteristics of the milling cutter is the number of teeth, seldom only one, sometimes two, and most frequently many. As a result, milling cutters are referred to generally as multi-tooth tools.

The most common cutter materials are high speed and super-hi speed steel, stellite, tantalum carbide, and tungsten carbide. Because of the efficiency of high speed steel, resulting from its ability to withstand severe usage where heavy cuts and high speeds and feeds are necessary, it has supplanted carbon steel as the most common cutter material. Stellite, tantalum carbide, and tungsten carbide are materials used as blades or for tipping the cutting blades of inserted tooth face mills.

Stellite is a non ferrous alloy that can be cast very readily but cannot be forged, and can be machined only by grinding. Milling cutters with cutting edges of stellite retain their cutting edge at high temperatures and can be used at higher speeds and feeds than cutters of ordinary high speed tool steel.

Tungsten carbide is better known as CEMENTED tungsten carbide. It is a dense, brittle, and extremely hard material, with a hardness approaching that of a diamond. Because of this latter property, it shatters easily, and

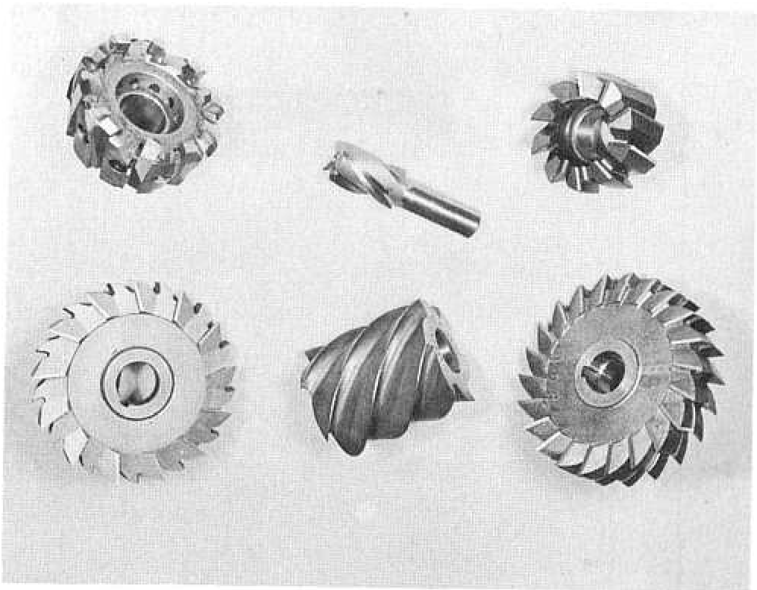

*Fig. 56. Typical milling cutters*



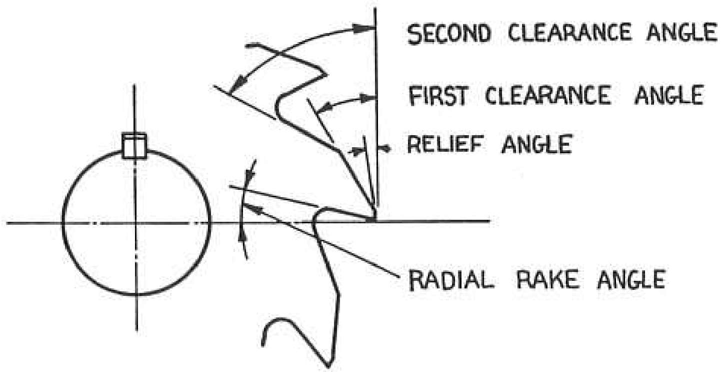


*Fig. 57. Milling cutter tooth profile and angles*

consequently a tungsten carbide cutter must be rigidly supported—the workpiece, too, must be solidly and firmly held. Carbides cannot be machined after sintering except by grinding. Special silicon carbide wheels are used for rough grinding carbide cutters, while a diamond impregnated wheel is used for finish grinding the cutting edge.

The common tooth form of milling cutters is shown in Fig. 57. In this illustration, the radial rake angle, the relief angle at the tip of the cutting edge, the clearance angles falling away from the relief, and the large chip space at the throat of the tooth are indicated. This is a common tooth form for milling cutters.

Among milling cutters, end mills and face mills may be classed as either right or left hand. The hand of a cutter is determined by the direction of rotation necessary to make it cut. To determine the hand, hold an end mill by the shank, with the shank end towards the holder. If it cuts when revolved clockwise or to the right, it is a right-hand cutter, and if it cuts when revolved counterclockwise or to the left, it is a left-hand cutter. Right - and left-hand cutters are used when, by reason of setup peculiarities or the nature of the work to be done, one or the other type of cutter interferes with the economical or accurate performance of the job. In the case of cutters other than end mills and face mills, they are quickly transformed into right or left hand by the method in which they are mounted on the arbor.

There are two basic types of cutter design: 1) Solid body and 2) inserted tooth. The solid body type cutter is manufactured from solid stock, the teeth being machined into or brazed onto the body. Inserted tooth cutters, on the other hand, have separate bodies with each of the teeth (blades) inserted and locked into position. In this type of cutter, the body remains a usable item long after the blades are worn out. Besides this advantage, such cutters can be equipped with blades using any of the available cutting materials, thus making them readily adaptable to many machining requirements.

## PLAIN MILLING CUTTERS

Plain milling cutters are cylindrical wit teeth cut in the periphery and ar provided with an accurately groun bore for mounting on an arbor. Thi type of cutter machines a flat surfac parallel to its axis. To meet plain mil ing and keyway cutting requirement: plain mills are made in a wide variet of diameters and widths. Cutters les than ¾ inch in width are commonl made with straight teeth, while wide cutters are made with spiral teeth With spiral teeth, the cutting actio becomes a shearing action which re sults in a smooth, vibration-free cut.

Fig. 58 illustrates a coarse tooth plai milling cutter used for removing larg amounts of metal from flat surfaces The coarse tooth construction give: solid support to the cutting edge anc provides for ample chip clearance.

## SIDE MILLING CUTTERS

Side milling cutters have teeth on the periphery and on both sides. These cutters are used for a variety of slotting operations to produce a relatively good finish. Sides of the cutter below the side teeth are recessed to clear the work. Straight tooth cutters of this type seldom exceed four inches in diameter.

## STAGGERED TOOTH MILLING CUTTERS

The cutter shown in Fig. 59, known as a staggered tooth side mill, is well suited for deep slotting operations where the depth of cut is limited by the cutter hub. Because of alternately right- and left-hand angles on the teeth with a maximum of chip clearance, this type of cutter can remove large amounts of metal without harmful vibration or chatter. If cutters are run at correct feeds and speeds, deep cuts with a good finish are readily obtained.

## INTERLOCKING SIDE MILLING CUTTERS

Interlocking side cutters, Fig. 60, are particularly suitable for milling work which must be held to extremely close tolerances, such as in milling bosses, bearings, or other plane surfaces. These cutters are designed to maintain an exact width when milling slots. They can be separated by spacing collars of the thickness required to get the correct width of face. The shearing action of these cutters—alternately right and left—eliminates side thrust and the cutting action is very smooth and rapid.

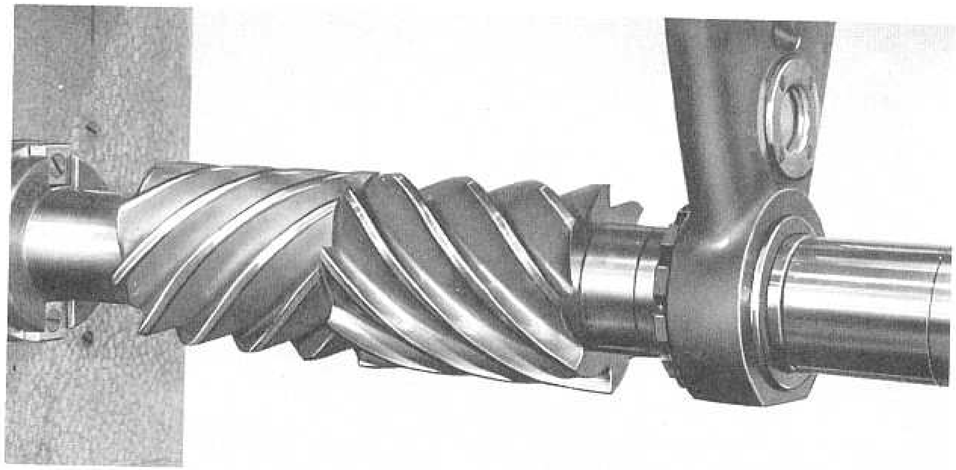

*Fig. 58. Plain milling cutters mounted on style B arbor*

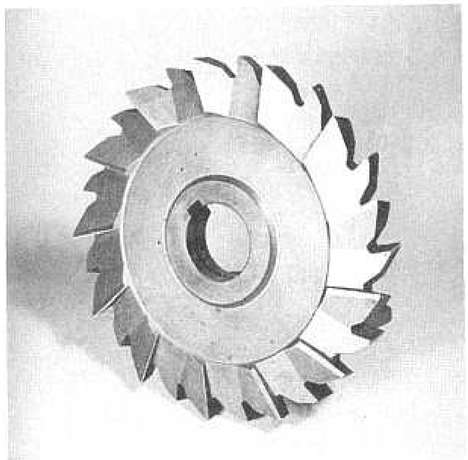

*Fig. 59. Staggered tooth side milling cutter*

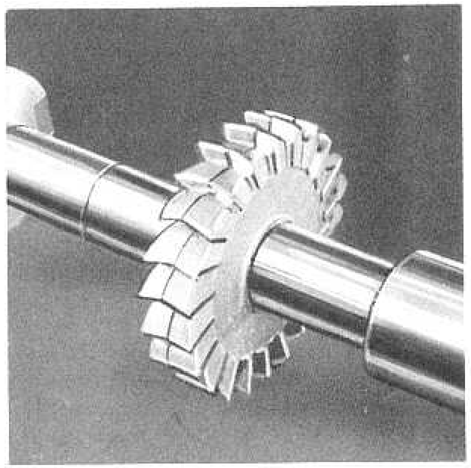

*Fig. 60. Interlocking side milling cutters*

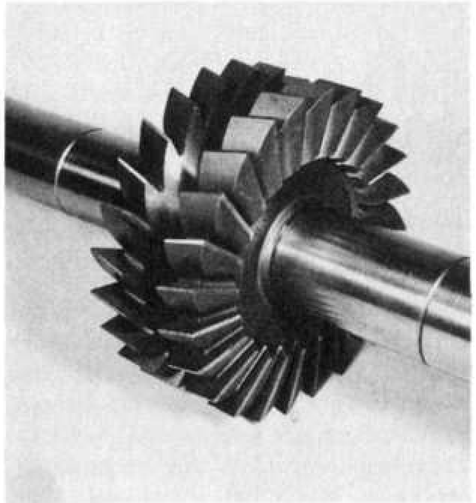

*Fig. 61. Half-side milling cutters*

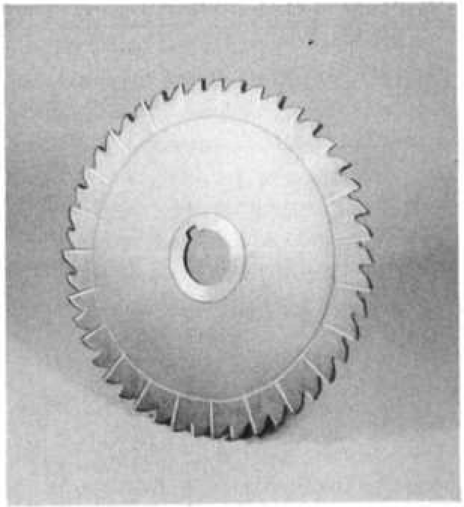

*Fig. 62. Staggered tooth slitting saw with side chip clearance*

## HALF-SIDE MILLING CUTTERS

Half-side cutters have teeth on the face but on one side only. One of the common operations performed with the half side cutter is straddle milling. Two half-side mills mounted on the arbor and separated by an arbor collar of proper length as shown in Fig. 61, are used to mill two sides of the work at the same time. This is known as straddle milling. An operation performed with one side mill is referred to as side milling, that is, milling at right angles to the arbor axis.

## METAL SLITTING SAWS

Slitting and slotting cutters are usually called saws because of their very narrow construction, which is similar to that of a wood saw. A SLITTING saw cutter is ground on the side and slightly dished towards the center in order to give a proper clearance to allow cutting deep slots. This cutter is also used for cutting off stock.

Slitting saws with staggered teeth, Fig. 62, resemble the staggered tooth side milling cutter. The alternate helical tooth form provides the necessary shearing action and chip space so important in milling deep cuts with coarse feeds.

Where a heavy cut is to be taken and the saw is 3/16 of an inch thick or more, a staggered tooth saw will be found to be most practical. Staggered tooth saws are not recommended in a narrower width, because of their tendency to weave in the cut.

A SLOTTING saw differs from the slitting type in that the teeth have a much finer pitch and the sides are usually left parallel. It is used principally for milling shallow slots such as are found on screw heads.



## FACE MILLS

For milling plane areas of workpieces, face milling cutters, Fig. 63, are used. Bodies of this type of cutter are made of heavy steel forgings. Usually blades are of the inserted type, although in some instances teeth are cut from the solid blank.

Inserted blades are made with a tapered face. They are held in place by means of a wedge having a corresponding taper, and the wedge is locked in position by means of a screw attached to the cutter body.

Blades inserted in the cutter may be chosen according to the type of material to be machined. High speed steel, stellite, and in some instances, carbide blades are made of solid stock. In the majority of cases in which carbide tips are necessary, small carbide tip blanks are brazed in place on the tip of a less expensive blade.

## END MILLS

The end mill, contrary to the term, has teeth not only on the end but also on

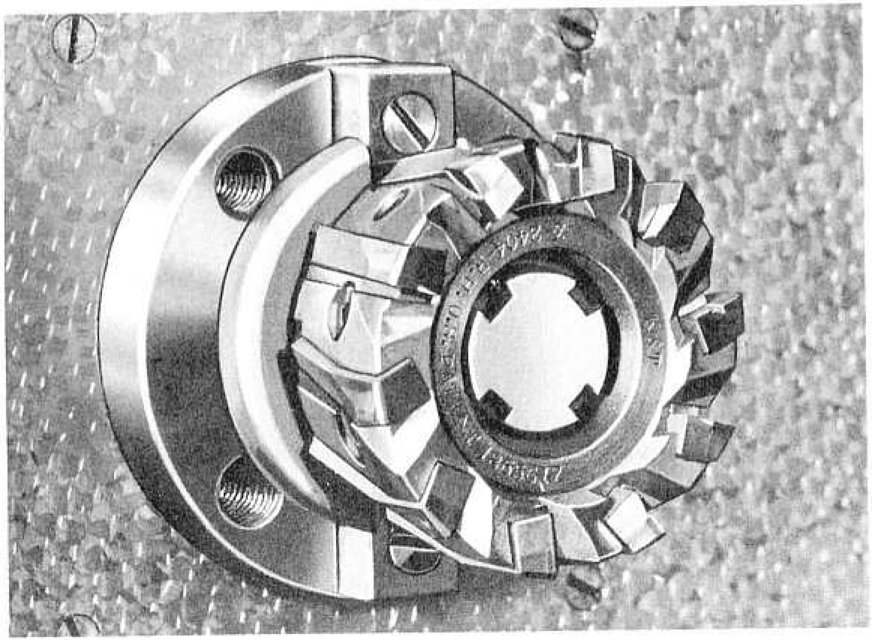

*Fig. 63. Face milling cutter on style C arbor mounted in machine spindle*

*Fig. 64. 4-lipped spiral end mill*

*Fig. 65. Shell end mill mounted on style C arbor*

its circumference, Fig. 64. Common end mills have from two to eight teeth, depending upon their diameter and the type of work for which they are intended. The teeth are formed by straight or spiral flutes and it is from this that such terms as "two lipped" and "four-lipped" have their origin. The terms are used to denote end mills with teeth in the same number.

Of end mills generally, the two-fluted type has a special purpose. It is used chiefly for the rapid removal of metal in slots or cavities. The steel helical flutes permit sinking directly into the metal without the necessity of a prior drilling operation.

Shell end mills, Fig. 65, derive their name from the fact that they are bored through, for mounting to a style C arbor. Though larger in size, they still have the appearance of an ordinary end mill with cutting edges on both bottom and outside diameter. Shell end mill cutters are employed largely for plane surface milling operations.

## FORM CUTTERS

The form cutter is a special milling cutter shaped to meet specifications of the job. Convex and concave solid or interlocking cutters, involute gear cutters, T-slot cutters, spline cutters, and thread cutters are the most common types of form cutters. The increased production and the accuracy of the completed work more than compensates for the high initial cost of form cutters.

Angular milling cutters, Fig. 66, are intended for use in finishing surfaces at an angle other than 90 degrees to the axis of rotation. They may possess either a single or double cutting angle and may be of inserted tooth or solid type construction. Double angle cutters are most frequently used for fluting operations on drills, taps, reamers, or milling cutters with helical teeth.

Milling cutters are a vital element in efficient machine operation. Only through experience in correct production operations can any operator become proficient at selecting the best tool for a given job. Examples of proper cutter applications and reasons for their selection will be outlined in a forthcoming publication.

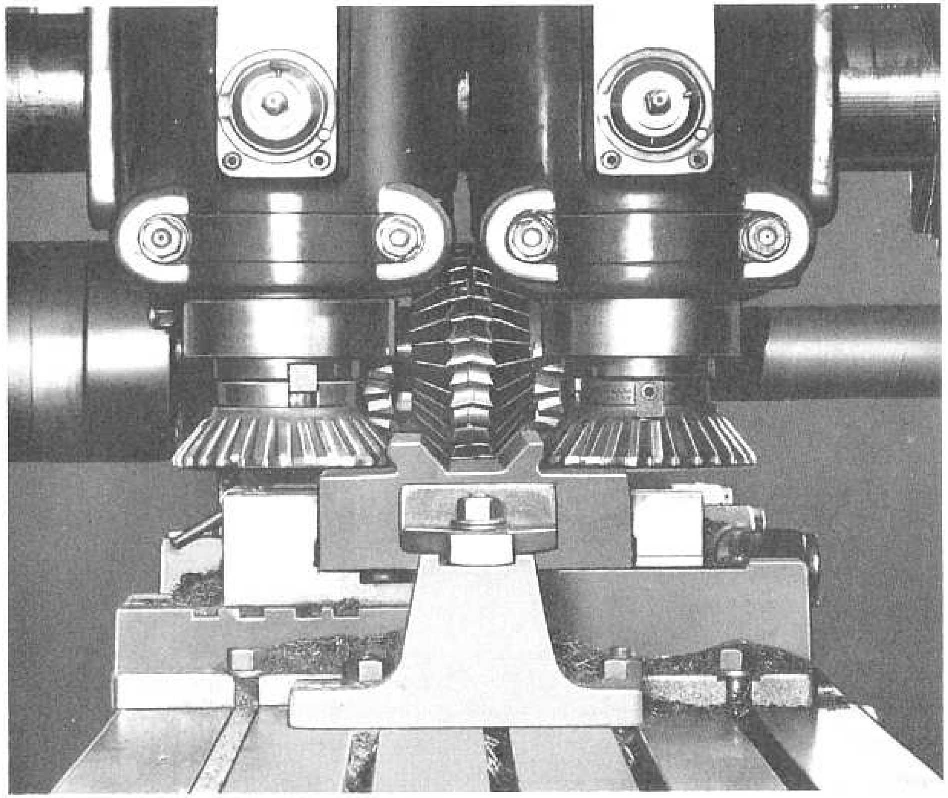

*Fig. 66. Two dovetail, two interlocking angle, and two staggered tooth cutters used in one operation*

# *Chapter Seven*

# KNEE-TYPE MACHINE OPERATION

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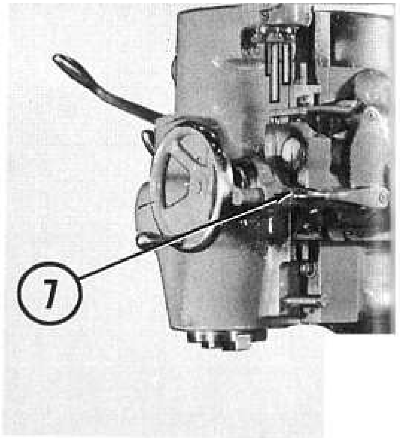
1. Drive motor push-button control
2. Adjustable spindle starting lever
3. Table directional control feed lever
4. Cross feed engagement lever for power feed to saddle
5. Vertical feed engagement lever for power feed to knee
6. Rapid traverse lever (not shown)
7. Vertical feed engagement lever for power feed to



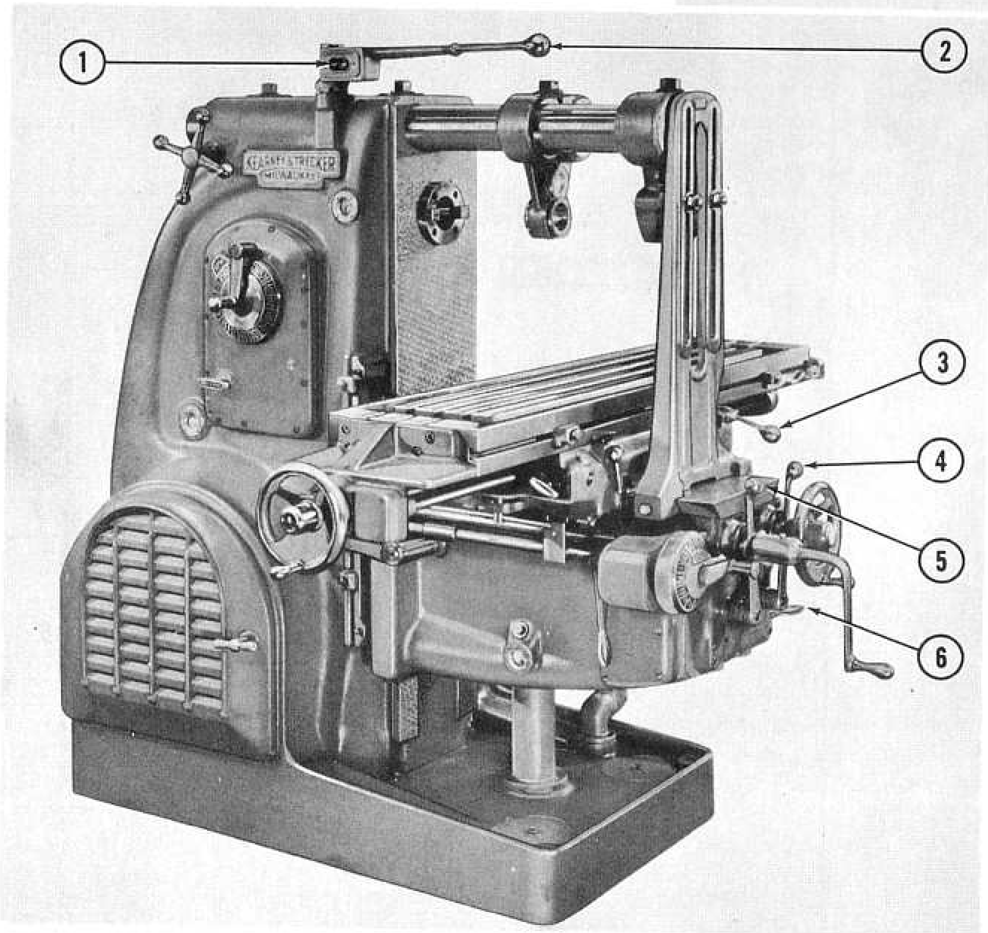
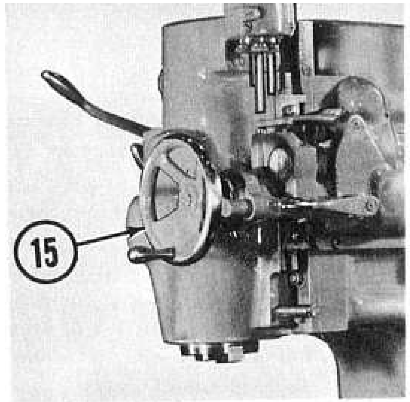




*Fig. 67. Knee-type machine power controls*



8. Handwheel for table longitudinal movement
9. Lever to reverse direction of spindle rotation
10. Spindle speed selection lever
11. Pilot wheel for moving overarms
12. Feed selection lever
13. Handwheel for cross movement of saddle
14. Handcrank for vertical movement of knee
15. Handwheel for vertical movement of sliding head



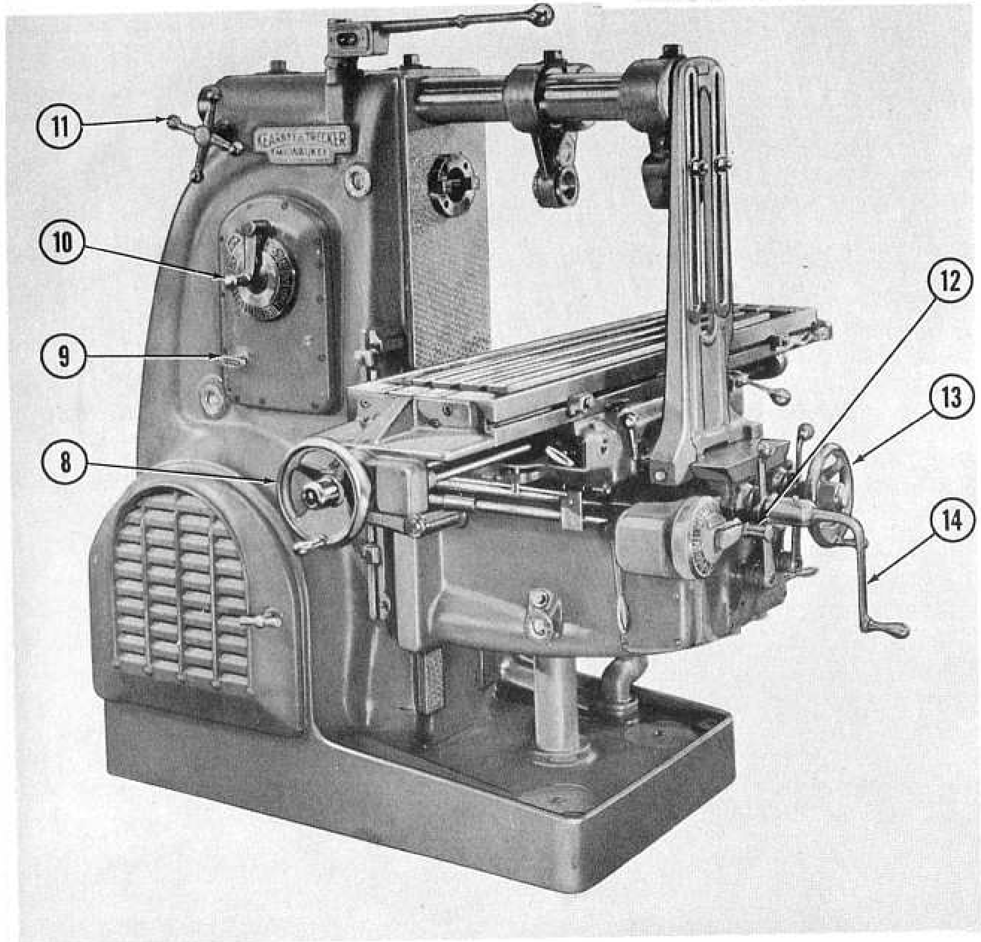
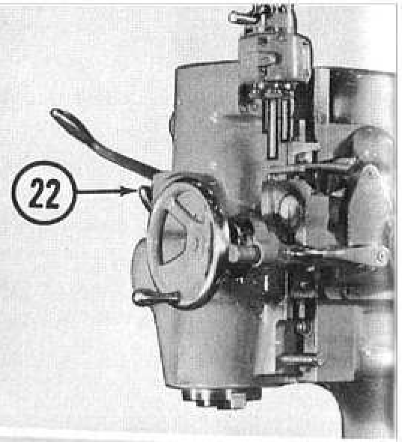




*Fig. 68. Knee-type machine hand controls.*

16. Equalized clamps for overarms
17. Arbor support clamps
18. Arbor brace clamps
19. Table clamp lever
20. Saddle clamp lever
21. Knee clamp lever
22. Sliding vertical head clamp lever



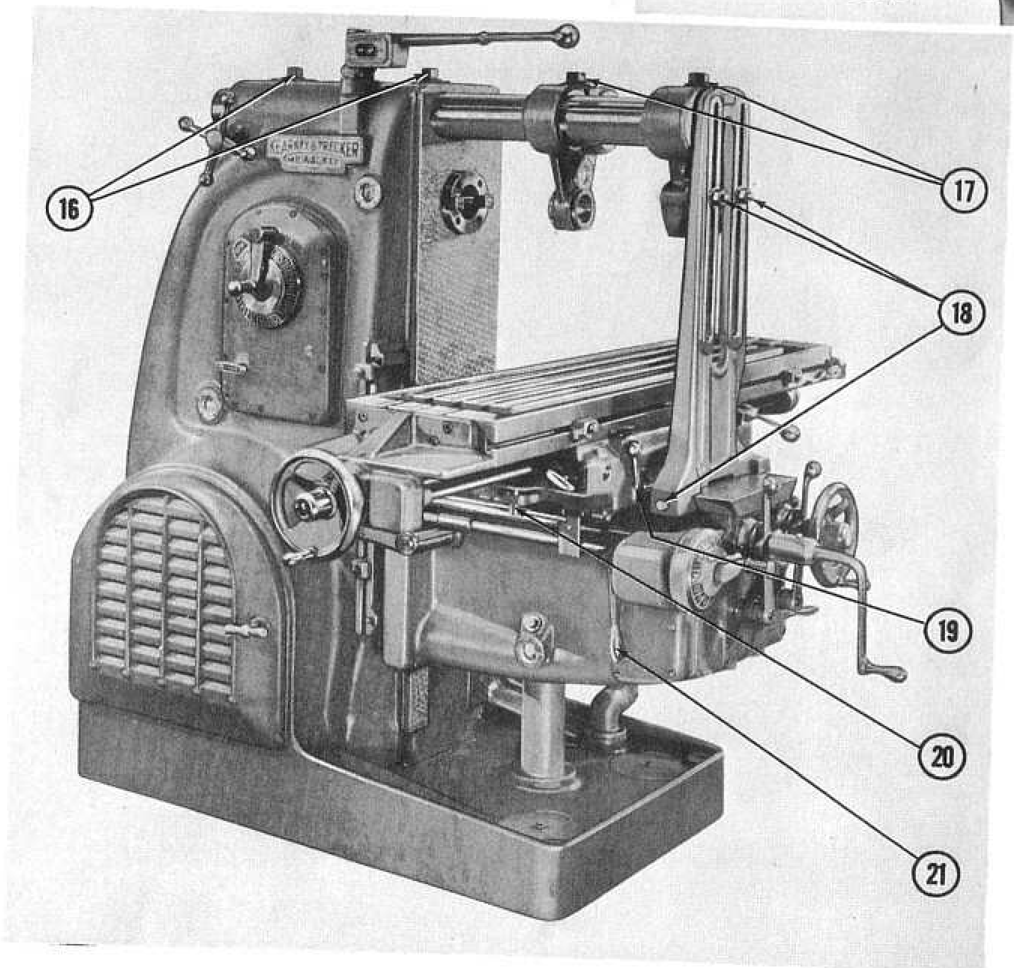




*Fig. 69. Knee-type machine clamps*



Location and identification of power controls, hand controls, and clamps for horizontal and vertical knee-type machines is given in Fig. 67, 68, and 69. Through the power controls, feed or rapid traverse rates of movement can be applied to the table, saddle, knee, and in vertical machines, the sliding vertical head. Rapid traverse makes it possible to move the knee, saddle, table, or sliding vertical head at a faster rate than is possible with hand or power feed rates.

All machines are equipped with handwheels or cranks for adjustment of the various machine units. Control levers have safety interlocks which prevent spinning handwheels and cranks. The overarm pilot wheel is used to move one or both overarms in or out.

Because rigidity is an important factor in milling practice, it is natural that all movable units be provided with clamps to lock the units in place after the cutter-workpiece relationship has been established.

Selector dials and levers are used to regulate feeds and speeds of the machine. Feed control is required to govern rate of feed (in inches per minute) for the table, saddle, knee, and sliding vertical head. Speed control is necessary to regulate the rate of spindle rotation (in revolutions per minute).

The operator will find the following standard hand and power movements on most milling machines.

1. Turn the table handwheel to the RIGHT, or engage the table longitudinal power feed lever to the RIGHT, and the table will move to the RIGHT; reverse the procedure and the table will move to the LEFT.

2. Turn the saddle handwheel to the RIGHT, or engage the saddle (cross) power feed lever to the RIGHT, and the saddle will travel IN, away from the operator. Engage these same controls to the LEFT and the saddle moves OUT.

3. Turn the knee elevating crank to the RIGHT or engage the knee (vertical) power feed lever to the RIGHT and the knee will move UP. If controls are operated to the LEFT, the knee will move DOWN.

4. Turn the sliding head handwheel to the RIGHT or pull the sliding head power feed lever DOWN, and the head will move DOWN. It moves UP when the controls are engaged in the opposite direction.

The table directional feed lever is so constructed that by raising the handle, it is possible to pass a pre-set trip dog without disengaging the table feed. Thus, the workpiece can be moved close to the cutter at rapid traverse rate until the trip dog disengages the table drive. The operator can then raise the lever, move it in the proper direction of travel, and allow the workpiece to feed into the cutter. This feature permits rapid traverse and feed movements of the table so that maximum productive results can be obtained with the machine.

Underlying this directional control system is a basic machine tool principle that has established the right hand or clockwise direction as the one for approaching the workpiece to the cutter or the cutter to the workpiece. This accounts for the downward movement of the sliding head when the handwheel is turned in a clockwise direction and the cutter is lowered to the workpiece. The knee is raised when the knee hand crank is turned in a clockwise direction, the workpiece being presented to the cutter. There have been exceptions to this principle where peculiarities of machine design have made it necessary, but it remains an accepted standard of machine tool builders generally.



*Chapter Eight*

# BED-TYPE MACHINE OPERATION

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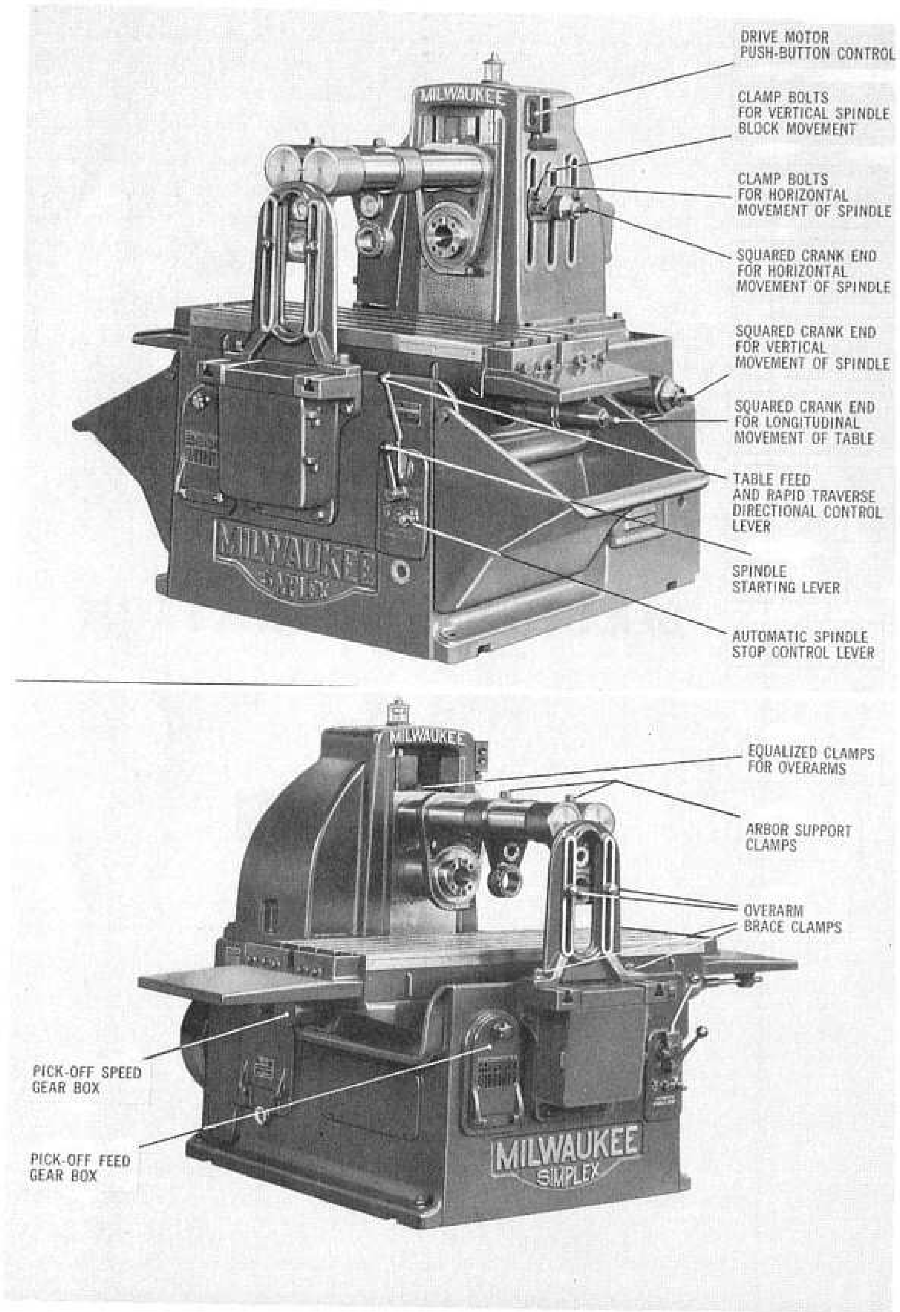


***Fig. 70. Bed-type machine controls and hand clamps***



Control systems of bed-type machines, as shown in Fig. 70, are usually less complicated than the systems used on knee-types. A push-button is used for starting and stopping the electric drive motor which is the source of power for all machine movements. When the hydraulically operated spindle starting lever is moved to the left, it engages the main drive clutch which sets the spindle in motion. If the lever is moved to the right, the multiple disc brake is engaged to stop the spindle.

Longitudinal movement of the table is the only power movement of a bed-type machine. Table movements at both feed and rapid traverse rates are governed by the table control lever. This control lever is directional and movements of the table and lever are in direct relation to each other. When the lever is in a vertical position, the table remains stationary because the control lever is in a neutral position. Four shifting positions of the lever permit table movement to the right or left in either feed or rapid traverse rate.

1. When the lever is IN and to the LEFT the table will feed to the left.

2. When the lever is IN and to the RIGHT the table will feed to the right.

3. When the lever is OUT and to the LEFT the table will move to the left at rapid traverse rate.

4. When the lever is OUT and to the RIGHT the table will move to the right at rapid traverse rate.

An automatic cycle arrangement for the table is possible with the hydraulic bed-type machines through the use of trip dogs and the rate change post. By setting rapid traverse, feed rate, reverse, and stop dogs in the proper location with respect to the rate change post and reversing plungers, it is possible to set up the automatic cycles illustrated diagramatically in Fig. 71.

The automatic spindle stop selector lever is manually controlled. When the selector is ON, the spindle will stop whenever the table moves at rapid traverse rate and will start when the table moves at feed rate. If the selector is OFF, the spindle will continue to rotate during both feed and rapid traverse rates of table movement.

Vertical movement of the spindle block, cross movement of the spindle quill, and longitudinal movement of the table are effected by handwheels or cranks. These movements provide bed-type machines with the three dimensional movements necessary in setting up the machine for production operations.

Rigidity is of prime importance in all production milling. Clamps lock the units in position for maximum rigidity and security.

Pick-off gears are used for the various spindle speeds and table feeds as needed. A spindle speed chart indicates the method of changing the pick-off gears to obtain various speed changes. A similar chart is used in setting table feed rate gears.

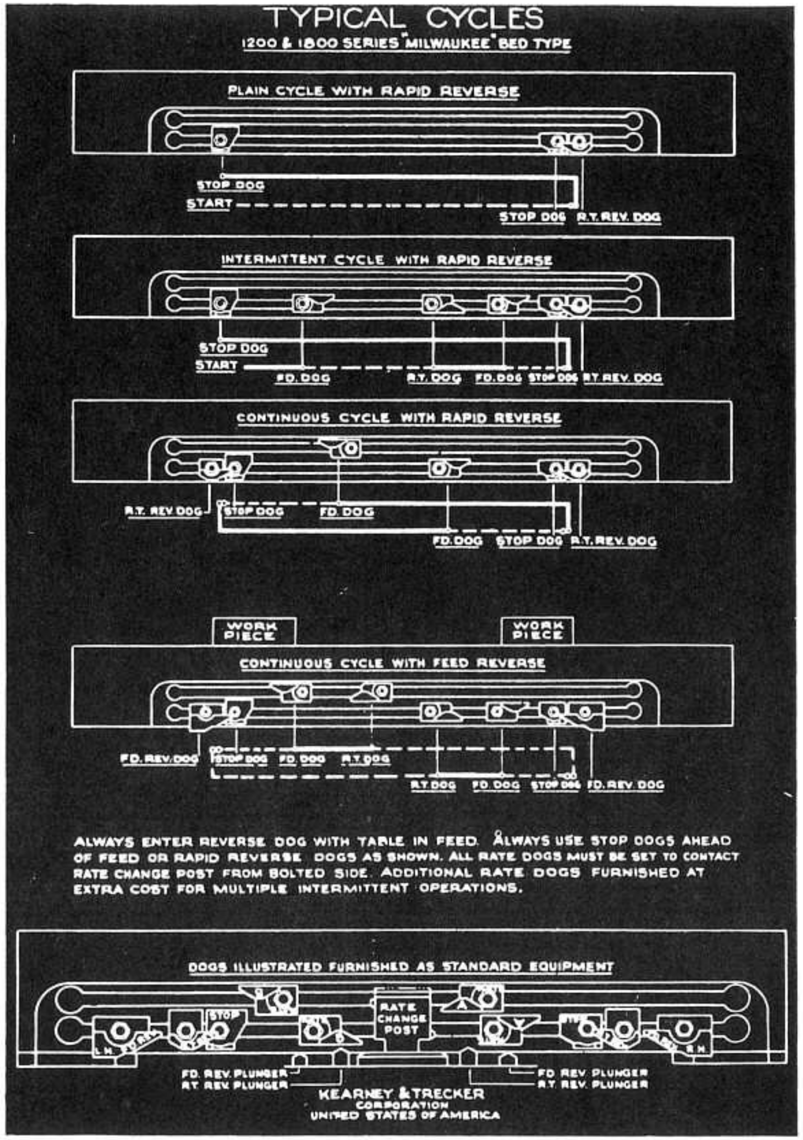


***Fig. 71. Typical automatic table cycles***



# *Chapter Nine*

# MACHINE ADJUSTMENTS

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EVERY machine operator should be acquainted with his machine to such an extent that he is able to make the minor adjustments necessary for setup changes and to keep the machine in good operating condition. For major repairs or adjustments, the plant maintenance department should be notified.

## MICROMETER DIALS

Adjustments of the movements made to bring about the proper cutter-work-piece relationship must frequently be very accurate. For this reason, graduated micrometer dials are provided on all hand-powered machine movements. Regardless of the number of divisions, all dials are graduated in thousands of an inch (0.001 inch).

## PRECISION MEASURING DEVICES

Where the usual system of measurement has proved unsatisfactory, precision measuring instruments are avail-

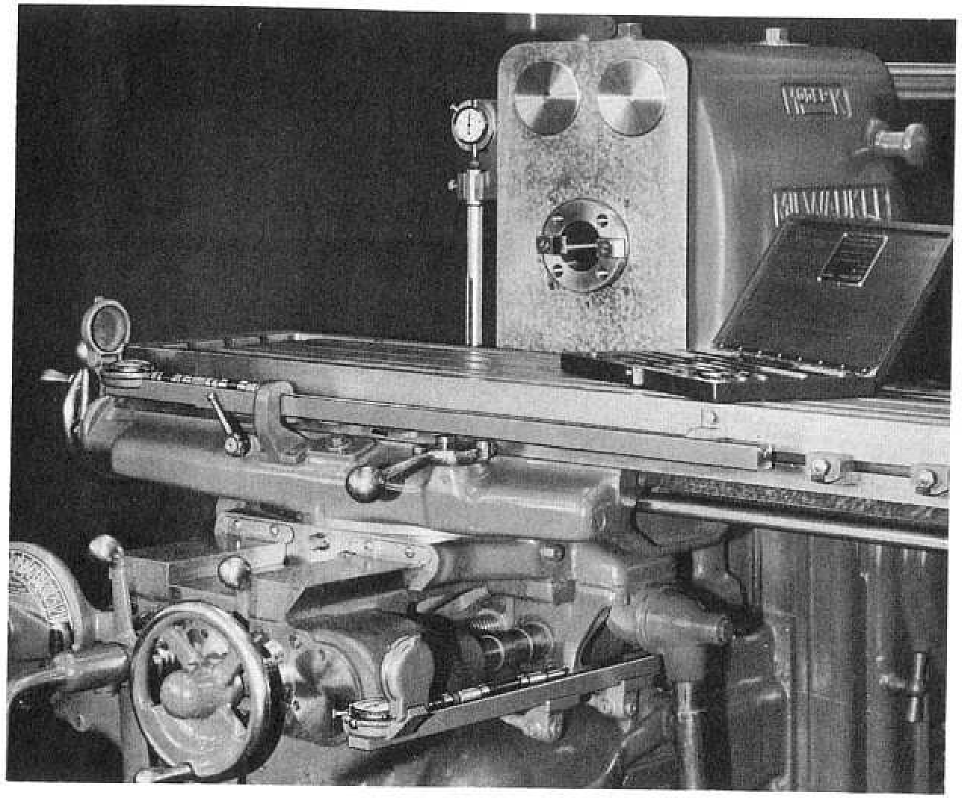

*Fig. 72. Precision measuring instruments*



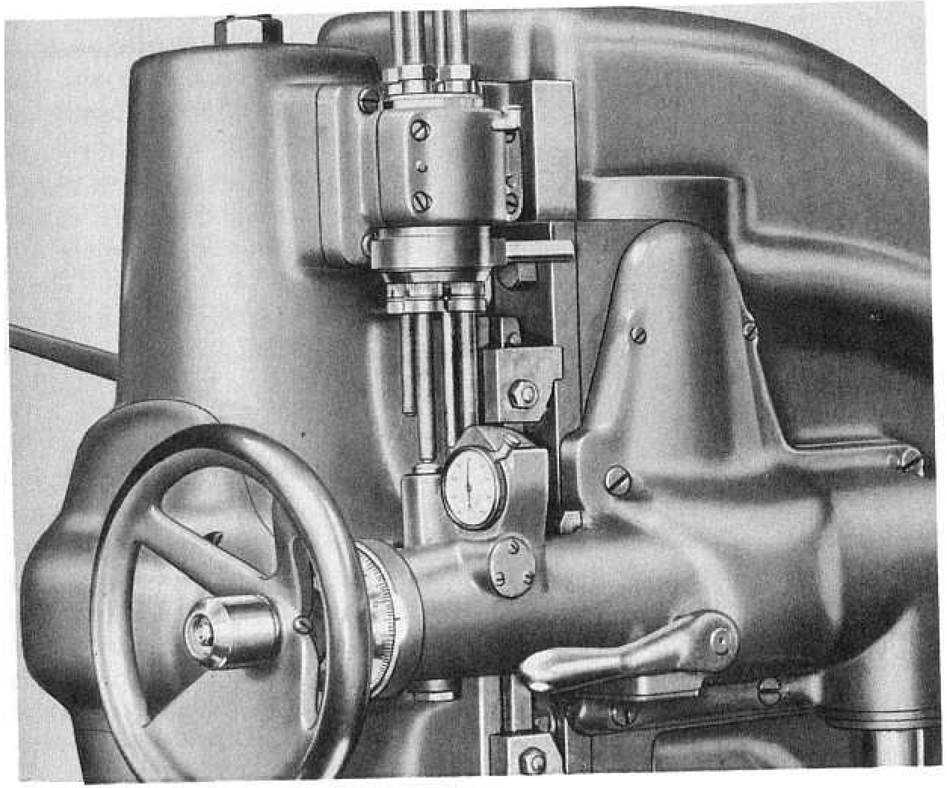

*Fig. 73. Four-position micrometer stop and dial indicator*

able. In order to permit precision movements in all directions, machines can be equipped with micrometer rods and dial indicators, Fig. 72, or with scales and verniers. Micrometer rods of varying length are laid in troughs to build up the required distance. A dial indicator at the end of each trough is used to check the adjustment visually.

## FOUR-POSITION MICROMETER STOP

Sliding head vertical machines are equipped with four-position micrometer stops, Fig. 73, to expedite step-milling operations. The four long abutment screws can be set at various heights by proper adjustment of the micrometer nuts. Stop screws pass through the cylinder so that one pull of the ratchet handle revolves the cylinder one-quarter turn, bringing the next stop screw into position. Stop screws may be adjusted to the proper height by measurement, trial, or gage.

When the vertical head is feeding down in a step cut, the stop screw will depress a stop plunger, which will automatically disengage the head feed and engage the head handwheel. The handwheel is turned until the micrometer dial registers zero. After the cut is finished, the head is raised and the cylinder is turned to the next stop screw for the succeeding cut.

## GIBS

Full-length tapered gibs with adjusting screws at both ends are used on the table, saddle, knee, and vertical head of knee-type machines for the adjustments of sliding units. The table gib is located at the front dovetail of the saddle, the knee gib at the left dovetail of the column, and the sliding head gib at the right side of the head. Two saddle gibs are usually used; the center gib at the top of the knee forms the guide for the saddle while the other gib, located at the left underside of the saddle, draws the saddle to the top of the knee.

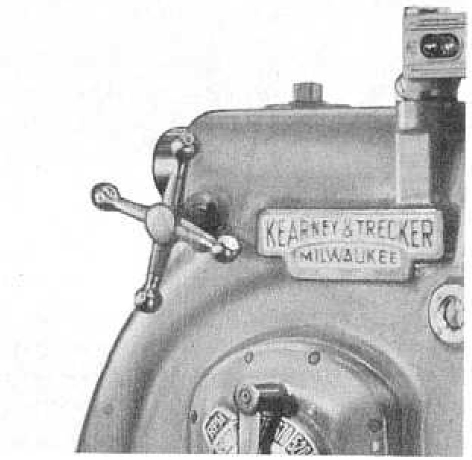


***Fig. 74. Overarm pilot handwheel***

On bed-type machines, the table gib is at the front dovetail of the saddle. The spindle block gib is located inside the left upright.

Gibs are tightened by backing off the screw at the small end about ⅛ turn and drawing up the screw at the large end until a very slight drag is felt when the unit is moved by hand. When the proper adjustment has been made, the screw at the large end of the gib should be backed off a very small amount to make certain a bow has not been placed in the gib.

## OVERARM MOVEMENT

Overarms are two parallel round steel bars rigidly fastened to the arbor by means of the triangular arbor support. After loosening the front and rear clamp bolts on the top of the column, the overarms can be moved in or out by means of the pilot wheel, Fig. 74. The pilot wheel has a pinion engaged with the rack gear in each overarm. By withdrawing the pilot wheel a short distance, the pinion contact with the right overarm is disengaged, allowing independent movement of the left overarm. Movement of both overarms can be effected by engaging both pinions in the overarm racks.

With heavy milling cuts, it is good practice to mount the overarm brace to tie the knee and overarms together. After the job is properly set up, move the overarms so that they are flush with the outer arbor support. Slip the brace over the knee dovetail and move inward until the inner face of



the brace contacts the outer arbor support. Lock the brace to the knee and the outer arbor support.

In production milling practice, machine setup changes are infrequent; for this reason no provision is made for mechanical overarm movement on bed-type machines.

## PICK-OFF GEAR BOX

Speed and feed changes on bed-type machines are made with pick-off gears. A spindle speed chart above the speed box, Fig. 75, shows the method of applying gears to obtain the various speeds. A similar chart near the feed box indicates the arrangement of gears on spline shafts to obtain the required feed rate. All pick-off gears are identified by the number of teeth in the gear.

Climb milling (milling down) means that direction of rotation of the cutter is in the direction of longitudinal table feed, Fig. 76. If the work and cutter are rigidly supported, a better surface finish and longer tool life will result with climb milling. Bed-type machines have climb cutting adjustment nuts as standard equipment, while knee-type machines may include them as special equipment.

Table screw adjustment should be maintained at all times because it is vitally important when climb milling. When adjustment is necessary to eliminate backlash between the table screw and adjusting nut, the plant service department should be notified. Under no circumstances should an operator attempt an adjustment.


***Fig. 75. Spindle speed pick-off gear box***

## LUBRICATION

Every modern machine tool must be equipped with an adequate lubrication system if the maximum efficiency and life of the machine are to be realized. Wherever practical, lubricant is distributed from central reservoirs in the column, knee, saddle, or head of the various machines. Individual oilers have been confined to the end table bearings, handwheels, cranks, and attachments.

Proper maintenance requires that each individual oiler be filled daily and all reservoirs be checked for capacity. Oil reservoirs are equipped with sight gages to facilitate checking and the oil flow gages tell instantly whether the various units are getting the proper lubrication.

Oil in the lubricant reservoirs should be removed at regular intervals and both the reservoir and attached oil lines cleaned with flushing oil.

Daily inspection and periodic flushing out of machines cannot be overemphasized. If this practice is followed, no lubrication difficulties should develop in a modern milling machine.

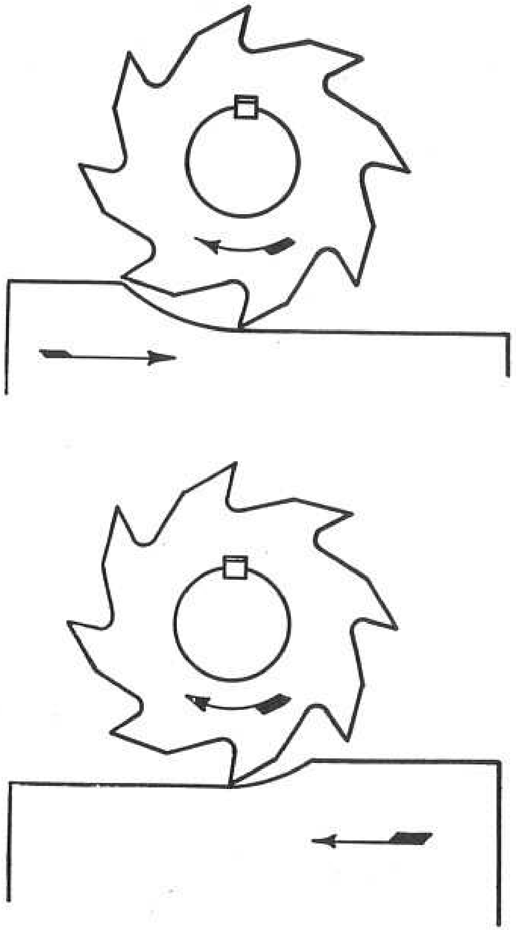

*Fig. 76. Conventional milling (top) vs. Climb milling (bottom)*