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OPERATION OF MACHINE TOOLS

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VERTICAL AND HORIZONTAL BORING MACHINES

CONTENTS

CHAPTER I

THE VERTICAL BORING MILL

All the different types of turning machines now in use originated from the lathe. Many of these tools, however, do not resemble the lathe because, in the process of evolution, there have been many changes made in order to develop turning machines for handling certain classes of work to the best advantage. The machine illustrated in Fig. 1 belongs to the lathe family and is known as a vertical boring and turning mill. This type, as the name implies, is used for boring and turning operations, and it is very efficient for work within its range. The part to be machined is held to the table *B* either by clamps or in chuck jaws attached to the table. When the machine is in operation, the table revolves and the turning or boring tools (which are held in tool-blocks *T*) remain stationary, except for the feeding movement. Very often more than one tool is used at a time, as will be shown later by examples of vertical boring mill work. The tool-blocks *T* are inserted in tool-bars T_1 carried by saddles *S* which are mounted on cross-rail *C*. Each tool-head (consisting of a saddle and tool-bar) can be moved horizontally along cross-rail *C*, and the tool-bars T_1 have a vertical movement. These movements can be effected either by hand or power.

When a surface is being turned parallel to the work table, the entire tool-head moves horizontally along the cross-rail, but when a cylindrical surfaco is being turned, the tool-bar moves vertically. The tool-heads are moved horizontally by the screws *H* and H_1, and the vertical feed for the tool-bars is obtained from the splined shafts *V* and V_1, there being a separate screw and shaft for each head so that the feeding movements are independent. These feed shafts are rotated for the power feed by vertical shafts *A* and A_1 on each side of the machine. These vertical shafts connect with the feed shafts through bevel and spur gears located at the ends of the cross-rail. On most boring mills, connection is made with one of the splined shafts *V* or screw *H*, by a removable gear, which is placed on whichever shaft will give the desired direction of feed. The particular machine illustrated is so arranged that either the right or left screw or feed shaft can be engaged by simply shifting levers D_1 or *D*.

The amount of feed per revolution of the table is varied for each tool-head by feed-changing mechanisms located at *F* on each side of the machine. These feed boxes contain gears of different sizes, and by changing the combinations of these gears, the amount of feed is varied. Five feed changes are obtained on this machine by shifting lever *E*, and this number is doubled by shifting lever *G*. By having two feed boxes, the feeding movement of each head can be varied independently. The direction of either the horizontal or vertical feed can be reversed by lever *R*, which is also used for engaging or disengaging the feeds. This machine is equipped with the dials *I* and I_1 which can be set to automatically disengage the feed at any predetermined point. There are also micrometer dials graduated to thousandths of an inch and used for adjusting the tools without the use of measuring instruments.

The work table *B* is driven indirectly from a belt pulley at the rear, which transmits the power through gearing. The speed of the table can be varied for turning large or small parts, by levers *J* and *K*, and the table can be started, stopped or rotated part of a revolution by lever *L* which connects with a friction clutch. There are corresponding feed

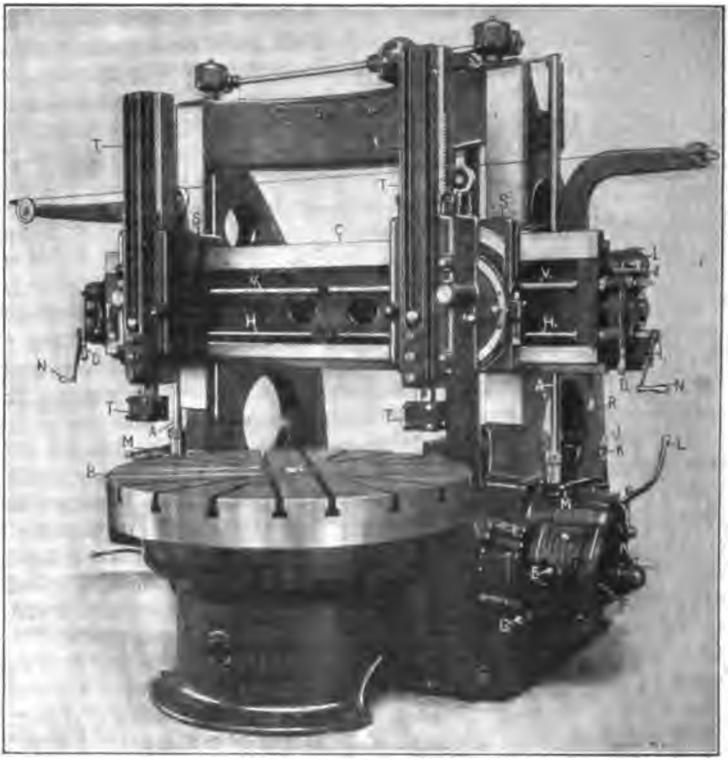

Fig. 1. Gisholt Vertical Boring and Turning Mill

and speed levers on the opposite side, so that the machine can be controlled from either position.

The heads can be adjusted along the cross-rail for setting the tools by hand-cranks *N*, and the tool slides can be moved vertically by turning shafts *V* with the same cranks. With this machine, however, these adjustments do not have to be made by hand, ordinarily, as there are rapid power movements controlled by levers *M*. These levers automatically disengage the feeds and enable the tool-heads to be rapidly shifted to the required position, the direction of the movement depending upon the position of the feed reverse lever *R* and lever *D*. This rapid traverse, which is a feature applied to modern boring mills of medium and large size, saves time and the labor connected with hand adjustments. The cross-rail *C* has a vertical adjustment on the faces of the right and left housings which support it, in order to locate the tool-heads at the right height for the work. This adjustment is effected by power and is controlled by levers at the sides of the housings. Normally, the cross-rail is bolted to the housings, and these bolts must be loosened before making the adjustment, and must always be tightened afterwards.

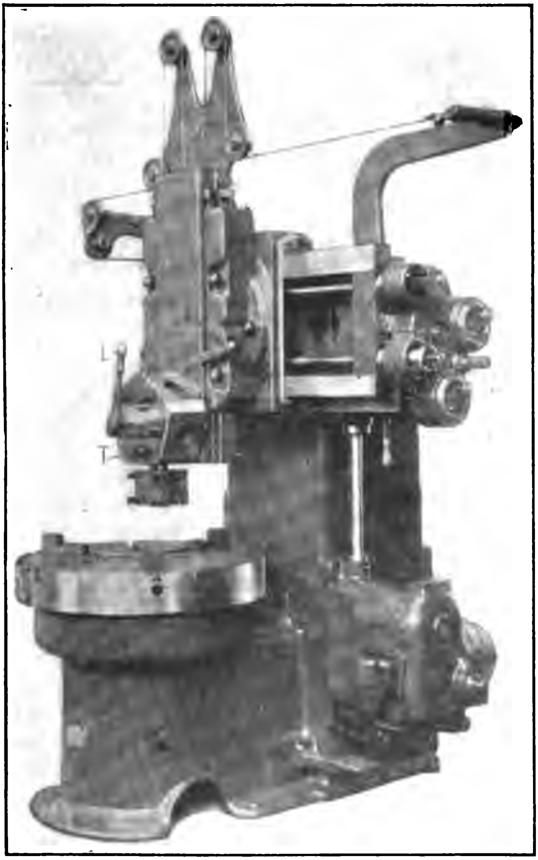

Fig. 2. Small Boring and Turning Mill with Single Turret-head

The function of these different levers has been explained to show, in a general way, how a vertical boring machine is operated. It should be understood, however, that the arrangement differs considerably on machines of different makes. The construction also varies considerably on machines of the same make but of different size. All modern vertical boring mills of medium and large sizes are equipped with two tool-heads, as shown in Fig. 1, because a great deal of work done on a machine of this type can have two surfaces machined simultaneously. On the other hand, small mills of the type illustrated in Fig. 2 have a single head. The tool-slide, instead of having a single tool-block, carries a five-sided turret *T* in which different tools can be mounted. These tools are shifted to the working position as they are needed, by loosening binder lever *L* and turning or "indexing" the turret. The turret is located and locked in any of its five positions by lever *I*, which controls a plunger that engages notches at the rear. Frequently, all the tools for machining a part can be held in the turret, so that little time is required for changing from one tool to the next. Some large machines having two tool-heads are also equipped with a turret on one head.

CHAPTER II

BORING AND TURNING IN A VERTICAL BORING MILL

The vertical boring mill is, in many respects, like a lathe placed in a vertical position, the table of the mill corresponding to the faceplate or chuck of the lathe and the tool-head to the lathe carriage. Much of the work done by a vertical mill could also be machined in a lathe, but the former is much more efficient for work within its range. To begin with, it is more convenient to clamp work to a horizontal table than to the vertical surface of a lathe faceplate, or, as someone has aptly said, "It is easier to lay a piece down than to hang it up." This is especially true of the heavy parts for which the boring mill is principally used. Very deep roughing cuts can also be taken with a vertical mill. The vertical mill is designed for turning and boring work which, generally speaking, is quite large in diameter in proportion to the width or height. The work varies greatly, especially in regard to its diameter, so that boring mills are built in a large range of sizes. The small and medium sizes will swing work varying from about 30 inches to 6 or 7 feet in diameter, whereas large machines, such as are used for turning very large flywheels, sheaves, etc., have a swing of 16 or 20 feet and larger sizes are used in some shops. The size of a vertical mill, like any other machine tool, should be somewhat in proportion to the size of the work for which it is intended, as a very large machine is unwieldy, and, therefore, inefficient for machining comparatively small parts.

Chucking and Setting Work on the Boring Mill Table

There are three general methods of holding work to the table of a boring mill; namely, by the use of chucks, by ordinary bolts and clamps, or in special fixtures. Chucks which are built into the table (as illustrated in Fig. 2) and have either universal or independent adjustments for the jaws, can be used to advantage for holding castings that are either round or irregular in shape. The universal adjustment is used for cylindrical parts, such as disks, flywheels, gear blanks, etc., and the independent adjustment, for castings of irregular shape. Chucks which have either an independent or universal movement for the jaws are known as a "combination" type and usually have three jaws. There is also a four-jaw type which has the independent adjustment only. This style is preferable for work that is not cylindrical and which must be held very securely. Chuck jaws that do not form a part of the machine table but are bolted to it in the required position, are also employed extensively, especially on comparatively large machines. Independent chuck jaws of this type are shown in Fig. 9.

Most of the work done in a vertical mill is held in a chuck. Occasionally, however, it is preferable to clamp a part directly to the table.

This may be desirable because of the shape and size of the work, or because it is necessary to hold a previously machined surface directly against the table in order to secure greater accuracy. Sometimes a casting is held in the chuck for turning one side, and then the finished side is clamped against the table for turning the opposite side. Parts which are to be machined in large quantities are often held in special fixtures. This method is employed when it enables the work to be set up more quickly than would be possible if regular clamps or chuck jaws were used.

Work that is to be turned or bored should first be set so that the part to be machined is about central with the table. For example, the rim of a flywheel should be set to run true so that it can be finished by removing about the same amount of metal around the entire rim; in other words, the rim should be set concentric with the table, as shown in Fig. 3, and the sides of the rim should also be parallel to the table. A simple tool that is very useful for testing the position of any cylindrical casting consists of a wooden shank into which is inserted a piece of wire, having one end bent. This tool is clamped in the toolpost and as the work revolves, the wire is adjusted close to the cylinderical surface being tested. The movement of the work with relation to the stationary wire point will, of course, show whether or not the part runs true. The advantage of using a piece of wire for testing, instead of a rigid tool, is that the wire, owing to its flexibility, will simply be bent backward if it is moved too close to a surface which is considerably out of true. The upper surface of a casting can be tested for parallelism with the table by using this same wire gage, or by comparing it with a tool held in the tool-post. An ordinary surface gage is also used for this purpose. The proper surface to set true, in any case, depends upon the requirements. A plain cylindrical disk would be set so that the outside ran true and the top surface was parallel with the table. When setting a flywheel, if the inside is to remain rough, the casting should be set by this surface rather than by the outside, so that the rim, when finished, will be uniform in thickness.

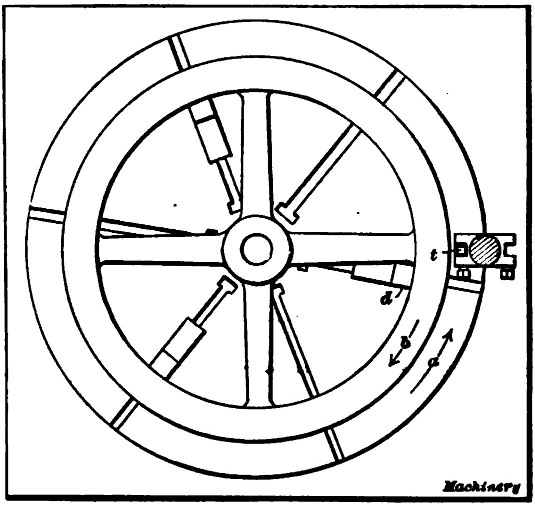

Fig. 3. Plan View showing Flywheel Casting Chucked for Turning

As far as possible, chucks should be used for holding cylindrical parts, owing to their convenience. The jaws should be set against an interior cylindrical surface whenever this is feasible. To illustrate, the flywheel in Fig. 3 is gripped by the inside of the rim which permits the outside to be turned at this setting of the work. The flywheel casting should also be set in the chuck so that a spoke rests against one of the jaws as at *d*. This jaw will then act as a driver and prevent the casting from slipping or turning in the chuck jaws, owing to the tangential pressure of the turning tool. When a cut is being taken, the table and work rotates as shown by arrow *a*, and the thrust of the cut (taken by tool *t*) tends to move the wheel backward against the direction of rotation as shown by arrow *b*. If one of the chuck jaws bears against one of the spokes, this movement is prevented. It is not always feasible to use a

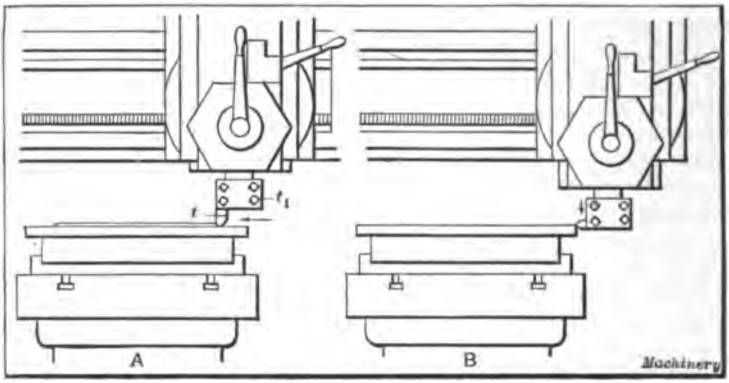

Fig. 4. (A) Turning a Flat Surface. (B) Turning a Cylindrical Surface

chuck jaw as a driver and then a special driver having the form of a small angle-plate, is sometimes bolted directly to the table. Another method of driving is to set a brace between a spoke or projection on the work and a chuck jaw or strip attached to the table. Drivers are not only used for flywheels, but in connection with any large casting, especially when heavy cuts have to be taken. Of course, some castings are so shaped that drivers cannot be employed.

Turning in a Boring Mill

The vertical type of boring mill is used more for turning cylindrical surfaces than for actual boring, although a large part of the work requires both turning and boring. We shall first consider, in a general way, how surfaces are turned and then refer to some boring operations. The diagram *A*, Fig. 4, illustrates how a horizontal surface would be turned. The tool *t* is clamped in tool-block t_1, in a vertical position, and it is fed horizontally as the table and work rotates. The tool is first adjusted by hand for the proper depth of cut and the automatic horizontal feed is then engaged. When a cylindrical surface is to be turned, the tool (provided a straight tool is used) is clamped in a horizontal position and is fed downward as indicated at *B*. The amount that the tool should feed per revolution of the work depends upon the kind of material being turned, the diameter of the turned part and the depth of the cut.

Most of the work machined in a vertical boring mill is made of cast iron and, ordinarily, at least one roughing and one finishing cut is taken. The number of roughing cuts required in any case depends, of

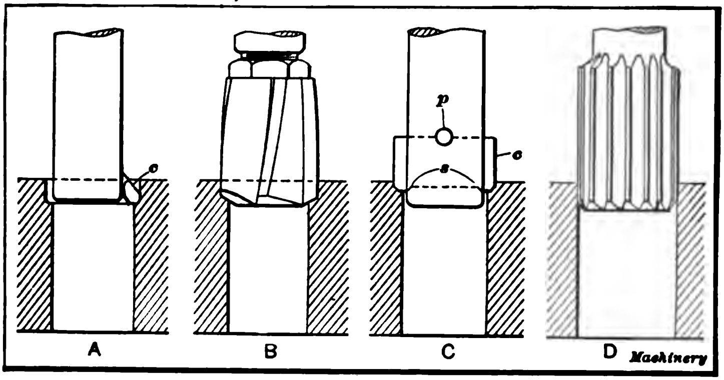

Fig. 5. Methods of Boring and Reaming Holes

course, upon the amount of metal to be removed. An ordinary roughing cut in soft cast iron might vary in depth from 1/8 to 3/8 inch and the tool would probably have a feed per revolution of from 1/16 to 1/8 inch, although deeper cuts and coarser feeds are sometimes taken. These figures are merely given to show, in a general way, what cuts and feeds are practicable. The tool used for roughing usually has a rounded end which leaves a ridged or rough surface. To obtain a smooth finish,

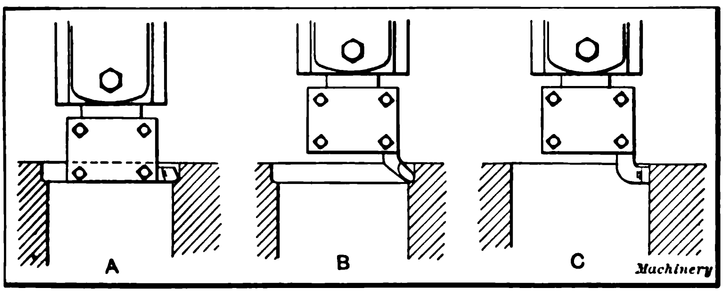

Fig. 6. Boring with Regular Turning Tools

broad flat tools are used. The flat cutting edge is set parallel to the tool's travel and a coarse feed is used in order to reduce the time required for taking the cut. The finishing feeds for cast iron vary from 1/4 to 3/4 inch on ordinary work. The different tools used on the vertical mill will be referred to more in detail later.

All medium and large sized vertical boring mills are equipped with two tool-heads and two tools are frequently used at the same time, especially on large work. Fig. 9 illustrates the use of two tools simultaneously. The casting shown is a flywheel, and the tool on the right side turns the upper side of the rim, while the tool on the left side turns the outside or periphery. As a boring mill table rotates in a counter-clockwise direction, the left-hand tool is reversed to bring the cutting edge at the rear. By turning two surfaces at once, the total time for machining the casting is, of course, greatly reduced. The turning of fly-

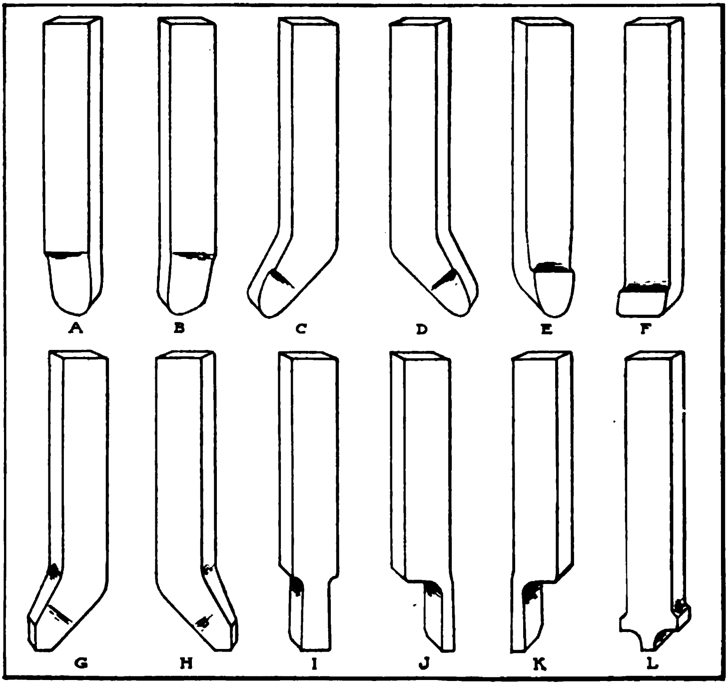

Fig. 7. Set of Boring Mill Tools

wheels is a very common vertical boring mill operation, and this work will be referred to in detail later on.

Boring Operations

There are several methods of machining holes in the vertical boring mill. Ordinarily, small holes are cored in castings and it is simply necessary to finish the rough surface to the required diameter. Some of the tools used for boring and finishing holes are shown in Fig. 5. Sketch *A* shows a boring tool consisting of a cutter *c* inserted in a shank, which, in turn, is held in the tool slide, or in a turret attached to the tool slide. With a tool of this type, a hole is bored by taking one or more cuts down through it. The tool shown at *B* is a four-lipped drill which is used for drilling cored holes preparatory to finishing by a cutter or reamer. This drill would probably finish a hole to within about 1/32 inch of the finish diameter, thus leaving a small amount of metal for the reamer to remove. The tool illustrated at *C* has a double-ended flat cutter *c*, which cuts on both sides. These cutters are often made in sets for boring duplicate parts. Ordinarily, there are two cutters in a set, one being used for roughing and the other for finishing. The cutter passes through a rectangular slot in the bar and this particular style is centrally located by shoulders *s*, and is held by a taper pin *p*. Some cutter bars have an extension end which passes through a close-fitting bushing in the table to steady the bar. Sketch *D* shows a finishing reamer. This tool takes a very light cut and is intended to finish holes that have been previously bored close to the required size.

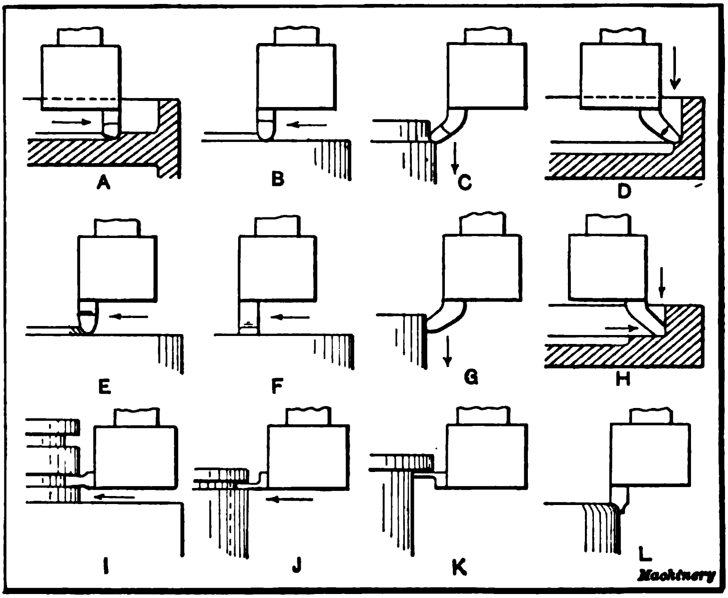

Fig. 8. Diagrams Illustrating Use of Different Forms of Tools

Sometimes a flat cutter *C* is used for roughing and a reamer for finishing. The reamer is especially desirable for interchangeable work, when all holes must have a smooth finish and be of the same size. When a reamer is held rigidly to a turret or tool-slide, it is liable to produce a hole that is either tapering or larger than the reamer diameter. To prevent this, the reamer should be held in a "floating" holder which, by means of a slight adjustment, allows the reamer to align itself with the hole. There are several methods of securing this "floating" movement.

Large holes or interior cylindrical surfaces are bored by tools held in the regular tool-head. The tool is sometimes clamped in a horizontal position as shown at *A*, Fig. 6, or a bent type is used as at *B*. Cast iron is usually finished by a broad flat tool as at *C*, the same as when turning exterior surfaces. Obviously a hole that is bored in this way must be large enough to admit the tool-block.

Turning Tools for the Vertical Boring Mill

A set of turning tools for the vertical boring mill is shown in Fig. 7. These tools can be used for a wide variety of ordinary turning operations. When a great many duplicate parts are to be machined, special tool equipment can often be used to advantage, but as the form of this equipment depends upon the character of the work, only standard tools have been illustrated herewith. The tool shown at *A* is a right-hand, "hog-nose" roughing tool, and a left-hand tool of the same type is shown at *B*. Tool *C* is an offset or bent, left-hand round nose for roughing, and *D* is a right-hand offset tool. A straight round nose is shown at *E*. Tool *F* has a flat, broad cutting edge and is used for finishing. Left- and right-hand

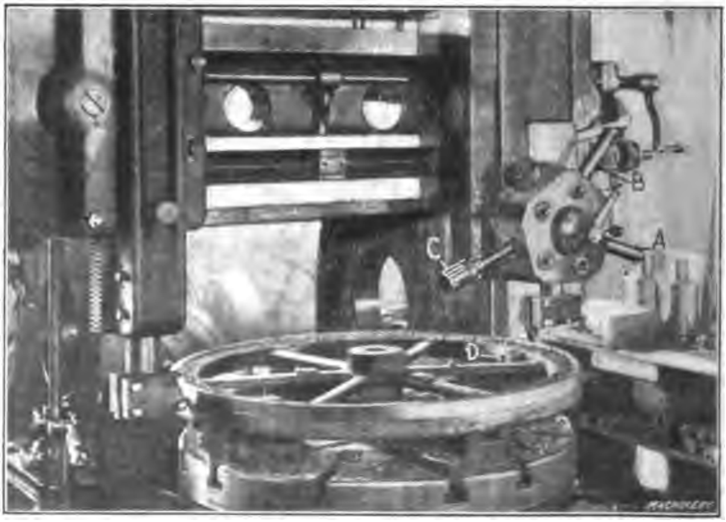

Fig. 9. Turning the Rim of a Flywheel

finishing tools of the offset type are shown at *G* and *H*, respectively. Tool *I* has a square end and is used for cutting grooves. Right- and left-hand parting tools are shown at *J* and *K*, and tool *L* is a form frequently used for rounding corners.

The diagrams in Fig. 8 show, in a general way, how each of the tools illustrated in Fig. 7 are used, and corresponding tools are marked by the same reference letters in both of these illustrations. The right- and left-hand roughing tools *A* and *B* are especially adapted for taking deep roughing cuts. One feeds away from the center of the table, or to the right (when held in the right-hand tool-block) and the other tool is ground to feed in the opposite direction. Ordinarily, when turning plain flat surfaces, the cut is started at the outside and the tool feeds toward the center, as at *B*, although it is sometimes more convenient to feed in the opposite direction, as at *A*. The tool shown at *A* could also be used for turning cylindrical surfaces, by clamping it in a horizontal position across the bottom of the tool-block. The feeding movement would then be downward or at right-angles to the work table. The offset round-nose tools *C* and *D* are for turning exterior or interior cylinder surfaces. As this form of tool extends below the tool-block, it can be fed down close to a shoulder. The straight type shown at *E* is adapted for steel or iron, and when the point is drawn out narrower, it is also used for brass, although the front is then ground without slope. Tool *F* is for light finishing cuts and broad feeds. The amount of feed per revolution of the work should always be less than the width of the cutting edge. The offset tools *G* and *H* are for finishing exterior and interior cylindrical surfaces. These tools also have horizontal cutting edges and are sometimes used for first finishing a cylindrical and then a horizontal surface, or *vice versa*. Tool *I* is adapted to such work as cutting packing-ring grooves in engine pistons, forming square or rectangular grooves, and

Fig. 10. Tool B set for Boring the Hub

similar work. The parting tools *J* and *K* can also be used for forming narrow grooves or for cutting off rings, etc. The sketch *K* (Fig. 8) indicates how the left-hand tool might be used for squaring a corner under a shoulder. Tool *L* is frequently used on boring mills for rounding the corners of flywheel rims, in order to give them a more finished appearance. It has two cutting edges so that either side can be used.

The turning tools of a vertical boring mill are similar, in many respects, to those used on a lathe, although the shanks of the former are shorter and more stocky than those of lathe tools. The cutting edges of some of the tools also differ somewhat, but the principles which govern the grinding of lathe and boring mill tools are identical, and those who are not familiar with tool grinding are referred to MACHINERY'S Reference Book No. 92 on lathe work, in which this subject is treated.

Turning a Flywheel on a Vertical Mill

The turning of a flywheel is a good example of the kind of work for which a vertical boring mill is adapted. A flywheel should preferably

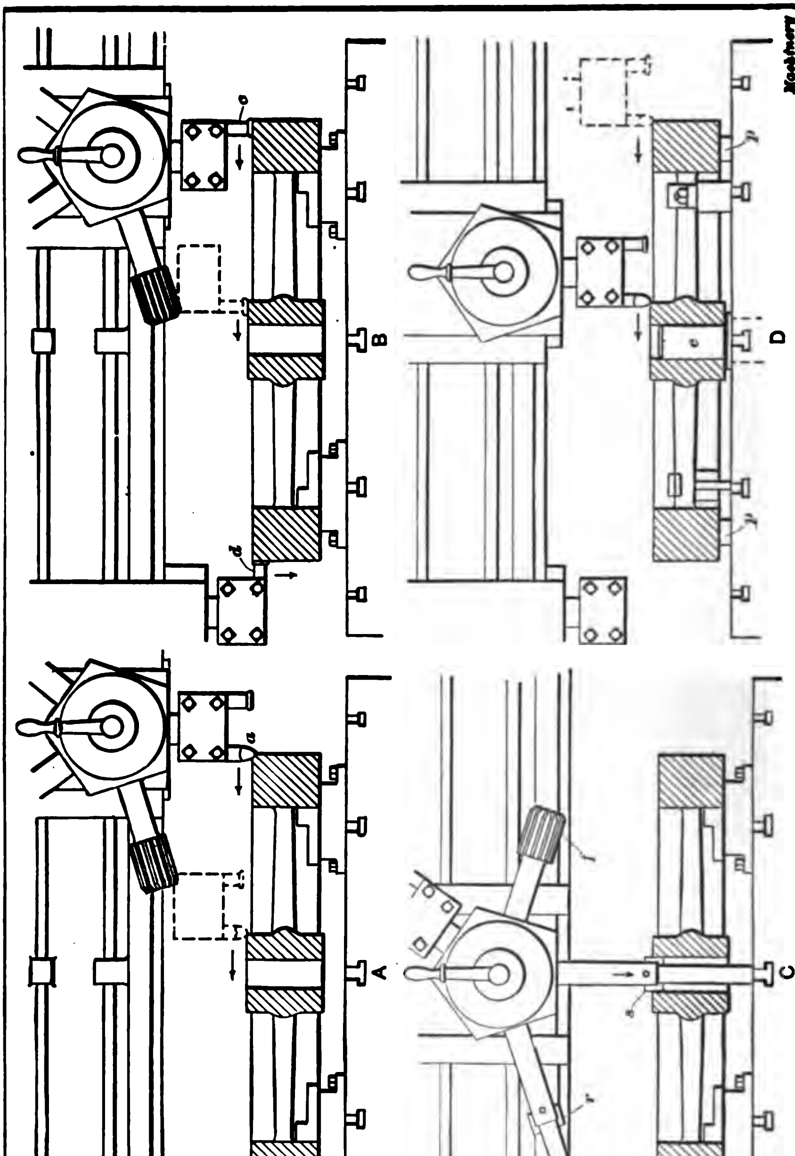

Fig. 11. Diagrams showing Method of Turning and Boring a Flywheel on a Double-head Mill having One Turret Head

be machined on a double-head mill so that one side and the periphery of the rim can be turned at the same time. A common method of holding a flywheel is shown in Fig. 9. The rim is gripped by four chuck jaws *D* which, if practicable, should be on the inside where they will not interfere with the movement of the tool. Two of the jaws, in this case, are set against the spokes on opposite sides of the wheel, to act as drivers and prevent any backward shifting of work when a heavy cut is being taken. The illustration shows the tool to the right rough turning the side of the rim, while the left-hand tool turns the periphery. Finishing cuts are also taken over the rim, at this setting, and the hub is turned on the outside, faced on top, and the hole bored. The three tools *A*, *B*

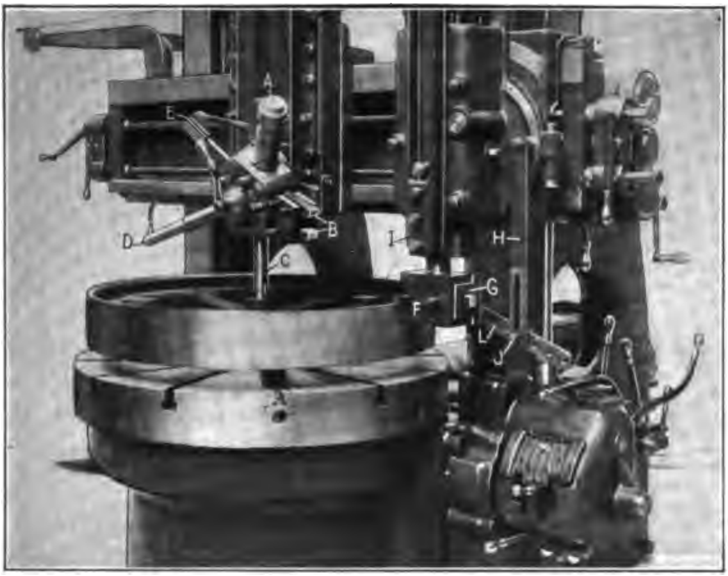

Fig. 12. Gisholt Mill equipped with Convex Turning Attachment

and *C*, for finishing the hole, are mounted in the turret. Bar *A*, which carries a cutter at its end, first rough bores the hole. The sizing cutter *B* is then used to straighten it before inserting the finishing reamer *C*. Fig. 10 shows the turret moved over to a central position and the sizing cutter *B* set for boring. The head is centrally located (on this particular machine) by a positive center-stop. The turret is indexed for bringing the different tools into the working position, by loosening the clamping lever *L* and pulling down lever *I* which disengages the turret lock-pin. When all the flywheels in a lot have been machined as described, the opposite side is finished.

In order to show more clearly the method of handling work of this class, the machining of a flywheel will be explained more in detail in connection with Fig. 11, which illustrates practically the same equipment as is shown in Figs. 9 and 10. The successive order in which the various operations are performed is as follows: Tool *a* (see sketch *A*) rough turns the side of the rim, while tool *b*, which is set with its cutting edge toward the rear, rough turns the outside. The direction in which each tool moves is indicated by the arrows. When tool *a* has crossed the rim, it is moved over for facing the hub, as shown by the dotted lines. The side and periphery of the rim is next finished by the broad-nose finishing tools *c* and *d* (see sketch *B*). The feed should be increased for finishing, so that each tool will have a movement of say 1/4 or 3/8 inch per revolution of the work, and the cuts should be deep enough to remove the marks made by the roughing tools. Tool *c* is also used for finishing the hub as indicated by the dotted lines. After these cuts are taken, the outside of the hub and inner surface of rim are

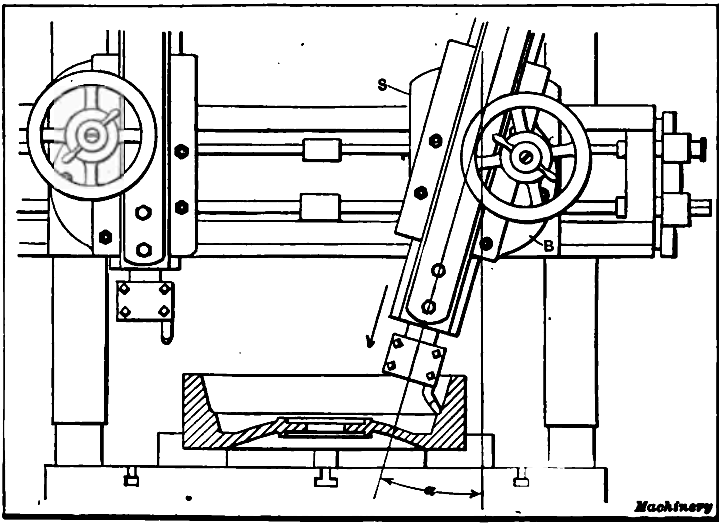

Fig. 13. Turning a Taper or Conical Surface

usually turned down as far as the spokes, by using offset tools similar to the ones shown at *C* and *D* in Fig. 7. The corners of the rim and hub are also rounded to give the work a more finished appearance, by using a tool *L*.

The next operation is that of finishing the hole through the hub. The hard scale is first removed by a roughing cutter *r* (sketch *C*), which is followed by a "sizing" cutter *s*. The hole is then finished smooth and to the right diameter by reamer *f*. The bars carrying cutters *r* and *s* have extensions or "pilots" which enter a close-fitting bushing in the table, in order to steady the bar and hold it in alignment.

When the hole is finished, the wheel is turned over, so that the lower side of the rim and hub can be faced. The method of holding the work for the final operation is shown at *D*. The chuck jaws are removed, and the finished side of the rim is clamped against parallels *p* resting on the table. The wheel is centrally located for turning this side by a plug *c* which is inserted in a hole in the table and fits the bore of the hub.

The work is held by clamps which bear against the spokes. Roughing and finishing cuts are next taken over the rim and hub and the corners are rounded, which completes the machining operations. If the rim needs to be a certain width, about the same amount of metal should be removed from each side, unless sandy spots or "blow-holes" in the casting make it necessary to take more from one side than the other. That side of the rim which was up when the casting was made, should be

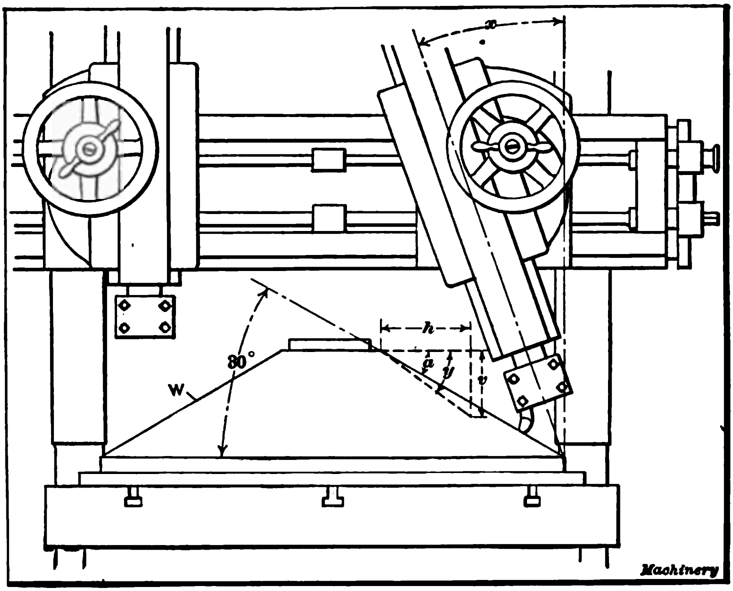

Fig. 14. Turning a Conical Surface by using the Combined Vertical and Horizontal Feeds

turned first, because the porous, spongy spots usually form on the "cope" or top side of a casting.

Convex Turning Attachment for Boring Mills

Fig. 12 shows a vertical boring mill arranged for turning pulleys having convex rims; that is, the rim, instead of being cylindrical, is rounded somewhat so that it slopes from the center toward either side. The reason for turning a pulley rim convex is to prevent the belt from running off at one side, as it sometimes tends to do when a cylindrical pulley is used. The convex surface is produced by a special attachment which causes the turning tool to gradually move outward as it feeds down, until the center of the rim is reached, after which the movement is inward.

This attachment consists of a special box-shaped tool-head *F* containing a sliding holder *G*, in which the tool is clamped by set-screws passing through elongated slots in the front of the tool-head. In addition, there is a radius link *L* which swivels on a stud at the rear of the tool-head and is attached to vertical link *H*. Link *L* is so connected to the sliding tool-block that any downward movement of the tool-bar *I* causes the tool to move outward until the link is in a horizontal position, after which the movement is reversed. When the attachment is first set up, the turning tool is placed at the center of the rim and then link *L* is clamped to the vertical link while in a horizontal position. The cut is started at the top edge of the rim, and the tool is fed downward by power, the same as when turning a cylindrical surface. The amount of curvature or convexity of a rim can be varied by inserting the clamp bolt *J* in different holes in link *L*.

The tools for machining the hub and sides of the rim are held in a turret mounted on the left-hand head, as shown. The special tool-holder *A* contains two bent tools for turning the upper and lower edges of the pulley rim at the same time. Roughing and finishing tools *B* are for

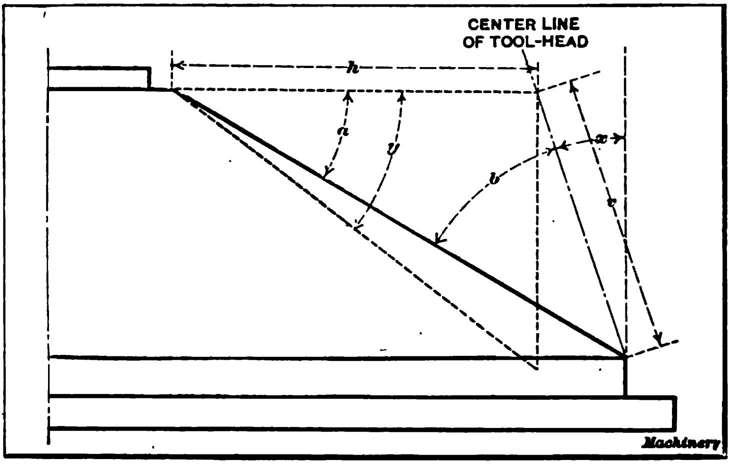

Fig. 15. Diagram showing Method of Obtaining Angular Position of Tool-head when Turning Conical Surfaces by using Vertical and Horizontal Feeding Movements

facing the hub, and the tools *C*, *D*, and *E* rough bore and finish the hole for the shaft.

Turning Taper or Conical Surfaces

Conical or taper surfaces are turned in a vertical boring mill by swiveling the tool-bar to the proper angle, as shown in Fig. 13. When the taper is given in degrees, the tool-bar can be set by graduations on the edge of the circular base *E*, which show the angle *a* to which the bar is swiveled from a vertical position. The base turns on a central stud and is secured to the saddle *S* by the bolts shown, which should be tightened after the tool-bar is set. The vertical power feed can be used for taper turning the same as for cylindrical work.

Occasionally it is necessary to machine a conical surface which has such a large included angle that the tool-bar cannot be swiveled far enough around to permit turning by the method illustrated in Fig. 13. Another method, which is sometimes resorted to for work of this class, is to use the combined vertical and horizontal feeds. Suppose we want to turn the conical casting W (Fig. 14), to an angle of 30 degrees, as shown, and that the tool-head of the boring mill moves horizontally 1/4 inch per turn of the screw and has a vertical movement of 3/16 inch per turn of the upper feed-shaft. If the two feeds are used simultaneously, the tool will move a distance h of say 8 inches, while it moves downward a distance v of 6 inches, thus turning the surface to an angle y. This angle is greater (as measured from a horizontal plane) than the angle required, but, if the tool-bar is swiveled to an angle x, the tool, as it moves downward, will also be advanced horizontally, in addition to the regular horizontal movement. The result is that angle y is diminished, and if the tool-bar is set over the right amount, the conical surface can be turned to an angle a of 30 degrees. The problem, then, is to determine what the angle x should be for turning to a given angle a. The way angle x is calculated will be explained in connection with the enlarged diagram, Fig. 15, which shows one-half of the casting.

The sine of the known angle a is first found in a table of natural sines. Then the sine of angle b is determined as follows: $\sin b = \frac{\sin a \times h}{v}$, in which h represents the rate of horizontal feed and v the rate of vertical feed. The angle corresponding to sine b is next found in the table of sines. We now have angles b and a, and by subtracting these angles from 90 degrees, the desired angle x is obtained. To illustrate:

The sine of 30 degrees is 0.5; then $\sin b = \frac{0.5 \times 1/4}{3/16} = 0.6666$; hence angle $b = 41$ degrees 49 minutes, and $x = 90° - (30° + 41° 49') = 18$ degrees 11 minutes.

If angle a were greater than angle y obtained from the combined feeds with the tool-bar in a vertical position, it would then be necessary to swing the lower end of the bar to the left rather than to the right of a vertical plane.

CHAPTER III

TURRET-LATHE TYPE OF VERTICAL BORING MILL

The machine illustrated in Fig. 16 was designed to combine the advantages of the horizontal turret lathe and the vertical boring mill. It is known as a "vertical turret lathe," but resembles, in many respects, a vertical boring mill. This machine has a turret on the cross-rail the same as the vertical boring mill, and, in addition, a side-head *S*. The side-head has a vertical feeding movement, and the tool-bar *T* can be fed horizontally. The tool-bar is also equipped with a four-sided turret for holding turning tools. This arrangement of the tool-heads makes it possible to use two tools simultaneously upon comparatively small work. When both heads are mounted on the cross rail, as with a double-head boring mill, it is often impossible to machine certain parts to advantage, because one head interferes with the other.

The drive to the table is from a belt pulley at the rear, and fifteen speed changes are available. Five changes are obtained by turning the pilot-wheel *A* and this series of five speeds is compounded three times by turning lever *B*. Each spoke of pilot-wheel *A* indicates a speed which is engaged only when the spoke is in a vertical position, and the three positions for *B* are indicated by slots in the disk shown. The number of table revolutions per minute for different positions of pilot-wheel *A* and lever *B*, are shown by figures seen through whichever slot is at *C*. There are five rows of figures corresponding to the five spokes of the pilot-wheel and three figures in a row, and the speed is shown by arrows on the sides of the slots. The segment disk containing these figures also serves as an interlocking device which prevents moving more than one speed controlling lever at a time, in order to avoid damaging the driving mechanism.

The feeding movement for each head is independent. Lever *D* controls the engagement or disengagement of the vertical or cross feeds for the head on the cross-rail. The feed for the side-head is controlled by lever *E*. When this lever is pushed inward, the entire head feeds vertically, but when it is pulled out, the tool-bar feeds horizontally. These two feeds can be disengaged by placing the lever in a neutral position. The direction of the feeding movement for either head can be reversed by lever *R*. The amount of feed is varied by feed-wheel *F* and clutch-rod *G*. When lever *E* is in the neutral position, the side-head or tool-bar can be adjusted by the hand-cranks *H* and *I*, respectively. The cross-rail head and its turret slide have rapid power traverse movements for making quick adjustments. This rapid traverse is controlled by the key-handles *J*. The feed screws for the vertical head have micrometer dials *K* for making accurate adjustments. There are also large dials at *L* which indicate vertical movements of the side head and horizontal movements of the tool slide. All of these dials have small adjustable clips *c* which are numbered to correspond to numbers on the faces of the respective turrets. These clips or "observation stops" are used in the production of duplicate parts. For example: suppose a tool in face No. 1 for the main turret is set for a given diameter and height of shoulder on a part which is to be duplicated. To obtain the same setting of the tools for the next piece, clips No. 1, on both the vertical feed rod and screw dials,

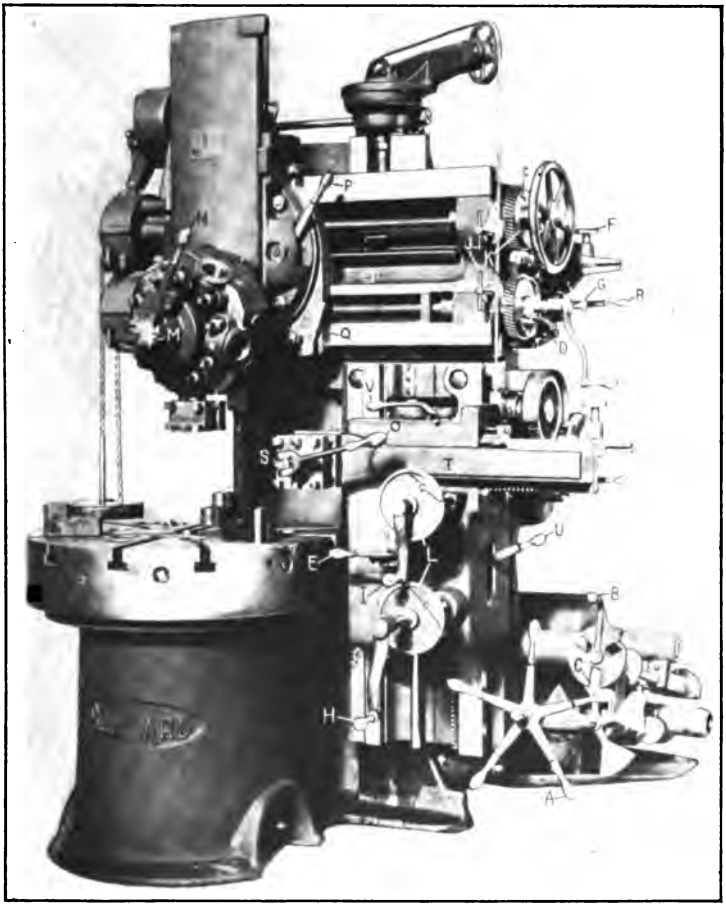

Fig. 16. Bullard Vertical Turret Lathe

are placed opposite the graduations which are intersected by stationary pointers secured to the cross-rail. The clips are set in this way after the first part has been machined to the required size and before disturbing the final position of the tools. For turning a duplicate part, the tools are simply brought to the same position by turning the feed screws until the clips and stationary pointers again coincide. For setting tools on other faces of either turret, this operation is repeated, except that clips are used bearing numbers corresponding to the turret face in use.

The main turret of this machine has five holes in which are inserted the necessary boring and turning tools, drills or reamers, as may be required. By having all the tools mounted in the turret, they can be quickly and accurately moved into working position. When the turret is indexed from one face to the next, binder lever N is first loosened. The turret then moves forward away from its seat, thus disengaging the indexing and registering pins which accurately locate it in any one of the five positions. The turret is revolved by turning crank *M*, one turn of this handle moving the turret 1/5 revolution or from one hole to the next. The side-head turret is turned by loosening lever *O*. The turret slide can be locked rigidly in any position by lever *P* and its sad-

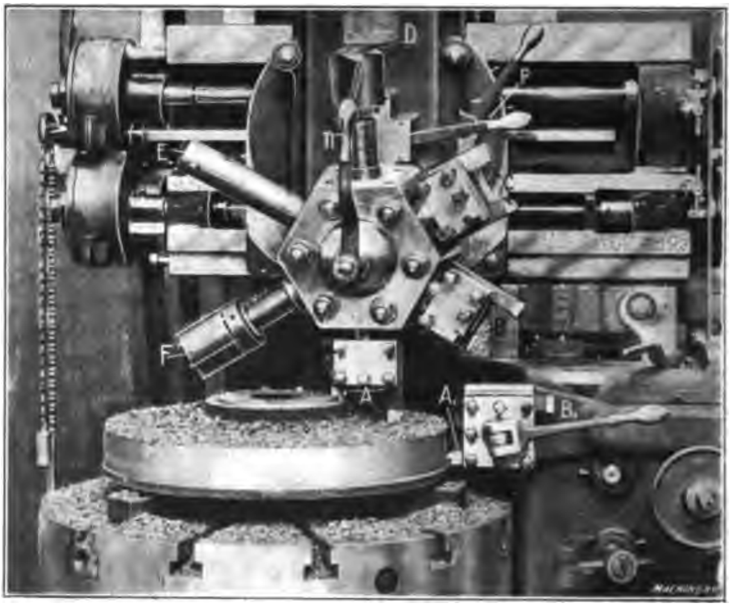

Fig. 17. Turning a Gear Blank on a Vertical Turret Lathe

dle is clamped to the cross-rail by lever *Q*. The binder levers for the saddle and tool-slide of the side-head are located at *U* and *V* respectively. A slide that does not require feeding movements is locked in order to obtain greater rigidity.

The vertical slide can be set at an angle for taper turning, and the turret is accurately located over the center of the table for boring or reaming, by a positive center stop. The machine is provided with a brake for stopping the work table quickly, which is operated by lifting the shaft of pilot-wheel *A*. The side- and cross-rails are a unit and are adjusted together to accommodate work of different heights. This adjustment is effected by power on the particular machine illustrated, and it is controlled by a lever near the left end of the cross-rail. Before making this adjustment, all binder bolts which normally hold the rails rigidly to the machine column, must be released, and care should be taken to tighten them after the adjustment is made.

Examples of Vertical Turret Lathe Work

In order to illustrate how a vertical turret lathe is used, one or two examples of work will be referred to in detail. These examples also indicate, in a general way, the class of work for which this type of machine is adapted. Fig. 17 shows how a cast-iron gear blank is machined. The work is gripped on the inside of the rim by three chuck jaws, and all of the tools required for the various operations are mounted in the main and side turrets. The illustration shows the first operation which is that of rough turning the hub, the side of the blank and its

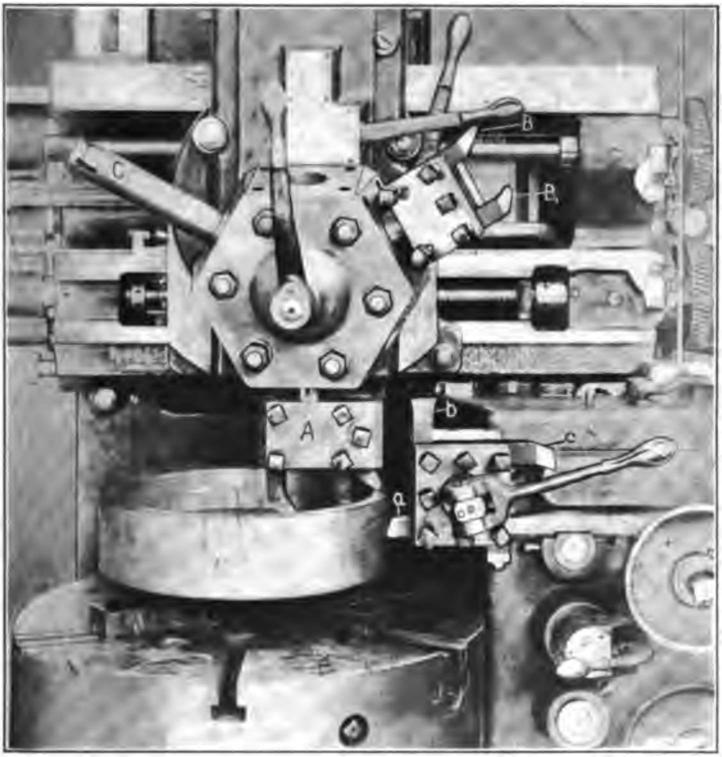

Fig. 18. Turning Gasoline Engine Flywheel on Vertical Turret Lathe—First Position

periphery. The tools *A* for the hub and side are both held in one tool-block on the main turret, and tool A_1 for roughing the periphery is in the side turret. With this arrangement, the three surfaces can be turned simultaneously. The main turret is next indexed one-sixth of a revolution which brings the broad finishing tools *B* into position, and the side turret is also turned to locate finishing tool B_1 at the front. (The indexing of the main turret on this particular machine is effected by loosening binder lever *n* and raising the turret lock-pin by means of lever *p*.) The hub, side and periphery of the blank are then finished. When tools *B* are clamped in the tool-blocks, they are, of course, set for turning the hub to the required height. The third operation is performed by the tools at *C*, one of which "breaks" or chamfers the corner of the cored hole to provide a starting surface for drill *D*, and the other turns the outside of the hub, after the chamfer tool is removed. The four-lipped shell-drill *D* is next used to drill the cored hole and then this hole is bored close to the finished size and concentric with the circumference of the blank by boring tool *E*, which is followed by the finishing reamer *F*. When the drill, boring tool and reamer are being used, the turret is set

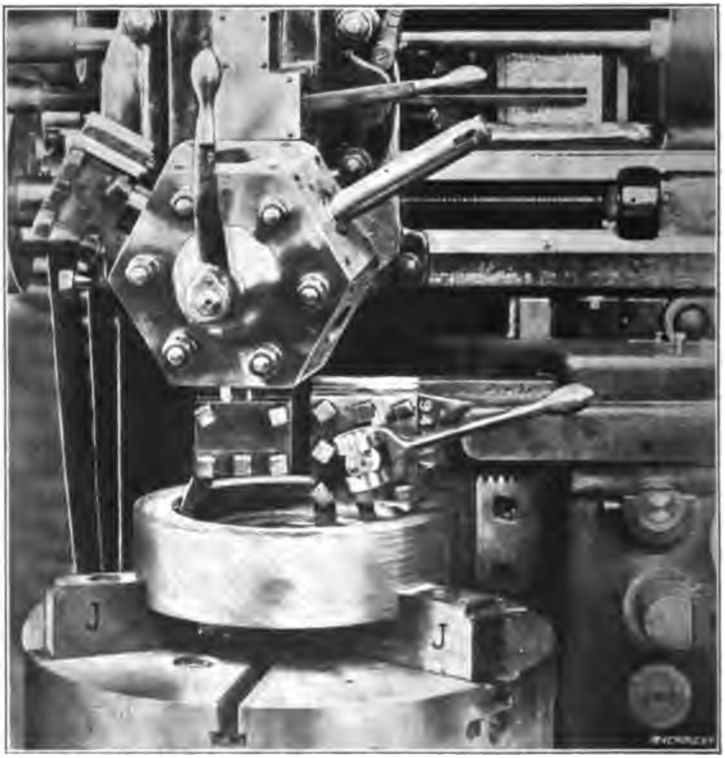

Fig. 19. Turning Gasoline Engine Flywheel—Second Position

over the center or axis of the table by means of a positive center stop on the left-side of the turret saddle. If it is necessary to move the turret beyond the central position, this stop can be swung out of the way.

Figs. 18 and 19 illustrate the machining of an automobile flywheel, which is another typical example of work for a machine of this type. The flywheel is finished in two settings. Its position for the first series of operations is shown in Fig. 18, and the successive order of the four operations for the first setting is shown by the diagrams, Fig. 20. The first operation requires four tools which act simultaneously. The three held in tool-block *A* of the turret, face the hub, the web and the rim of the flywheel, while tool *a* in the side-head rough turns the outside diameter. The outside diameter is also finished by broad-nosed tool *b* which is given a coarse feed. In the second operation, the under face of the rim is finished by tool *c*, the outer corners are rounded by tool *d* and the inner surface of the rim is rough turned by a bent tool *B*, which is moved into position by indexing the main turret. In the third operation, the side-head is moved out of the way and the inside of the rim is finished by another bent tool B_1. The final operation at this setting is the boring of the central hole, which is done with a bar *C* having in-

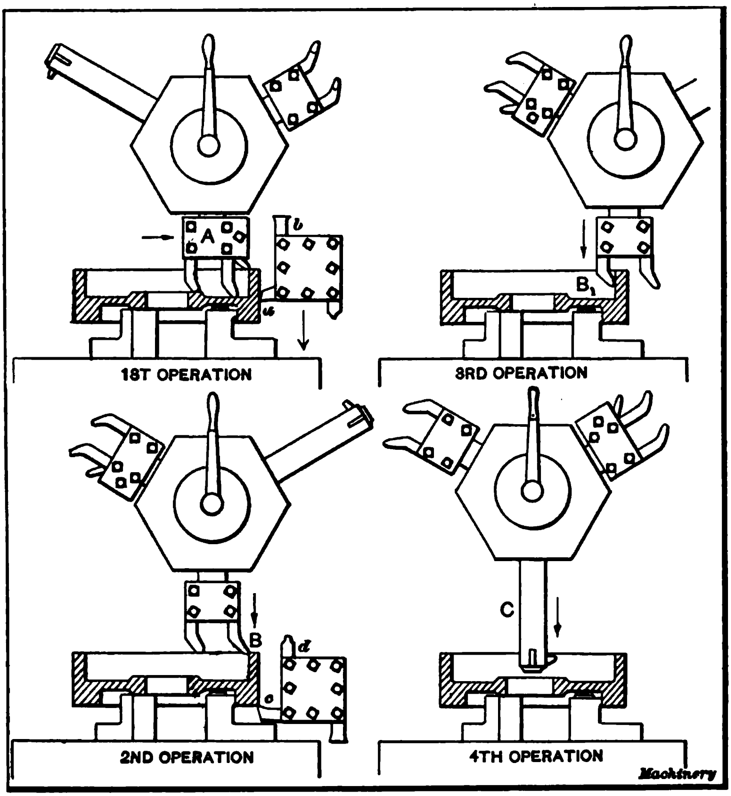

Fig. 20. Diagrams showing How Successive Operations are Performed by Different Tools in the Turret

terchangeable cutters which make it possible to finish the hole at one setting of the turret.

The remaining operations are performed on the opposite side of the work which is held in "soft" jaws *J* accurately bored to fit the finished outside diameter as indicated in Fig. 19. The tool in the main turret turns the inside of the rim and the side-head is equipped with two tools for facing the web and hub simultaneously. As the tool in the main turret operates on the left side of the rim, it is set with the cutting edge toward the rear. In order to move the turret to this position, which is beyond the center of the table, the center stop previously referred to is swung out of the way.

CHAPTER IV

HORIZONTAL BORING, DRILLING AND MILLING MACHINE

A boring machine of the horizontal type is shown in Fig. 21. The construction and operation of this machine is very different from that of a vertical boring mill and it is also used for a different class of work. The horizontal machine is employed principally for boring, drilling or milling, whereas the vertical design is especially adapted to turning and boring. The horizontal type is also used for turning or facing flanges or similar surfaces when such an operation can be performed to advantage in connection with other machine work on the same part.

The type of machine illustrated in Fig. 21 has a heavy base or bed to which is bolted the column *C* having vertical ways on which the spindle-head *H* is mounted. This head contains a sleeve or quill in which the spindle *S* slides longitudinally. The spindle carries cutters for boring, whereas milling cutters or the auxiliary facing arm, are bolted to the end *A* of the spindle sleeve. The work itself is attached either directly or indirectly to platen *P*. When the machine is in operation, the cutter or tool revolves with the spindle sleeve or spindle and either the cutter or the part being machined is given a feeding movement, depending on the character of the work. The spindle can be moved in or out by hand for adjustment, or by power for feeding the cutter as when boring or drilling. The entire spindle-head *H* can also be moved vertically on the face of the column *C*, by hand, for setting the spindle to the proper height, or by power for feeding a milling cutter in a vertical direction. When the vertical position of the spindle-head is changed, the back-rest block *B* also moves up or down a corresponding amount, the two parts being connected by shafts and gearing. Block *B* steadies the outer end of the boring-bar and the back-rest in which this block is mounted, can be shifted along the bed to suit the length of the work, by turning the squared end of shaft *D* with a crank. The platen *P* has a cross-feed, and the saddle *E* on which it is mounted can be traversed lengthwise on the bed; both of these movements can also be effected by hand or power. There is a series of power feeding movements for the cutters and, in addition, rapid power movements *in a reverse direction from the feed* for returning a cutter quickly to its starting position, when this is desirable.

This machine is driven by a belt connecting pulley *G* with an overhead shaft. When the machine is in operation, this pulley is engaged with the main driving shaft by a friction clutch *F* controlled by lever *L*. This main shaft drives through gearing a vertical shaft *I*, which by means of other gears in the spindle head imparts a rotary movement to the spindle. As a machine of this type is used for boring holes of various diameters and for a variety of other work, it is necessary to

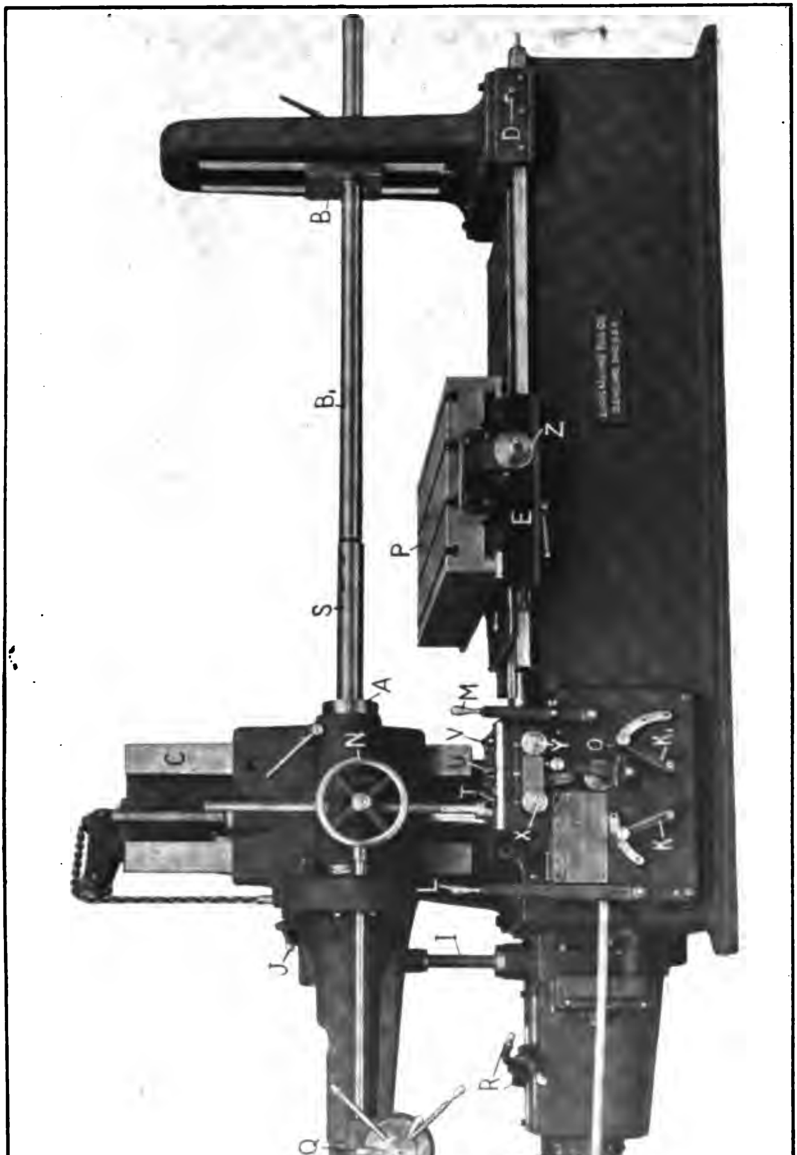

Fig. 21. Lucas Horizontal Boring, Drilling and Milling Machine

have a number of speed changes for the spindle. Nine speeds are obtained by changing the position of the sliding gears controlled by levers *R* and this number is doubled by back-gears in the spindle-head and controlled by lever *J*.

The amount of feed for the spindle, spindle-head, platen or saddle is varied by two levers *K* and K_1 which control the position of sliding gears through which the feeding movements are transmitted. The direction of the feed can be reversed by shifting lever *O*. With this particular machine, nine feed changes are available for each position of the spindle back-gears, making a total of eighteen changes which range from 0.004 to 0.006 inch per revolution of the spindle. The feeding movement is transmitted to the spindle-head, spindle, platen or saddle, as required, by the three distributing levers *T*, *U* and *V*, which control clutches connecting with the transmission shafts or feed screws. When lever *T* is turned to the left, the longitudinal power feed for the spindle is engaged, whereas turning it to the right throws in the vertical feed for the spindle-head. Lever *U* engages the cross-feed for platen *P* and lever *V*, the longitudinal feed for saddle *E*. These levers have a simple but ingenious interlocking device which makes it impossible to engage more than one feed at a time. For example, if lever *T* is set for feeding the spindle, levers *U* and *V* are locked against movement.

The feeds are started and stopped by lever *M* which also engages the rapid power traverse when thrown in the opposite direction. This rapid traverse operates for whatever feed is engaged by the distributing levers and, as before stated, in a reverse direction. For example, if the reverse lever *O* is set for feeding the spindle to the right, the rapid traverse would be to the left, and *vice versa*. The cross-feed for the platen can be automatically tripped at any point by setting an adjustable stop in the proper position and the feed can also be tripped by a hand lever at the side of the platen.

All the different feeding movements can be effected by hand as well as by power. By means of handwheel *N*, the spindle can be moved in or out slowly, for feeding a cutter by hand. When the friction clamp *Q* is loosened, the turnstile *W* can be used for traversing the spindle, in case a hand adjustment is desirable. The spindle-head can be adjusted vertically by turning squared shaft *X* with a crank, and the saddle can be shifted along the bed by turning shaft *Y*. The hand adjustment of the platen is effected by shaft *Z*. The spindle-head, platen and saddle can also be adjusted from the end of the machine, when this is more convenient. Shafts *X*, *Y* and *Z* are equipped with micrometer dials which are graduated to show movements of one-thousandth inch. These dials are used for accurately adjusting the spindle or work and for boring holes or milling surfaces that must be an exact distance apart.

Horizontal Boring Machine with Vertical Table Adjustment

Another design of horizontal boring machine is illustrated in Fig. 22. This machine is of the same type as that shown in Fig. 21, but its construction is quite different, as will be seen. The spindle cannot be adjusted vertically as with the first design described, but it is mounted

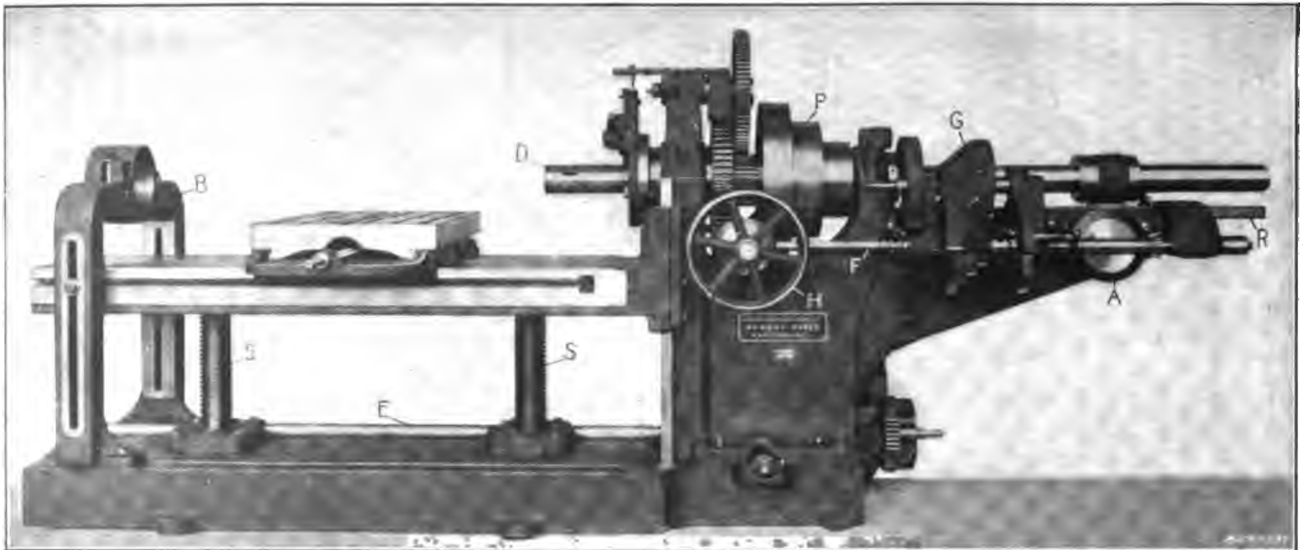

Fig. 22. Bement Horizontal Boring and Drilling Machine

and driven very much like the spindle of a lathe, and adjustment for height is obtained by raising or lowering the work table. The design is just the reverse, in this respect, of the machine shown in Fig. 21, which has a vertical adjustment for the spindle, and a work table that remains in the same horizontal plane. The raising or lowering of the table is effected by shaft *E*, which rotates large nuts engaging the screws *S*. Shaft *E* is turned either by hand or power.

The main spindle is driven by a cone pulley *P*, either directly, or indirectly through the back-gears shown. This arrangement gives six spindle speeds, and double this number is obtained by using a two-speed countershaft overhead. The motion for feeding the spindle longitudinally is transmitted to shaft *F*, which rotates bevel gear *A* and a pinion meshing with rack *R* which traverses the spindle. The large handwheel *H* and a corresponding wheel on the opposite side are used for adjusting the spindle rapidly by hand. The nest of gears at *G* gives the required feed changes by engaging different combinations. The yoke or outboard bearing *B* for the boring-bars can be clamped in any position along the bed for supporting the bar as close to the work as possible.

Horizontal boring machines are built in many other designs, but they all have the same general arrangement as the machines illustrated and operate on the same principle, with the exception of special types intended for handling certain classes of work exclusively. In the next chapter some examples of work done on these machines will be illustrated and described.

CHAPTER V

TOOLS FOR BORING—EXAMPLES OF HORIZONTAL BORING MACHINE WORK

The horizontal boring, drilling and milling machine is very efficient for certain classes of work because it enables all the machining operations on some parts to be completed at one setting. To illustrate, a casting which requires drilling, boring and milling at different places, can often be finished without disturbing its position on the platen after it is clamped in place. Frequently a comparatively small surface needs to be milled after a part has been bored. If this milling operation can be performed while the work is set up for boring, accurate results will be obtained (provided the machine is in good condition) and the time saved that would otherwise be required for re-setting the part on another machine. Some examples of work on which different operations are performed at the same setting will be referred to later. The horizontal boring machine also makes it possible to machine duplicate parts without the use of jigs, which is important, especially on large work, owing to the cost of jigs.

Drilling and Boring—Cutters Used for Boring

Holes are drilled in a horizontal machine by simply inserting a drill of required size either directly in the spindle (*S*, Fig. 21, and *D*, Fig. 22) or in a reducing socket, and then feeding the spindle outward either by hand or power. When a hole is to be bored, a boring-bar B_1 (Fig. 21) is inserted in the spindle and the cutter is attached to this bar. The latter is then fed through the hole as the cutter revolves. The distinction made by machinists between drilling and boring is as follows: A hole is said to be drilled when it is formed by sinking a drill into solid metal, whereas boring means the enlargement of a drilled or cored hole.

There are various methods of attaching cutters to boring-bars and the cutters used vary for different classes of work. A simple style of cutter which is used widely for boring small holes is shown at *A* in Fig. 23. The cutter *c* is made from flat stock and the cutting is done by the front edges *e* and e_1, which are beveled in opposite directions. The cutter is held in the bar by a taper wedge *w* and it is centered by shoulders at *s*. The outer corners at the front should be slightly rounded, as a sharp corner would be dulled quickly. These cutters are made in different sizes and also in sets for roughing and finishing. The roughing cutter bores holes to within about 1/32 inch of the finish size and it is then replaced by the finishing cutter. A cutter having rounded ends as

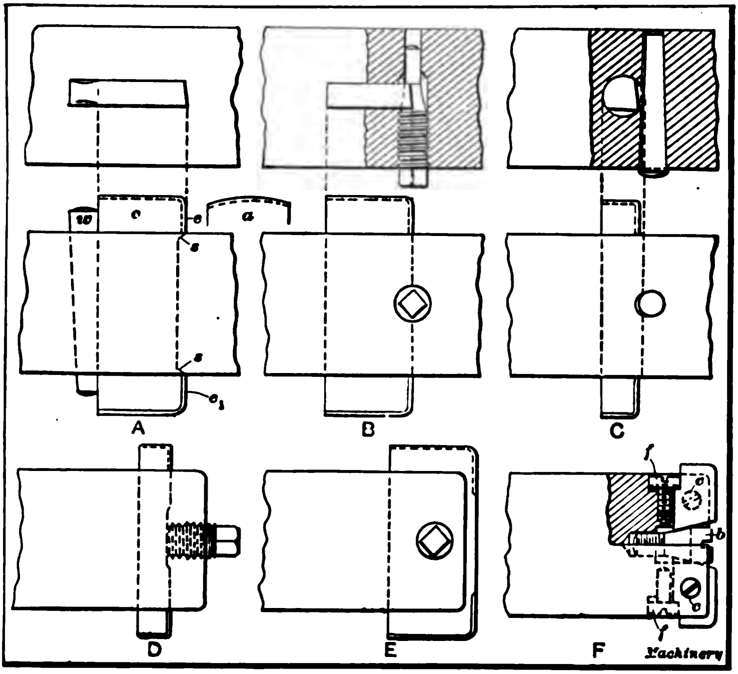

Fig. 23. Boring-cutters of Different Types

shown by the detail sketch *a*, is sometimes used for light finishing cuts. These rounded ends form the cutting edges and give a smooth finish. Another method of holding a flat cutter is shown at *B*. The conical end of a screw bears against a conical seat in the cutter, thus binding the latter in its slot. The conical seat also centers the cutter. A very simple and inexpensive form of cutter is shown at *C*. This is made from a piece of round steel, and it is held in the bar by a taper pin which bears against a circular recess in the side of the cutter. This form has the advantage of only requiring a hole through the boring-bar, whereas it is necessary to cut a rectangular slot for the flat cutter.

Fig. 24 illustrates how a hole is bored by cutters of the type referred to. The bar rotates as indicated by the arrow *a* and at the same time feeds longitudinally as shown by arrow *b*. The speed of rotation depends upon the diameter of the hole and the kind of material being bored, and the feed per revolution must also be varied to suit conditions. No definite rule can be given for speed or feed. On some classes of work a long boring-bar is used, which passes through the hole to be bored and is steadied at its outer end by the back-rest *B*, Figs. 21 and 22. On

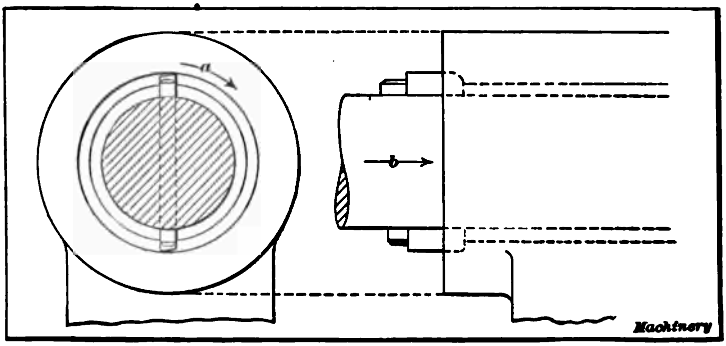

Fig. 24. Boring with a Flat Double-ended Cutter

other work, a short bar is inserted in the spindle and the cutter is attached at the outer end. An inexpensive method of holding a cutter at the end of a bar is shown at *D*, Fig. 23. The cutter passes through a slot and is clamped by a bolt as shown. When it is necessary to bore holes that are "blind" or closed at the bottom, a long boring-bar which passes through the work cannot, of course, be used. Sometimes it is

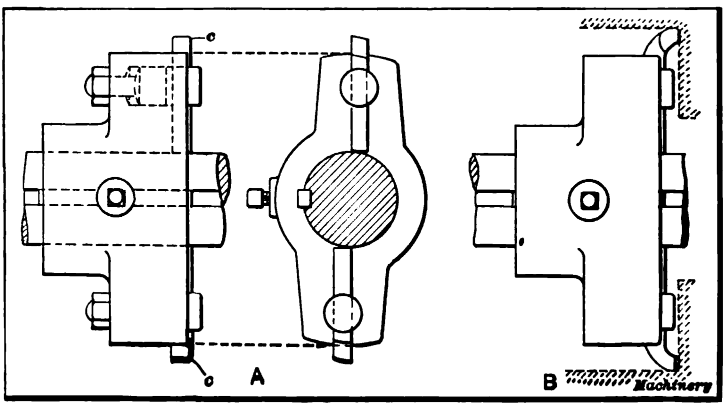

Fig. 25. Cutter-heads for Boring Large Holes

necessary to have a cutter mounted at the extreme end of a bar in order to bore close to a shoulder or the bottom of a hole. One method of holding a cutter so that it projects beyond the end of a bar is indicated at *E*. A screw similar to the one shown at *B* is used, and the conical end bears in a conical hole in the cutter. This hole should be slightly offset so that the cutter will be forced back against its seat. The tool shown at *F* has adjustable cutters. The inner end of each cutter is tapering and bears against a conical-headed screw *b* which gives the required outward adjustment. The cutters are held against the central bolt by filister-head screws *f* and they are clamped by the screws *c*. Boring tools are made in many different designs and the number and form of the cutters is varied somewhat for different kinds of work.

Cutter-heads for Boring Large Holes

When large holes are to be bored, the cutters are usually held in a cast-iron head which is mounted on the boring-bar. One type of cutter-head is shown in Fig. 25. This particular head is double-ended and carries two cutters *c*. The cutter-head is bored to fit the bar closely and it is prevented from turning by a key against which a setscrew is tightened. By referring to the end view, it will be seen that each cutter

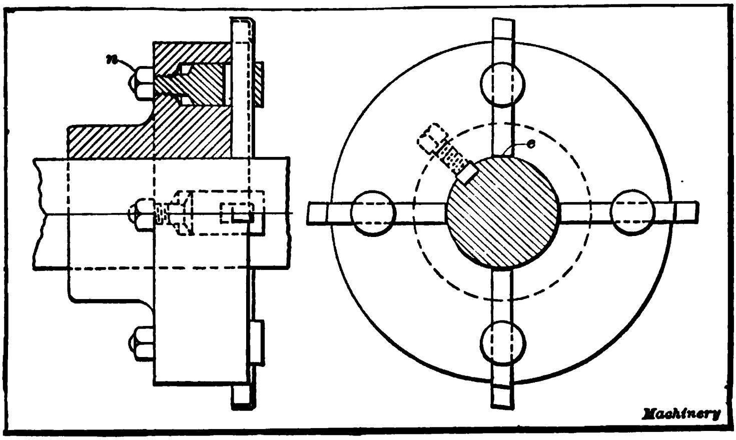

Fig. 26. Cutter-head with Four Boring Tools

is offset with relation to the center of the bar, in order to locate the front of the tool on a radial line. The number of cutters used in a cutter-head varies. There should be at least two, and three or four are often used. By having several cutters, the work of removing a given amount of metal in boring is distributed, and holes can be bored more quickly with a multiple cutter-head, although more power is required to drive the boring-bar. The boring-bar is also steadied by a multiple cutter-head, because the tendency of any one cutter to deflect the bar is counteracted by the cutters on the opposite side.

A disk-shaped head having four cutters is illustrated in Fig. 26. The cutters are inserted in slots or grooves in the face of the disk and they are held by slotted clamping posts. The shape of these posts is shown by the sectional view. The tool passes through an elongated slot and it is tightly clamped against the disk by tightening nut *n*. This head is also driven by a key which engages a keyway in the boring-bar.

Two other designs of cutter-heads are shown in Fig. 27. The one illustrated at *A* has three equally spaced cutters which are held in an inclined position. The cutters are clamped by screws *c* and they can be adjusted within certain limits by screws *s*. The cutters are placed at an angle so that they will extend beyond the front of the head, thus permitting the latter to be moved up close to a shoulder. The cutter-heads shown in Figs. 25 and 26 can also be moved up close to a shoulder

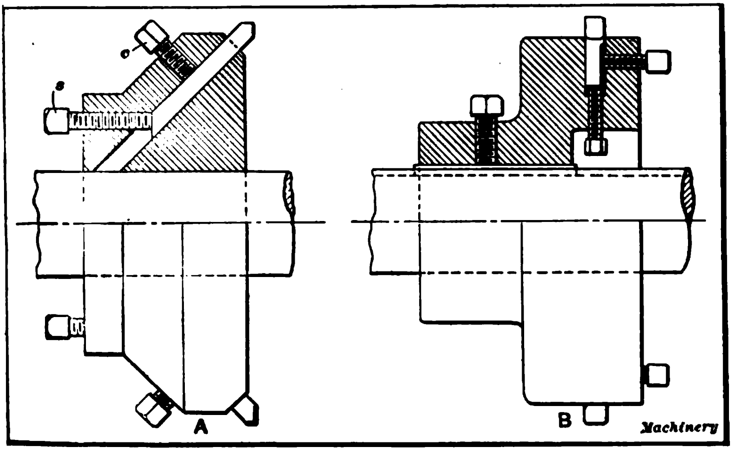

Fig. 27. Cutter-heads equipped with Adjustable Tools

if bent cutters are used as shown in the right-hand view, Fig. 25. The idea in bending the cutters is to bring the cutting edges in advance of the clamping posts so that they will reach a shoulder before the binding posts strike it. The arrangement of cutter head *B* (Fig. 27) is clearly shown by the illustration.

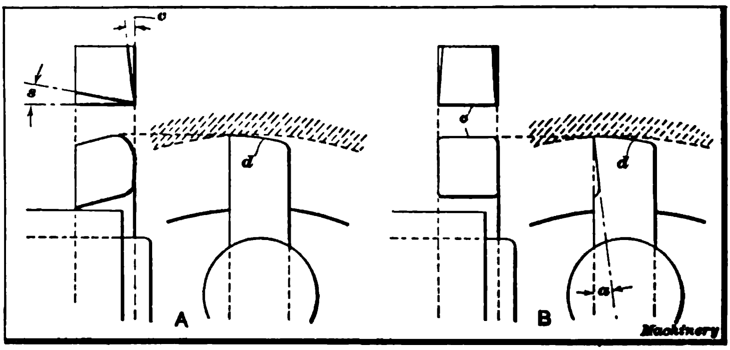

Fig. 28. Boring Tools for Roughing and Finishing Cuts

Fig. 29 illustrates the use of a cutter-head for cylinder boring. After the cylinder casting is set on the platen of the machine, the boring-bar with the cutter-head mounted on it, is inserted in the spindle. The bar *B* has a taper shank and a driving tang similar to a drill shank, which fits a taper hole in the end of the spindle. The cutter-head *C* is fastened to the bar so that it will be in the position shown when the spindle is shifted to the right, as the feeding movement is to be in the opposite direction. The casting *A* should be set central with the bar by adjusting the work-table vertically and laterally, if necessary, and the outer support *F* should be moved close to the work, to make the bar as rigid as possible.

The cylinder is now ready to be bored. Ordinarily, one roughing and one finishing cut would be sufficient, unless the rough bore were considerably below the finish diameter. As previously explained, the speed and feed must be governed by the kind of material being bored and the diameter of the cut. The power and rigidity of the boring machine and the quality of the steel used for making the cutters also effect the cutting speed and feed. Of course, the finishing cut is very light, and a

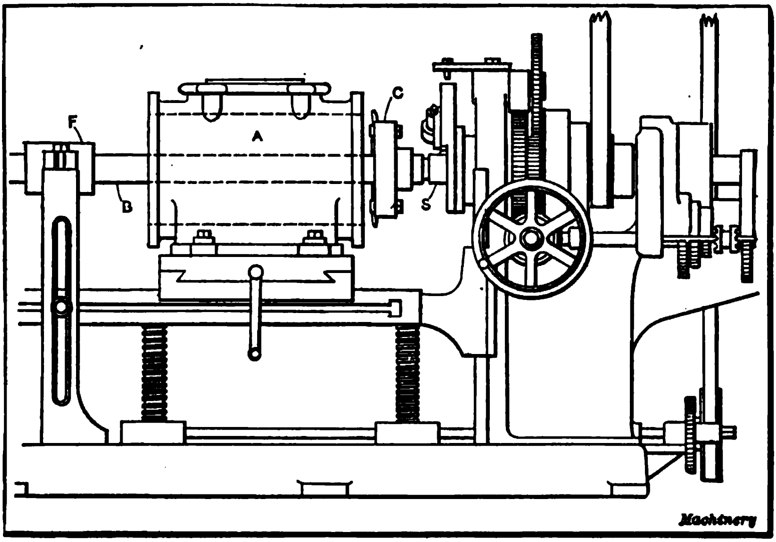

Fig. 29. Cylinder mounted on Horizontal Machine for Boring

tool having a flat cutting edge set parallel to the bar, is ordinarily used when boring cast iron. The coarse feed enables the cut to be taken in a comparatively short time and the broad-nosed tool gives a smooth finish if properly ground.

The coarse finishing feed is not always practicable, especially if the boring machine is in poor condition, owing to the chattering of the tool, which results in a rough surface. The last or finishing cut should invariably be a continuous one, for if the machine is stopped before the cut is completed, there will be a ridge in the bore at the point where the tool temporarily left off cutting. This ridge is caused by the cooling and resulting contraction and shortening of the tool during the time that it is stationary. For this reason independent drives are desirable for boring machines.

Cutter heads are often provided with two sets of cutters, one set being used for roughing and the other for finishing. It is a good plan to make these cutters so that the ends *e* (Fig. 26) will rest against the bar or bottom of the slot, when the cutting edge is set to the required radius. The cutters can then be easily set for boring duplicate work. One method of making cutters in sets is to clamp the annealed stock in

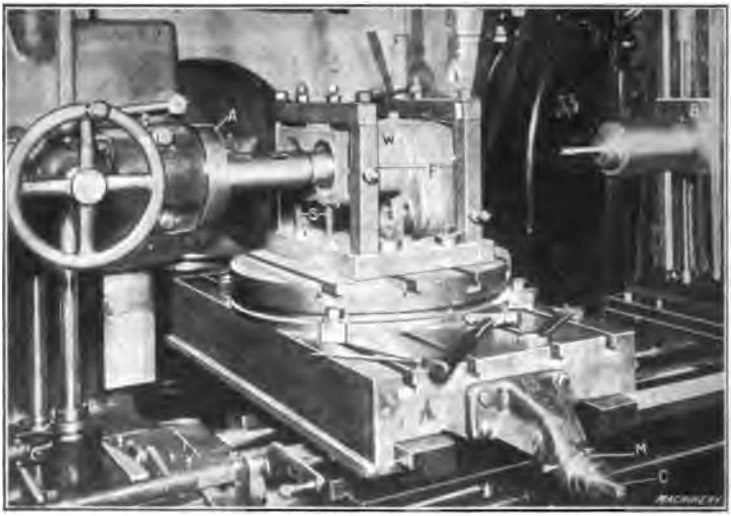

Fig. 30. Boring a Duplex Cylinder on a Horizontal Machine

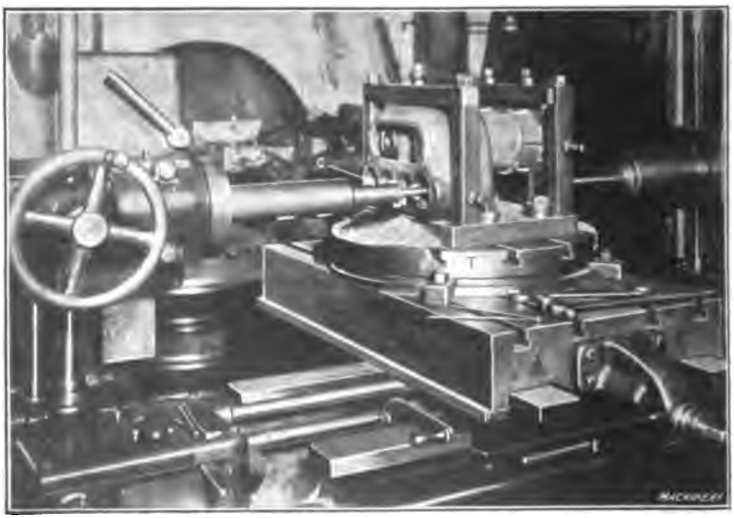

Fig. 31. Cylinder turned around for Machining Valve Seats

the cutter-head and then turn the ends to the required radius by placing the head in the lathe. After both sets of cutters have been turned in this way, they are ground to shape and then hardened.

Boring cutters intended for roughing and finishing cuts are shown in the detail view Fig. 28 at *A* and *B*, respectively. The side of the roughing cutter *A* is ground to a slight angle *c* to provide clearance for the cutting edge, and the front has a backward slope *s* to give the tool keenness. This tool is a good form to use for roughing cuts in cast iron. The finishing tool at *B* has a broad flat edge *e* and it is intended for coarse feeds and light cuts in cast iron. If a round cutting edge is used for finishing, a comparatively fine feed is required in order to obtain a smooth surface. The corners of tool *B* are rounded and they should be ground to slope inward as shown in the plan view. The top or ends *d* of both of these tools are "backed off" slightly to provide clearance. This end clearance should be just enough to prevent the surface back of cutting edge from dragging over the work. Excessive end clearance not

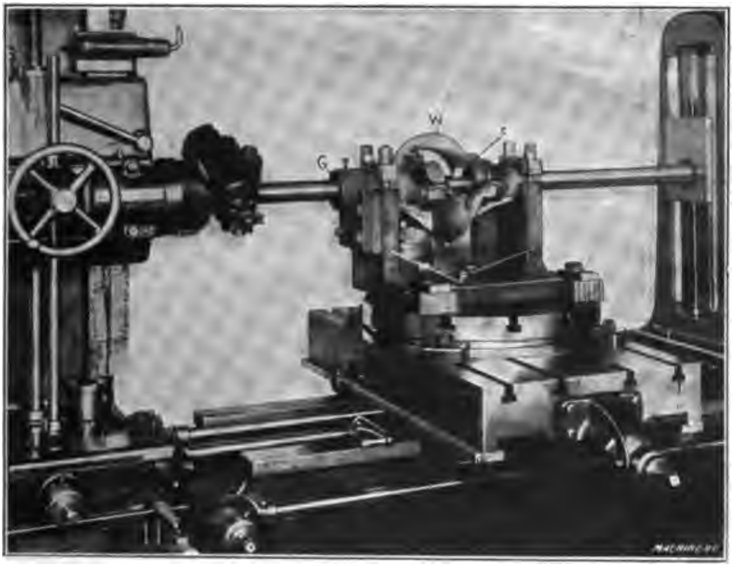

Fig. 32. Boring Differential Gear Casing

only weakens the cutting edge, but tends to cause chattering. As a finishing tool cuts on the upper end instead of on the side, the front should slope backward as shown in the side view, rather than side-wise as with a roughing cutter. The angle of the slope should be somewhat greater for steel than cast iron, unless the steel is quite hard.

Miscellaneous Examples of Boring, Facing and Milling

The method of holding work on a horizontal boring machine depends on its shape. A cylinder or other casting having a flat base can be clamped directly to the platen, but pieces of irregular shape are usually held in special fixtures. Fig. 30 shows how the cylinder casting of a gasoline engine is set up for the boring operation. The work *W* is placed in a fixture *F* which is clamped to the machine table. One end of the casting rests on the adjustable screws *S* and it is clamped by setscrews located in the top and sides of the fixture. There are two cylinders cast integral and these are bored by a short stiff bar mounted in the end of the spindle and having cutters at the outer end. A long bar of the type which passes through the work and is supported by the out-board bearing *B* could not be used for this work, as the top of each cylinder is closed.

When one cylinder is finished the other is set in line with the spindle by adjusting the work-table laterally. This adjustment is effected by screw *C*, and the required center-to-center distance between the two cylinders is obtained by the micrometer dial *M* on the cross-feed screw. After the first cylinder is bored, the dial is set to the zero position by loosening the small knurled screw shown, and turning the dial around.

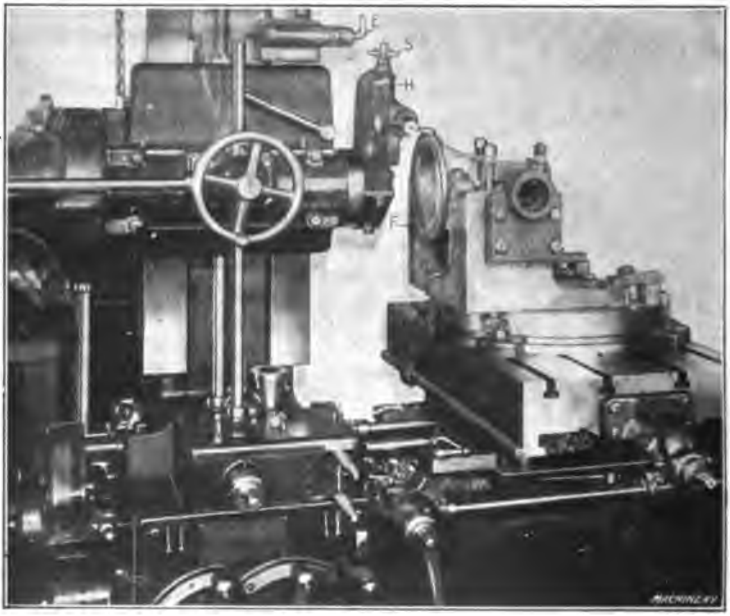

Fig. 33. Facing and Turning Flange of Differential Gear Casing

The feed screw is then rotated until the dial shows that the required lateral adjustment is made, which locates the casting for boring the second cylinder. The end of the casting is also faced true by a milling cutter. Ordinarily, milling cutters are bolted directly to the spindle sleeve *A* on this particular machine, which gives a rigid support for the cutter and a powerful drive.

The next operation is that of boring and milling the opposite end of the cylinder. This end is turned toward the spindle (as shown in Fig. 31) without unclamping the work or fixture, by simply turning the circular table *T* half way around. This table is an attachment which is clamped to the main table for holding work that must be turned to different positions for machining the various parts. Its position is easily changed, and as the work remains fixed with relation to the table, the alignment between different holes or surfaces is assured, if the table is turned the right amount. In this case, the casting needs to be rotated one-half a revolution or 180 degrees, and this is done by means of angular graduations on the base of the table. The illustration shows the casting set for boring the inlet and exhaust valve chambers. The different cutters required for boring are mounted on one bar as shown, and the work is adjusted cross-wise to bring each valve chamber in position, by using the micrometer dial. The single-ended cutter *c* forms a shallow circular recess or seat in the raised pad which surrounds the opening. The cover joint directly back of the cylinders is finished by milling.

Another example of boring, in which the circular table is used, is shown in Fig. 32. The work *W* is a casing for the differential gears of

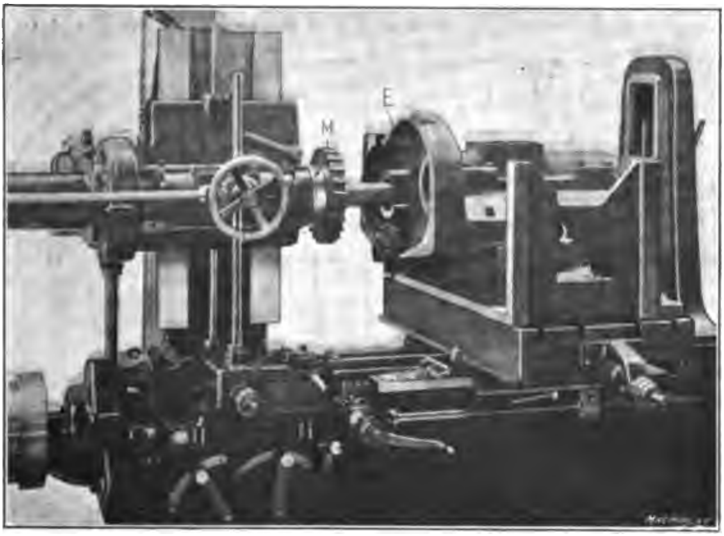

Fig. 34. Example of Work requiring Boring and Milling

an automobile. It is mounted in fixture *F* which is bolted to the table. The casting has round ends, which are clamped in V-blocks, thus aligning the work. This fixture has a guide-bushing *G* which is centered with the bar and cutter in order to properly locate the casting. There is a bearing at each end of the casing, and two larger ones in the center. These are bored by flat cutters similar to the style illustrated at *A* in Fig. 23. The cutter for the inner bearings is shown at *c*. After the bearings are bored, the circular table is turned 90 degrees and the work is moved closer to the spindle (as shown in Fig. 33) for facing flange *F* at right angles to the bearings. Circular flanges of this kind are faced in a horizontal boring machine by a special facing- arm or head *H*. For this particular job this head is clamped directly to the spindle sleeve, but it can also be clamped to the spindle if necessary. The turning tool is held in a slotted tool-post, and it is fed radially for turning the side or face of the flange, by the well-known star feed at *S*. When this feed is in operation the bent finger *E* is turned downward so that it strikes one of the star wheel arms for each revolution; this turns the wheel slightly, and the movement is transmitted to the tool-block by a feed screw. The illustration shows the tool set for turning the outside or periphery of the flange. This is done by setting the tool to the proper radius and then feeding the work horizontally by shifting the work-table along the bed. By referring to Fig. 32 it will be seen that the facing head does not need to be removed for boring, as it is attached to the spindle driving quill and does not interfere with the longitudinal adjustment of the spindle. This facing head is also used frequently for truing the flanges of cylinders which are to be bored, and for similar work.

Fig. 34 shows another example of work which requires boring and milling. This casting is mounted on a fixture which is bolted to the

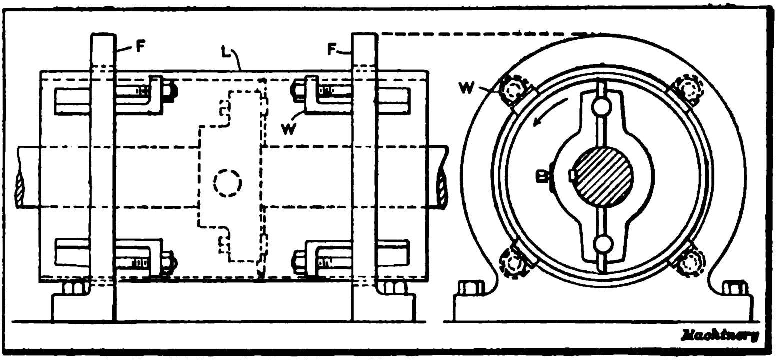

Fig. 35. Cylinder Lining Mounted in Fixture for Boring

main table. In this case the circular table is not necessary, because the work can be finished without swiveling it around. After the boring is completed the edge *E* is trued by the large-face milling cutter *M* bolted to the spindle sleeve. The irregular outline of the edge is followed by moving the table crosswise and the spindle vertically, as required.

A method of holding a lining or bushing while it is being bored is shown in Fig. 35. The lining *L* is mounted in two cast-iron fixtures *F*. These fixtures are circular in shape and have flat bases which are bolted to the table of the machine. On the inside of each fixture, there are four equally spaced wedges *W* which fit in grooves as shown in the end view. These wedges are drawn in against the work by bolts, and they prevent the lining from rotating when a cut is being taken. This form of fixture is especially adapted for holding thin bronze linings, such as are used in pump cylinders, because only a light pressure against the wedges is required, and thin work can be held without distorting it. If a very thin lining is being bored, it is well to loosen the wedges slightly before taking the finishing cut, so that the work can spring back to its normal shape.

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