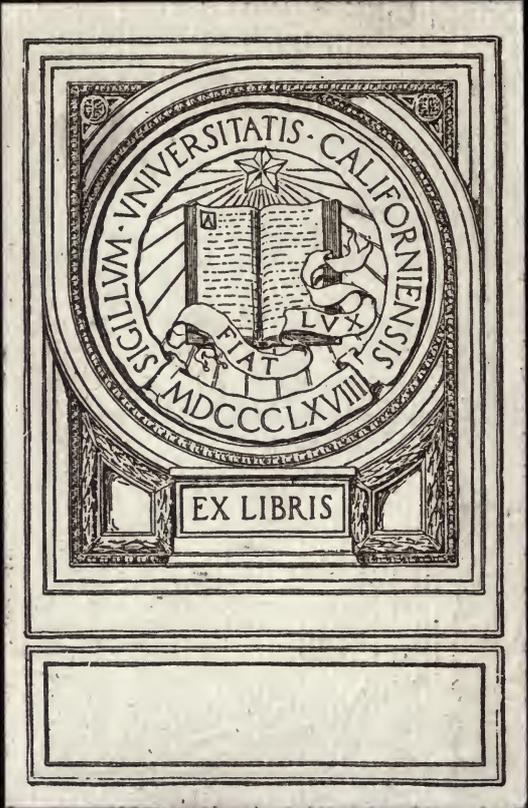


PRODUCTION
MILLING



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PRODUCTION MILLING

PRODUCTION MILLING

A TREATISE DEALING WITH THE METHODS
EMPLOYED IN PROGRESSIVE AMERICAN
MACHINE SHOPS FOR OBTAINING QUANTITY
PRODUCTION ON VARIOUS TYPES OF
MILLING MACHINES

BY

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PREFACE

RECENT years have witnessed the introduction of many improved methods of performing milling operations. On production work, where high rates of output are essential, this result has been accomplished in various ways, although mainly by a reduction of the nonproductive time of the men and machines in the milling department. In the preparation of this treatise, the author's object has been the same as that of a member of the planning department in a factory, who is called upon to devise methods of milling and to design fixtures that will enable repetition operations to be economically performed. Information and illustrations relating to the latest developments in production milling practice have been gathered by personal studies of the methods used in many of the most progressive manufacturing plants; and an acknowledgement is made to the large number of factory executives who have cooperated in carrying on this work. All of the methods discussed have been successfully used under actual shop conditions.

It has been assumed that all mechanics reading this book are familiar with the various types of production milling machines. For that reason, only brief descriptions of the essential features of each type of milling machine have been included. It is the purpose of this book to explain the application of some of the more efficient methods of operating milling machines on repetition work, rather than to discuss milling machine design. In connection with the examples of machining operations performed on the various types of milling machines, information is included covering the speed and feed at which each operation is performed and the rate of production that is obtained. In a great majority of these cases, the stated output is close to what would appear to be the maximum possible production

for the job; therefore, these data should prove of value to other manufacturers handling similar work, in checking up their results with a view to comparing them with those secured by others. No attempt has been made to deal with workholding fixture design, beyond explaining certain fundamental principles which must be observed to keep the ratio of "loading time" to "cutting time" down to a point where a satisfactory output can be secured.

THE AUTHORS.

New York, *January*, 1921.

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PRODUCTION MILLING

CHAPTER I

GENERAL TYPES OF MILLING MACHINES USED ON PRODUCTION WORK

MILLING machines are employed for performing a great variety of machining operations. Their range of application extends from the most delicate kinds of precision work done in the tool-room to the heavy-duty work of rapidly removing excess stock from heavy castings and forgings. It is obvious that there must be substantial differences in the designs of milling machines used for such a wide variety of work, as well as in the methods used for equipping and operating them for different classes of milling operations. As implied by the title, this treatise will deal with the subject of production milling and contains, therefore, an explanation of the latest practice in tooling and operating those types of machines that find successful application in the quantity production of duplicate parts. No space will be devoted to the discussion of tool-room work or to an explanation of the methods of performing milling operations where only one piece of work is set up on the machine at a time.

Factors that Increase Rates of Production. — Two of the most important factors to consider in the performance of any machining operation, including milling, where a high rate of output is essential, are first, to make sure that the work is done under conditions which closely approximate the maximum rates of speed and feed suitable for the particular case under consideration, and second, to plan the method of operation so that the idle time for both the machine and its operator is reduced to a minimum. There are various commonly

used methods of obtaining these results, but one of the most successful in the case of production milling is to employ a type of machine and a method of designing the work-holding fixtures which will enable a number of pieces of work to be set up so that they can all be milled by a single cut. The subsequent discussion will include detailed descriptions of the way in which this principle has been applied to specific milling operations; but as a general statement it may be said that the setting up of a number of pieces of work simultaneously will increase the rates of production by enabling the operator to unload finished pieces while the milling operation is being performed on other pieces of work. This not only reduces the idle time of the operator by keeping him constantly employed, but it also reduces the idle machine time, because the operator usually has had time to remove most of the milled work from the fixture when the last piece is completed.

General Types of Production Milling Machines. — Milling machines which find the most general application in American manufacturing plants may be roughly divided into three general classes as follows:

1. Automatic milling machines.
2. Continuous rotary milling machines.
3. Straight-line feed milling machines.

Each of these general classes may be further subdivided, so that milling machines may be classified under the following headings:

1. Automatic millers with straight-line feed movement.
2. Automatic millers with circular feed movement.
3. Automatic millers of the turret type.
4. Continuous rotary millers with the table rotating in a horizontal plane.
5. Continuous rotary millers with the table rotating in a vertical plane.
6. Standard millers with special rotary fixtures.
7. Planer-type millers.
8. Lincoln-type millers.
9. Knee-type millers with multiple fixtures.

Automatic Millers with Straight-line Feed Movement. — There are several different types of automatic milling machines equipped with tables that have a reciprocating straight-line feed movement. The term “automatic” is usually applied to this general type of milling machine although, strictly speaking, it should be known as “semi-automatic” because, while the feed movements are automatically controlled by tripping dogs and suitable auxiliary mechanisms, it is necessary for the operator to set up and remove the work by hand. On a strictly automatic machine, both functions are mechanically controlled. There are a number of possible combinations of feed and rapid traverse movements for straight-line automatic millers, and these will be described in detail in a subsequent chapter; but at this time it may be mentioned that these variations may include the employment of an intermittent feed and rapid traverse movement for rapidly advancing the work to the cutters and for performing the milling operations at a suitable rate of feed, after which the table is rapidly traversed back to the starting position. In some cases, such a complex movement may not be desirable and in its place the milling machine table simply feeds the work under the cutters until the operation is completed, after which the feed movement is automatically stopped and the table does not return to the starting position until the operator manipulates a hand-lever.

Automatic Millers with Circular Feed Movement. — There may be a number of different combinations for the arrangement of feed movements on this type of milling machine, just as there is a considerable difference in the arrangements of straight-line machines with automatic control of the feed movements. However, the usual method of operation is to have the work-holding fixtures distributed around the circumference of the table, and if it is possible to place adjacent pieces of work quite close together, there is no need of using the automatic feature, because a uniform rate of feed is constantly employed for passing the pieces of work under the cutters. In some cases, however, there is considerable space

between adjacent surfaces to be milled, and a serious loss of time would occur through using the slow rate of feed for traversing the table through the space that must be covered in order to bring each successive piece of work into contact with the cutters. In such cases, an automatic control is frequently employed for alternately engaging the rapid traverse movement and the feed movement, which results in quickly bringing the work up to the cutters and then feeding it under the cutters at the proper rate for the material that is being milled.

Automatic Millers of Turret Type. — It has been explained that the purpose of simultaneously setting up more than one piece of work is to enable both the operator and his machine to be kept constantly employed. In the case of the turret type of automatic milling machine, this result is accomplished in a different way. Two parallel work-tables with straight-line feed movements are mounted on an auxiliary turntable, and while the pieces mounted on one table are being milled, the operator is removing the finished pieces from fixtures on the other table and mounting fresh blanks in their places. Then, when the milling operation has been completed on pieces carried by the table that is in the working position, the auxiliary turntable or turret is indexed to bring the other table into the operating position. Thus the only idle time for the machine is the brief period that occurs while the table is being indexed.

Continuous Rotary Millers with Table Rotating in Horizontal Plane. — On any type of continuous rotary milling machine, the work is mounted in a continuous ring of fixtures extending around the circumference of a circular table which rotates to carry successive pieces of work under a single milling cutter or between a pair of cutters, according to the requirements of the operation to be performed. After a machine of this type has been set up and the tools adjusted to give the required dimensions for the work, it is merely necessary for the operator to stand at the front of the machine and devote his entire time to removing machined pieces and setting up

fresh blanks in their places as the table carries the fixtures around to the loading position. Little mechanical skill is required to operate a machine of this type; but as it is a matter of general knowledge that the "setting-up" time for a milling job may be greatly in excess of the actual "milling" time, great care must be taken to design the clamping mechanisms on the fixtures in such a way that the time required to remove finished pieces and set up fresh blanks is reduced as far as possible.

Continuous Rotary Millers with Table Rotating in Vertical Plane. — Advantageous features of operation, which have been explained in the preceding reference to continuous rotary milling machines with horizontal tables, are all secured in cases where a machine is equipped with a circular table arranged for rotation in a vertical plane. For handling some classes of work, designers feel that it is more satisfactory to have the table mounted in a vertical position. Certainly one advantage is secured which may be of considerable importance in some cases, namely, that the chips of metal removed by the milling cutters fall off by gravity and may be collected in a container conveniently located for the laborer who comes around at specified intervals and shovels the chips into a truck to remove them from the machine shop.

Standard Millers with Special Rotary Fixtures. — For manufacturing plants which have a sufficient number of parts to be milled so that one or more machines can be constantly used on a single job, it will usually be found desirable to employ standard rotary milling machines for such operations, rather than to use knee-type millers equipped with special fixtures for applying the continuous rotary principle of milling. There are many shops, however, that are frequently called upon to handle a job comprising a sufficiently large number of duplicate parts so that it is a profitable investment to have a rotary fixture to turn out such work whenever an order is received. Special rotary fixtures may be used in this way in jobbing shops specializing in contract work, and the same is true of many manufacturing plants of moderate

size, which make a variety of products with only a moderate output in each class of work. In such factories, advantage may be taken of the increased production obtained with continuous rotary machines through the application of these special fixtures; and when there is no work for the continuous rotary machine to do, the fixture may be removed in order that the machine may be used as a standard knee-type miller.

Planer-type Millers. — The term “planer type” has come to be quite generally employed for designating large-sized milling machines on which it is usual to set up a string of parts to be milled, arranged in a straight line along the table. Recently, machines of this type have also come to be quite generally known as “multiple-spindle” milling machines because they are generally equipped with both horizontal and vertical spindles to provide for simultaneously milling two or more surfaces on a piece of work. Some builders of this type of miller make a practice of designing and building each machine to meet the special requirements of the job on which it is to be used. This is done because machines of this type generally represent a substantial investment and it is considered more economical to develop a special lay-out that will make the machine ideally adapted for the work on which it is to be continually employed, than to include expensive mechanisms which would afford a wide range of speed and feed changes and other adjustments to provide for handling work of various kinds. Of course, this applies only to cases where machines are especially designed and built for manufacturers who have a sufficient volume of work to keep each miller constantly employed on a specified job. When milling machines are so built, the customer generally sends a blue-print of the piece to be milled and information concerning the material of which it is made, the depth of cut to be taken, the degree of accuracy that is required in the finished work, and the number of pieces that must be milled per hour to obtain the necessary daily output. With these data at his disposal, the machine designer proceeds to lay out an equip-

ment in which the milling machine builder's standard features of construction are employed with suitable modifications to produce the most economical machine that will give the desired results. Planer-type milling machines are employed for medium or large-sized work, and it is quite a general practice to have a string of fixtures set up in a row along the table which is usually of considerable size.

Lincoln-type Millers. — In handling small and medium-sized work, the Lincoln type of milling machine is generally employed for the same classes of milling operations for which a planer-type machine would be used if the work were of larger size. These machines are often equipped with a string of fixtures mounted in a row, so that advantage may be taken of the reduction of idle time and the corresponding increase in production that results from setting up a number of pieces simultaneously. Also, as the rate of feed, depth of cut, and other conditions of operation in handling production work are usually severe, the Lincoln type of milling machine construction without the customary knee adjustment is said to possess a greater degree of rigidity.

Knee-type Millers with Multiple Fixtures. — In progressive manufacturing plants where advantage is taken of every possibility of increasing rates of production and reducing unit costs, various types of multiple work-holding fixtures are employed on knee-type milling machines. In every case, the purpose is to reduce the idle time to a minimum. One of the commoner methods of equipping such millers is to arrange a string of fixtures in a row along the table. Successful results are also secured by the so-called twin-fixture principle, where two fixtures of similar design are mounted at opposite ends of the table so that, after the milling operation has been performed on a piece held in one fixture, the position of the table is reversed to bring the work held in the fixture at the opposite end of the table into contact with the cutters; then, while the milling operation is being performed on this second piece, the operator removes the milled piece from the first fixture and sets up a fresh blank in its place. Another successful method

of equipping knee-type millers is to use turret fixtures which are mounted on a pivotal support with means of indexing and locking the fixture in either of two positions, so that work held at one side of the fixture may be milled while the operator is removing the finished part from the opposite side and setting up a fresh blank in its place. It is often possible to use twin indexing fixtures of this type with unusually successful results.

CHAPTER II

PRODUCTION MILLING ON AUTOMATIC MACHINES

INDUSTRIAL plants engaged in the manufacture of products on which there are large numbers of small or medium-sized parts to be milled, find that these repetition milling operations can be advantageously performed on automatic milling machines. There are several millers of this general type built for the market, all of which are furnished with automatic control for the feed movement, in order to make it unnecessary for the operator to give his time to this part of the work. As a result, it is possible for one man to look after two or more machines, thus effecting a substantial reduction in the labor cost which must be charged against a job; this cutting down of the cost of labor, however, is not the only reduction of manufacturing costs which is made possible by the use of automatic milling machines under the most advantageous conditions of operation.

Automatic Control of Feed Movements. — Owing to the variety of arrangements of control which have been devised by the designers of different types of automatic millers, definite information as to the way in which savings in manufacturing costs are effected cannot be presented except in those sections of this chapter which deal with features of the different types of machines. At this time, however, a general statement can be made that the automatic control of the feed movement on milling machines of this type is the means of reducing idle time of the machine in traversing across the space from one piece of work to the next in cases where a number of parts are set up in a string fixture, in returning the table to the starting point at high speed after the cut has been completed, and through the application of similar time-saving methods of operation. The term “automatic millers” is generally applied

to machines of this type, but they would be more properly designated as "semi-automatic millers," because, although the feed movements of the table are mechanically controlled, the operator is required to set up the work and remove the milled parts. A machine cannot be properly described as "automatic" unless both of these functions are performed by mechanism, as in the case of automatic screw machines.

Cincinnati Automatic Plain Milling Machine. — It is proposed first to present a brief description of the essential features of each type of machine, and then to illustrate and describe some examples of practice in the performance of milling operations. The Cincinnati Milling Machine Co. builds an automatic plain miller in three different sizes, which have a table traverse of 12, 18, and 24 inches, respectively. Machines of each of these sizes are made in single and duplex styles, according to the requirements of the work on which the machine is to be used. Aside from differences in size, whether the machine is equipped with one or two spindles, the features of all of these machines are the same.

In consideration of the fact that these tools are to be used on production work, the design has been made as simple and rigid as possible. All unnecessary slides have been eliminated, and there is no saddle, the table resting directly upon the bed. A stream lubrication system forms a part of the regular equipment of each machine, in order that the cutters and work may be thoroughly cooled when the machine is taking the heaviest cut of which it is capable. On a machine that is to be used continuously on the same job, provision for obtaining any of a number of different speeds is not a matter of importance; it is merely necessary to provide for driving the spindle at that speed which is suitable for the work on which the machine is engaged. Hence, these millers are designed in such a way that the purchaser may specify any one of twenty-four spindle speeds, covering a range of from 31 to 603 revolutions per minute. It is important to note, however, that the gears which furnish this one speed may be reversed to provide an additional speed; and should it happen that at some later

date the machine is to be used on another job requiring a different speed, it will be an easy matter to order suitable gears to adapt the miller for this new job.

Arrangement of the Automatic Feed Mechanism. — These milling machines are so arranged that at the end of the feed movement of the table a dog will automatically disengage the spindle clutch and apply a brake to stop the spindle at the time that the direction of table travel is automatically reversed, so that the table returns to its starting position with the cutter stationary. Two advantages are obtained from this condition of operation, namely, provision is made for the safety of the operator, and the quality of the finished work is improved. When the nature of the work does not require the use of this feature, the automatic spindle stop may be easily disengaged. The feed mechanism is so arranged that any of twelve rates of feed may be selected, according to the requirements of the work. As in the case of provision made for selecting a suitable spindle speed, the continuous operation of these machines on a single class of work makes it unnecessary to provide means for obtaining any of a number of feed changes. Attention is called to the fact, however, that the arrangement of feed gears is similar to those that provide for driving the spindle; namely, that where any one rate of feed is specified, reversing the feed gears enables an additional rate of feed to be obtained. The twelve feeds from which a selection can be made cover a range from 1.09 to 18.3 inches per minute.

Combinations of Table Feed and Rapid Traverse Movements. — There are a number of different combinations of intermittent table feed and rapid traverse movements which may be used on a machine of this type. The machine table is provided with two dog slots, one controlling the rapid traverse and one, the feed traverse; thus by setting dogs in these two slots, it is possible to shift from the feed used while cutting to the rapid traverse as often as may be desirable, and also to reverse by rapid traverse. The fast power traverse is at the rate of 100 inches per minute, and is used for returning the table to its starting position after completing the forward

movement; the fast traverse is also utilized in cases where a string of parts is set up on the table and it is required to move the table rapidly across the spaces between adjacent parts which are to be milled. The use of a fast power traverse for moving rapidly across the gaps between successive pieces of work and for quickly returning the table to the starting point is the means of effecting a substantial reduction in the non-productive time of the machine.

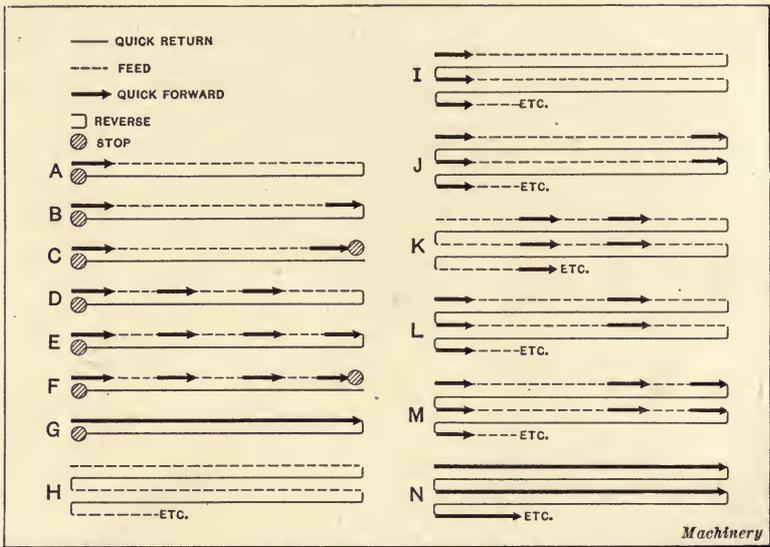


Fig. 1. Diagram showing Typical Cycles of Table Movements obtainable with the Intermittent Feed Mechanism on Cincinnati Automatic Milling Machines

Cycles of Feed Movements that are Frequently Used.—

Figure 1 shows in diagrammatic form several of the most useful cycles of feed and rapid traverse movements which are made available by providing suitably placed dogs on the table of one of these millers. The following are the three methods under which the machine is frequently operated: The first of these automatically controlled cycles of table movements is shown at A. It consists of moving the table forward at 100 inches per minute to bring the work to the cutters, and then feeding the work across the cutters at the rate of feed pro-

vided on the machine, after which the spindle is stopped, the table movement reversed, and the fast traverse movement engaged to return the table to the starting point at 100 inches per minute with the spindle stationary. The second commonly used cycle of table movements is indicated at C. It consists of traversing the table forward at 100 inches per minute, feeding across the work, again traversing the table forward at 100 inches per minute until the work clears the cutters, and finally stopping both the feed movement and

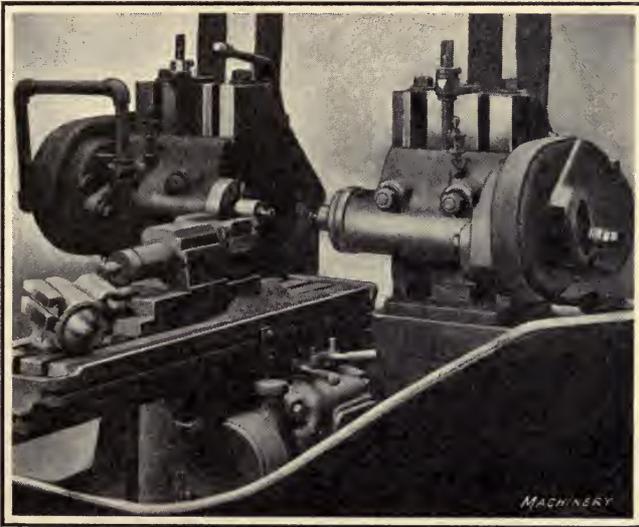


Fig. 2. Milling Two T-slots in the Work-head Spindle Carrier for a No. 1½ Grinding Machine

rotation of the spindle. When the work is removed, the table is traversed back to the starting point by shifting a lever on the feed-box by hand.

In operating under the conditions indicated at A and C, stopping of the spindle is automatically accomplished by tripping the feed mechanism and applying a brake to the spindle. After the work has been set up, manipulation of the main starting lever provides for engaging both the table movement and spindle drive. Owing to the interlocking mechanism, it is impossible to engage the feed without start-

ing the spindle. The third commonly used method of operating the machine is indicated at *E*, this system being used when it is desired to set up a string of pieces on the table. Dogs are provided to give the fast table movement by which the spaces between adjacent pieces of work are traversed at a rate of 100 inches per minute; and other dogs provide for reducing the rate of table movement to the slow feed that is employed while the machine is under cut. By using the proper number of dogs, this sequence of movement can be repeated as often as may be desired. After the last piece has been milled, the spindle is stopped, the table movement reversed, and the table traversed back to the starting point at 100 inches per minute.

Milling T-slots in Work-head Spindle Carrier for a Grinding Machine. — Figure 2 shows one of the 18-inch automatic duplex millers equipped for simultaneously milling two T-slots at opposite sides of a work-head spindle carrier for a No. 1½ grinder. The material is cast iron, and the operation is divided into two steps. The preliminary operation consists of milling a straight slot $\frac{1}{2}$ inch wide by $\frac{3}{4}$ inch deep by $3\frac{5}{8}$ inches long, this cut being taken by two high-speed steel end-mills which are set up in the opposed spindles of the machine, and driven at a speed of 91 feet per minute, with a feed of 4.6 inches per minute. The second step is to mill the T-slot part, which is $\frac{1}{2}$ inch deep by $\frac{3}{8}$ inch wide. High-speed steel T-slotting cutters of the usual form take this cut at a speed of 157 feet per minute, with a feed of 4.6 inches per minute. The total time consumed by both of these operations, including two chuckings of the work, is 3.3 minutes, which is the time per piece from floor to floor. The cycle of feed movements used for both of these operations is as follows: Traverse table forward at 100 inches per minute, feed work across cutters at 4.6 inches per minute, trip feed movement, stop spindle, reverse direction of table movement, and traverse it back to the starting point at 100 inches per minute.

Facing Bearings of Connecting-rods. — A duplex automatic miller is shown in Fig. 3, set up for simultaneously facing the

bearings at the large and small ends of connecting-rod forgings at the plant of the Continental Motors Corporation. It will be apparent that four inserted-tooth cutters are used for this job, which are so spaced that one pair of cutters faces both sides of the large end of the forging, while the other two cutters perform the same operation at the small end of the work. The two forgings are held in an indexing fixture so that after one end of each of these forgings has been milled, the fixture may be indexed to bring the opposite ends of the two pieces

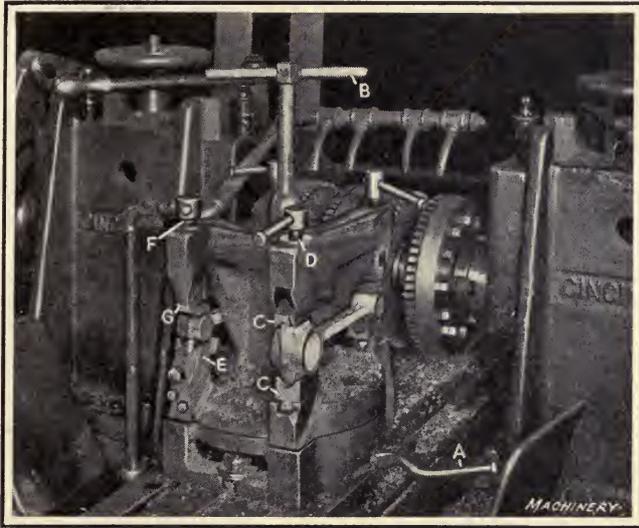


Fig. 3. Simultaneously straddle-milling Crankpin and Wrist-pin Bearings on Connecting-rods

of work into the operating position. Lever *A* is depressed to withdraw a tapered pin that locks the fixture in each of its two operating positions; and after the work has been indexed, a T-head wrench *B* is turned to tighten a clamping bolt that locks the fixture in place ready for taking the next cut. The large end of each of the forgings is located in this fixture by means of two V-blocks *C*, the upper one of each of these pairs of blocks being carried at the lower end of a bolt *D*. These V-blocks have the grooves running parallel to the direction of table travel in order that they may receive the bearing cap

bolt bosses on the forgings. At the small end of each piece of work there is a V-block *E*, in which the groove is placed at right angles to the direction of the table travel, and a bolt *F* clamps block *G* down on the work, in order to secure it in V-block *E*. These V-blocks *E* serve the additional purpose of supporting the end thrust of the cutters. It will be evident that at the top of both bolts *D* and *F* there are sliding pins by which these bolts may be turned in order to clamp the work

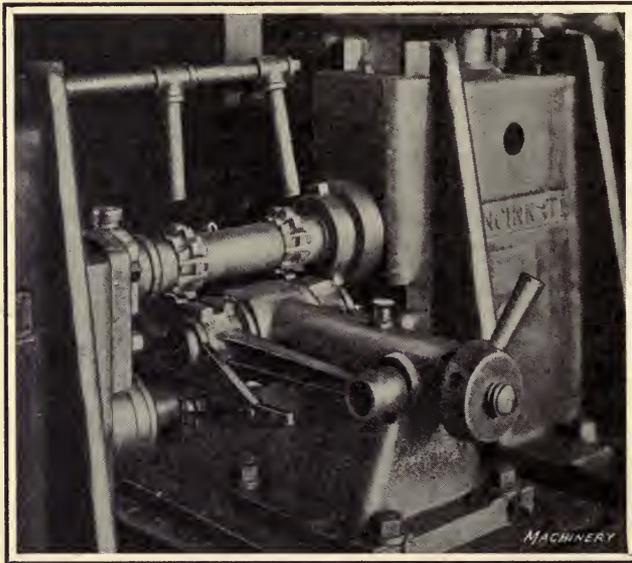


Fig. 4. Simultaneously milling Clearance Spaces between Bolt Bosses at Both Sides of Connecting-rods

in the fixture. The clamping mechanism is, of course, identically the same at the rear ends of the two pieces of work, which are in the milling position as they are shown in Fig. 3.

Setting up Connecting-rod Forgings. — In setting up connecting-rod forgings in this fixture, the method of procedure is as follows: The operator places a forging in each side of the fixture, and then tightens the clamps on the forging at the left-hand side of the fixture as shown in Fig. 3. After this has been done, the feed is engaged and the operator then proceeds

to tighten the clamps on the forging at the right-hand side of the fixture. The reason for following this procedure is that the length of cut on the crankpin bearing is substantially greater than that required on the wrist-pin bearing, so that sufficient time is allowed after the cut has been started at the large end of the work, held at the right-hand side of the fixture, to enable the operator to tighten the clamps on the second forging before the cutters come into engagement with the small end of this forging which is held at the left-hand side of the fixture. Such a method is the means of substantially reducing the idle time of the machine, and enables a higher rate of production to be obtained. On this job, the work is fed to the cutters at the rate of 2.4 inches per minute, and the cutting speed is 204 feet per minute. The rate of production obtained is forty finished connecting-rods per hour. The cycle for the automatically controlled feed movement of the table is as follows: Traverse work to cutters at 100 inches per minute, feed work across cutters at 2.4 inches per minute, trip feed, stop rotation of spindle, reverse movement of table, and finally traverse the table back to the starting point at 100 inches per minute.

Milling Clearance Spaces between Bolt Bosses of Connecting-rods. — Figure 3 shows an automatic duplex miller set up with the two opposed spindles at the same level, so that two pairs of cutters can be used to straddle-mill the ends of two forgings that are also held at the same level. It will be apparent from the illustration of the machine, however, that adjustment is provided for the two spindle heads, so that they may be placed either at the same level or with one spindle at a greater elevation than the other. This independent adjustment of the two spindle heads can often be successfully utilized to provide a more economical method of milling than would otherwise be possible. A case in point is shown in Fig. 4, which illustrates a good example of the way in which a Cincinnati automatic duplex milling machine may be arranged with the spindle heads at different levels, in order to provide for simultaneously milling the top and bottom sides

of a piece of work. The job shown in this illustration consists of milling clearance spaces between bolt bosses on connecting-rods for motor car engines. The machine is shown in use at the plant of the Studebaker Corporation.

Two cutters are mounted on each arbor, one close to the spindle and the other near the opposite end of the arbor. The latter cutter has considerable overhang. For that reason, it was considered necessary to provide an outboard support

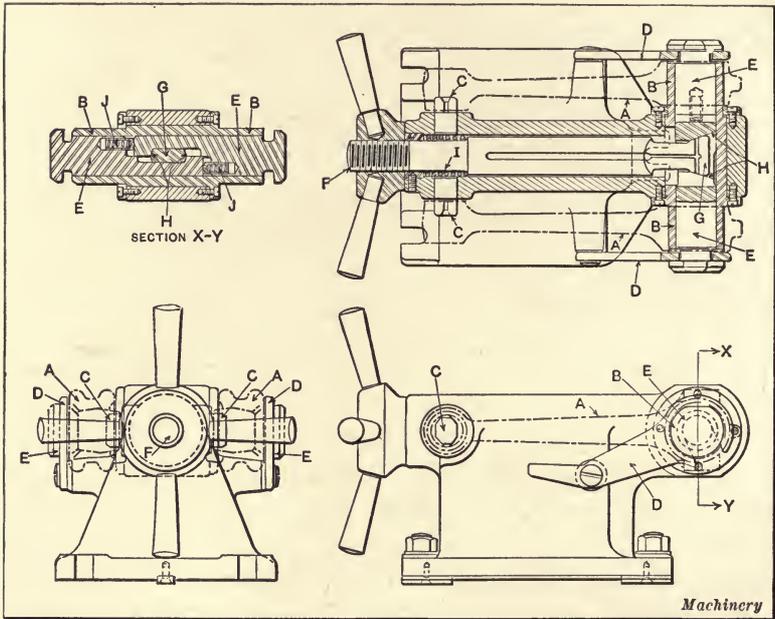


Fig. 5. Design of Work-holding Fixture shown in Operation on the Machine illustrated in Fig. 4

for each of the arbors on this machine. It will be seen that the work-holding fixture is so designed that provision is made for supporting two of the forgings to be milled, but in this case both forgings have to be set up and milled at the same time, after which the table is returned to the starting point. It is then necessary to keep the machine idle during the time required to unload the fixture and set up two new forgings ready for the next operation. On this job, the sequence of

rapid traverse, feed, and quick return movements of the table is the same as described for the previous milling operation. The rate of production obtained is sixty forgings per hour, which represents the time from floor to floor.

Design of Fixture Used in Milling Operation. — The fixture used on this machine represents quite an interesting example of tool design; Fig. 5 shows the construction in detail. It will be seen that the two connecting-rod forgings *A* are located by means of arbors *B* which enter the finished crankpin bearings, while at the opposite end short arbors *C* enter the wristpin bearings to prevent the work from turning on arbors *B*. Two slotted latches *D* are dropped over the heads of the clamping members *E* that slide inside the hollow mandrels *B*; and it will be apparent that while the heads of clamps *E* are made of such a size that the crankpin bearings will pass over them, the latches are large enough to hold the work on the arbors, after they have been dropped into place. The final step in clamping the work is accomplished by turning a capstan wheel which fits on the threaded end of draw-bolt *F*. At its opposite end, this draw-bolt has a tapered head *G*, which engages corresponding tapers *H* at the ends of clamping members *E*.

The manner in which these clamping members are cut away so that they overlap each other is best shown in the cross-sectional view on the line *X-Y*. It will be evident that when draw-bolt *F* is pulled back by turning the capstan wheel, it causes the tapered head *G* at the opposite end of this bolt to engage the tapers *H* and pull the two clamping members *E* inward, thus drawing their heads firmly against the latches *D* that secure the connecting-rod forgings in place on arbors *B*. After the milling operation has been completed, and it is desired to unload the fixture, the capstan wheel is loosened and compression spring *I* pushes back draw-bolt *F*, so that its hold on the clamps *E* is released. Two compression springs *J* are then able to push clamps *E* outward, so that the latches *D* are released and may be swung upward to allow the forgings to be lifted out of the fixture. The detailed description neces-

sary to explain the features of design of this fixture may make the method of loading and unloading the fixture appear rather complicated. As a matter of fact, this is not the case, as the forgings can be set up or removed by simply giving a turn to the capstan wheel at the end of the draw-bolt *F*, and then lifting up the two latches *D*, if the fixture is to be unloaded; or dropping these two latches *D* into place, and then turning

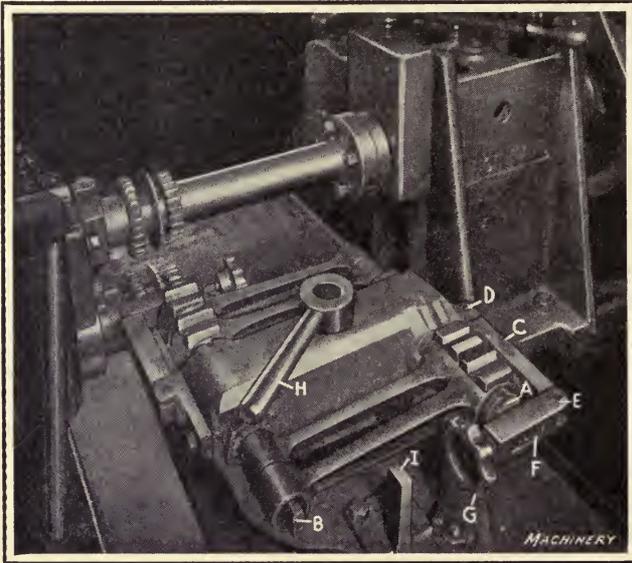


Fig. 6. Simultaneously straddle-milling Bolt Bosses at Both Sides of Connecting-rods and cutting off Crankpin Bearing Caps

the capstan in the opposite direction, to clamp the two forgings in place ready to be milled.

Straddle-milling Bolt Bosses and Cutting off Bearing Caps of Connecting-rods. — Figure 6 illustrates the work of simultaneously straddle-milling the bolt bosses at both sides of two connecting-rod forgings, and sawing off the crankpin bearing caps in the same operation. To provide for milling both sides of the forgings at the same time, it will be seen that the spindle head at the right-hand side of the machine has been sufficiently raised above the left-hand head, so that two

pairs of cutters may be used to simultaneously straddle-mill the ends of the bolt bosses at opposite sides of the forgings. Located on the arbor between each pair of straddle-milling cutters, there is a small slitting saw which provides for cutting off the bearing caps at the same time the milling operation is performed. It will be noticed that the cutters which work at the top of the forgings are located on their arbor at a considerable distance from the spindle; and to avoid springing this arbor, an outboard support has been provided for it on the cutter-head at the left-hand side of the machine.

Application of Time-saving Fixtures on Automatic Machines.

— The milling operation shown in Fig. 6 represents an advantageous combination of equipment for obtaining rapid production, because not only is the machine provided with automatic control for the feed and rapid traverse movements of the table, but an indexing type of fixture has also been provided, which enables the operator to remove the milled forgings and substitute fresh blanks in their place, while the cut is being taken on two forgings held at the opposite side of the same fixture. This might be termed an indexing type of string fixture, because at each station two forgings are set up in line, so that a cut may be taken on both of them before it is necessary to return the table and index the fixture ready for the next cut.

It will be evident that the two forgings carried at each side of this fixture are located by means of mandrels *A* and *B*, which are a close fit in the crankpin and wrist-pin bearings, respectively. In designing this fixture, provision had to be made for supporting the two forgings at their large ends in such a way that the crankpin bearing caps would be prevented from falling off mandrel *A* and getting damaged by the saws and cutters after the slitting saws have cut them off from the forgings. This result is accomplished by the clamping bar *C* which is supported by a pivot *D*, so that it may be swung into place against the ends of the forgings. This bar *C* is secured by a pivoted link *E* which is slotted to fit over a small projection *F* on the end of the mandrel *A*.

When it has been located in this position, clamping is accomplished by turning a small handwheel *G*, which manipulates a screw that is threaded into the end of link *E*, so that it may bind against the side of the projection *F* that passes through the opening in this link. In indexing the fixture, it is merely necessary to loosen the main binding screw *H* and release latch *I*; then after the fixture has been turned through 180 degrees, the latch enters a notch in the opposite side, after which binder *H* is tightened, and the fixture is in position for milling the next two forgings.

Sequence of Automatic Feed and Rapid Traverse Movements. — The sequence of automatically controlled feed and rapid traverse table movements used on this job is quite simple. It is merely a case of rapidly advancing the table to bring the work up to the cutters, after which the quick movement is tripped and the feed automatically engaged. Then when the work has been fed across the cutters, a dog disengages the feed, reverses the direction of table movement, and stops the rotation of the spindles, after which the table is traversed back to the starting point at high speed. Then the fixture is indexed to bring the next two forgings into the operating position, and the same sequence of movements is repeated, this cycle of operations being continued indefinitely, with very little idle time on the part of either the machine or its operator. On this job, the rate of production obtained is seventy forgings per hour, which represents the time from floor to floor.

Facing Seat for Crankpin Bearing Cap on Connecting-rods. — The automatic miller shown in Fig. 7 is used for facing the crankpin bearing cap seat on motor car engine connecting-rods. This is another example of a case in which the two spindle heads of a duplex machine are placed at different levels. But in this instance it is not necessary to have such a marked difference in the elevation of the two spindles, as in the cases shown in Figs. 4 and 6, because it is only required to have the cutters carried by the two spindles reach the faces of two connecting-rod forgings that are held one above

the other on each station of the indexing fixture. The sequence of movements is as follows: Rapidly traverse the table to bring the work up to the cutters, feed the work across the cutters, automatically reverse the direction of table movement, stop the spindle, and rapidly traverse the table back to the starting point.

Features in Design of Fixture for Milling Bearing Caps.—There are several interesting features in the design of the

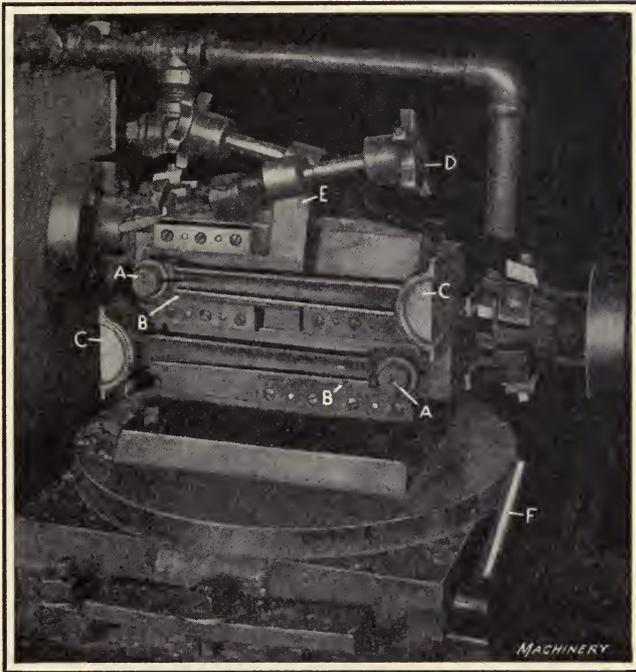


Fig. 7. Milling Seat for Crankpin Bearing Caps on Connecting-rods

fixture shown in this machine. In setting up two forgings on either of the stations, the finished wrist-pin bearings are slipped over pins *A*, each of which is carried on a slide *B*. At its crankpin end, each forging fits over a half-round block *C*, but at the time it is placed in the fixture the forging does not come firmly into contact with this block. After the two

pieces to be milled have been put into place in this fixture, capstan wheel *D* is turned, with the result that it rocks link *E* about the pivotal support on which this link is carried. Link *E* is also pivoted to each of the slides *B*, and as it is moved by turning handwheel *D*, link *E* causes the two slides *B* and pins *A* carried by them, to move in opposite directions, thus clamping the crankpin ends of the two connecting-rods firmly against the half-round blocks *C*. The work projects sufficiently beyond these blocks *C* to allow the ends of the yoke to be milled.

In the position in which the milling operation is performed, the thrust of the cutters on the work is back against the body of the fixture, so that there is no tendency for the forgings to slide off their locating pins *A* and blocks *C*. Aside from the special means provided for holding the work, this indexing fixture does not call for a detailed description, because it is of a standard type which will be more fully dealt with in a later chapter discussing the design and use of indexing milling fixtures. But at this time it may be stated that to release this fixture ready for indexing, it is merely necessary to manipulate the lever *F*; and after the fixture has been indexed through 180 degrees, swinging this lever in the opposite direction clamps the fixture in place ready for the next cut to be taken. The rate of production on this job is one hundred connecting-rods per hour, which represents the time from floor to floor.

Facing the Base of Crankpin Bearing Caps for Connecting-rods. — The milling operation illustrated in Fig. 8 is similar to the one which has just been described. This job consists of milling the base of crankpin bearing caps that fit on the seats milled on the rods during the preceding operation. The fixture used is also provided with a clamping lever *A* that serves the double purpose of accurately locating the fixture in the desired position and then providing means for clamping it in place while the cut is being taken. It merely remains to describe the method of holding the bearing caps in place on the fixture while they are being milled. As in the preceding case, there are two half-round blocks *B* on each station of the

fixture, against which the two bearing caps are clamped. These caps *C* are clamped against blocks *B* by means of V-blocks *D* that engage the under sides of the bolt bosses on bearing caps *C*. The two V-blocks *D* are threaded right- and left-hand respectively, so that they may be forced in opposite directions by means of a right- and left-hand screw which is turned by means of a handle *E* that may be slipped into any

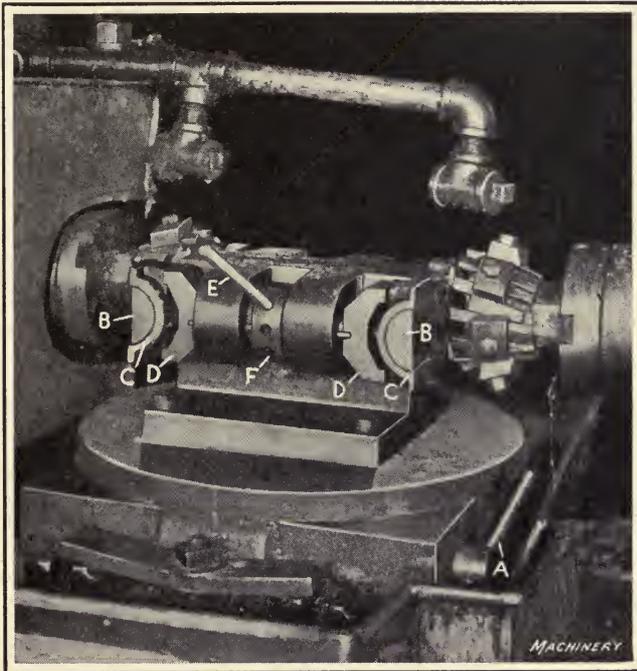


Fig. 8. Milling Base of Crankpin Bearing Caps for Connecting-
rods

of the holes in hub *F*. On this job the rate of production obtained is one hundred caps per hour. The same sequence of feed and traverse movements of the table is used as in the preceding operation on connecting-rods.

Milling Base of Differential Bearing Caps.—Figure 9 shows an 18-inch automatic miller set up for milling the base of differential bearing caps for motor cars. It will be evident

that the two spindle heads are placed at the same level, so that a cutter carried by each spindle may be utilized to mill off the faces of one of the bearing caps. An indexing milling fixture is used for holding these castings, which is so designed that two pieces are held in position to be milled; and while the operation is being performed on these two parts, two other

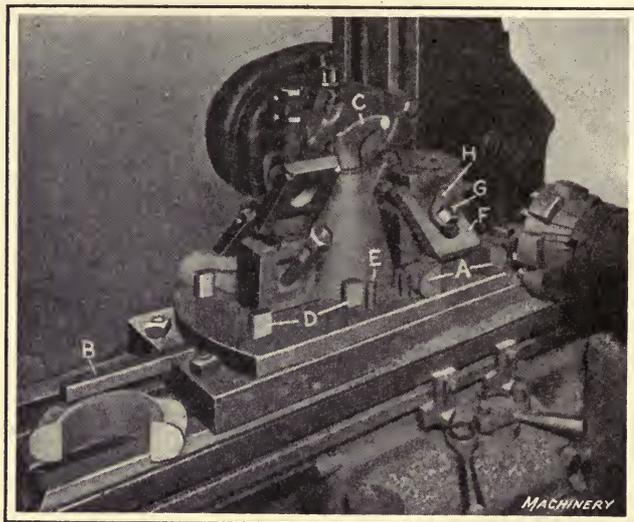


Fig. 9. Milling Base of Differential Bearing Caps. An Indexing Fixture holds the Work

finished pieces may be removed from the opposite station of the fixture and fresh castings set up in their places. This milling operation consists of facing off two surfaces *A* on each of the bearing caps, and as there is a space of about four inches between these two surfaces, dogs are arranged on the milling machine table to provide for first traversing the table at a rate of 100 inches per minute, to bring the work up to the cutters. Then a dog trips the rapid traverse and engages the feed movement, to mill the first face *A*. After this has been done, the rapid traverse is again utilized to move the table across the space between the two surfaces *A*, after which the feed movement is once more engaged automatically for milling the second surface on the work. At this point, another dog

disengages the feed, stops the spindle, and reverses the direction of table movement, after which the table is returned to the starting point at high speed.

After two bearing caps held at one side of this indexing fixture have been milled, pin *B* is withdrawn and handle *C* is turned to release the binder that clamps the fixture in place during the time that the cut is being taken. The fixture is then indexed through 180 degrees, and after pin *B* has again located it in the desired position, handle *C* is turned in the opposite direction to reclamp the fixture. At each station, it will be noticed that there are two half-round blocks *D* which engage the under side of the lugs at each side of the differential bearing-cap castings, in order to locate them in position for milling. At each station there is also a pin *E*, against which the end of the casting is placed in order that this pin may support the thrust exerted by the milling cutters. The casting is held down in the fixture by a pivoted clamp *F*, and when it is desired to remove the milled casting, this clamp is released by first loosening bolt *G* about a half turn, and then swinging slotted latch *H* about the pivot which holds it on strap *F*. There is a hole in strap *F* of sufficient size to pass the nut on bolt *G*. This arrangement allows the clamp to be released by simply making a half turn of the nut, and is the means of saving a great deal of time in loading and unloading the fixture. On this job, the rate of production obtained is one hundred finished bearing caps per hour.

Milling Grooves in Typewriter Key Lever Brackets. — Previous descriptions of automatic millers have shown the application of machines provided with two spindles. Figure 10 shows an example of production milling on a single-spindle automatic miller. It is used at the plant of the Royal Typewriter Co. for milling a groove in the key lever bracket for a typewriter. The work is cast iron, and ordinarily no special provision would have to be made for cooling the cutters and work. In this case, however, the cutters are engaged in milling a groove $\frac{1}{4}$ inch wide by $\frac{3}{8}$ inch deep, and, as they are in contact with both the bottom and sides of this groove during

the entire time that the cut is being taken, there is very little opportunity to dissipate the heat generated by the cut. As a result, it was considered necessary to provide means for cooling the cutters, and the use of a blast of cool air was finally adopted for this purpose. It will be seen that at each side of both of the cutters there is a hood *A* in which holes have been drilled on the inner side. These hoods are connected with a compressed air line, so that while the machine is in operation, a stream of cool air is constantly striking against the cut-

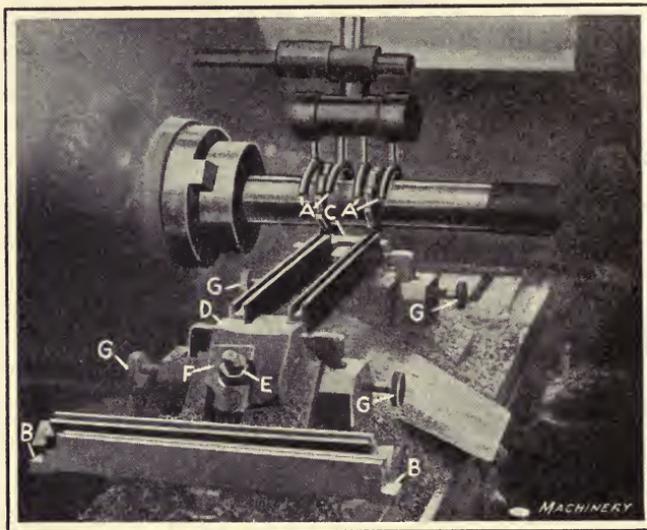


Fig. 10. Automatic Milling Machine with Air-cooled Cutters for performing Grooving Operation

ters. The application of this air blast to the cutters also serves the additional purpose of blowing away the chips, so that the cutting action is not retarded.

The dogs are set to traverse the table rapidly in order to bring the work up to the cutters, after which the feed is automatically engaged to pass the two castings under the milling cutters. After the cut has been completed, the spindle is stopped, the direction of table movement reversed, and the table is returned to the starting point at the high traverse

speed. It has already been stated that the grooves in these key lever brackets are $\frac{1}{4}$ inch wide by $\frac{3}{8}$ inch deep, and the length of the groove is 13 inches. The rate of feed employed is 8.3 inches per minute, and the cutters, which are $2\frac{3}{4}$ inches in diameter, are driven at a speed of 135 revolutions per minute, which corresponds to a cutting speed of $97\frac{1}{2}$ feet per minute. The rate of production obtained on this job is 450 milled key lever brackets in a nine-hour working day.

Design of Fixture for Milling Key Lever Brackets. — The fixture in which two key lever brackets are held for the groove milling operation is designed to facilitate the work of setting up these parts, as far as possible. The location is obtained from the milled under side of the work, and the pieces are held down in the fixture by means of a lug *B* at each end. At the rear of the fixture, there is a bar *C* under which one of the lugs *B* on the work is slipped. Then a pivoted strap *D* is clamped down on the lug at the front end of the work. This strap *D* is secured by the nut *E* on a bolt, this nut being small enough to pass through the hole in strap *D*. A pivoted C-washer *F* is swung into place under the clamping nut at the time that the work is being secured in the fixture. Sidewise location and clamping of the work is accomplished by means of four knurled-head screws *G*. These screws engage the sides of the work at each end, and press them inward against a center stop on the fixture.

Milling V-slots in Steel Rings. — Figure 11 shows another single-spindle automatic milling machine which is engaged in machining a row of pieces mounted in a string fixture. The operation performed on this machine consists of milling a V-slot across the top of a steel ring, and the string fixture is designed to hold six pieces of work. The material is low-carbon steel and it will be seen that the cut is taken by a special angular cutter with staggered teeth. The rings are $1\frac{7}{8}$ inches in diameter with walls $\frac{1}{4}$ inch thick; and the slots to be milled are $\frac{9}{32}$ inch deep by $\frac{1}{8}$ inch wide at the top and $\frac{1}{4}$ inch wide at the bottom. The cutter is made of high-speed steel; it is

$3\frac{1}{2}$ inches in diameter and runs at 103 revolutions per minute, which gives a cutting speed of $94\frac{1}{2}$ feet per minute. The rate of feed is 3.87 inches per minute, and the actual production time from floor to floor is 1.1 minutes for each piece; that is to say, the hourly rate of production is fifty-four and one half pieces. For performing this operation, the dogs which automatically control the feed and traverse movements of

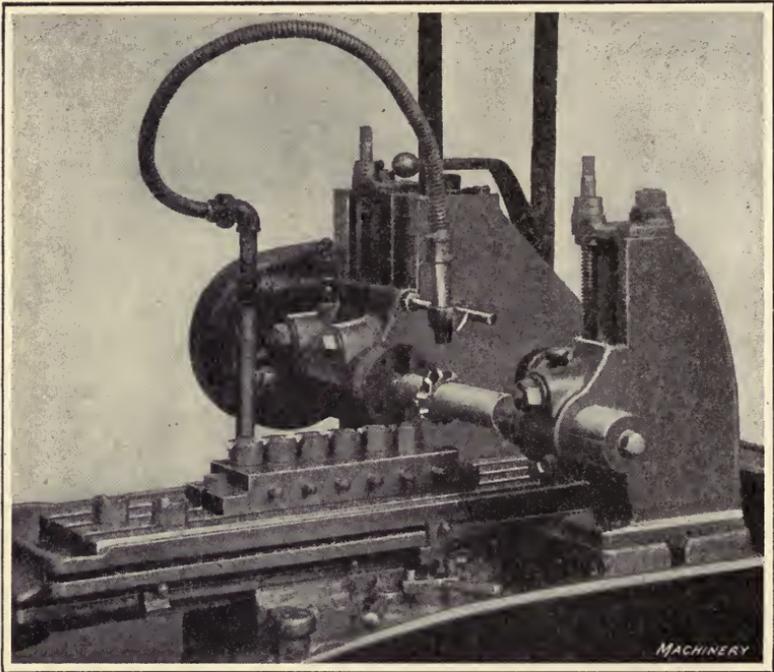


Fig. 11. Automatic Milling Machine equipped with String Fixture for milling V-slots

the table are so arranged that the cycle is as follows: Traverse the work to the cutter, feed the six pieces under the cutter, stop the spindle, reverse the direction of table movement, and rapidly traverse the table back to the starting point.

Cincinnati Plain Manufacturing Milling Machine. — There is a small machine of the column and knee type built for milling large numbers of small or medium sized duplicate parts. It is a simple manufacturing miller equipped with a single-

pulley drive, so that no countershaft is required; and it is made in two sizes, with 12 and 18 inches table travel, respectively. The drive is furnished by tight and loose pulleys 9 inches in diameter, and a 2-inch double belt direct from the main lineshaft. Twelve changes of speed are available, covering a range from 30 to 600 revolutions per minute. A simple and effective form of belt shifter is provided, which automatically operates a brake and brings the spindle to a quick stop at the time the belt is thrown on the loose pulley. By reversing and interchanging four gears, four changes of feed may be obtained; namely, 0.011, 0.015, 0.022, and 0.032 inch per spindle revolution. The feed is provided with a tripping mechanism which may be set to limit the movement by hand anywhere within the full 12 or 18 inches traverse of the table, automatically engage the power feed, and also automatically disengage this feed at the end of the cut. The range of movements provided on the 12-inch machine is 12 inches longitudinal by 6 inches transverse by $10\frac{1}{2}$ inches vertical; and the corresponding movements on the 18-inch machine are 18 inches longitudinal by 6 inches transverse by $10\frac{1}{2}$ inches vertical.

Method of Operation. — The feed movements of this miller are controlled by the operator's right hand from his position at the left-hand end of the table in front of the machine. The combination belt shifter and spindle brake lever is manipulated by the left hand and the work-holding fixture is immediately in front of the operator. He is never required to leave the working position. When a piece of work has been placed in the fixture, the operator moves the table forward at the rate of $2\frac{3}{4}$ inches per turn of the hand-wheel, until the table dog comes into contact with a trip, which automatically engages the power feed of the table. At the end of the cut, a second dog disengages the table feed and stops the table, which is then returned to the starting point, again bringing the fixture immediately in front of the operator. The same cycle of operations is repeated after the fixture has been unloaded and fresh work set up. This cycle of movements greatly simplifies the operator's work. The table may be

moved forward as rapidly as possible without the need of slowing down as the work approaches the cutters, because the table dog automatically engages the power feed at the proper time, without any need of observing special precautions. This effects a substantial saving in time and production cost. With the dogs properly set, the actual feeding distance is also

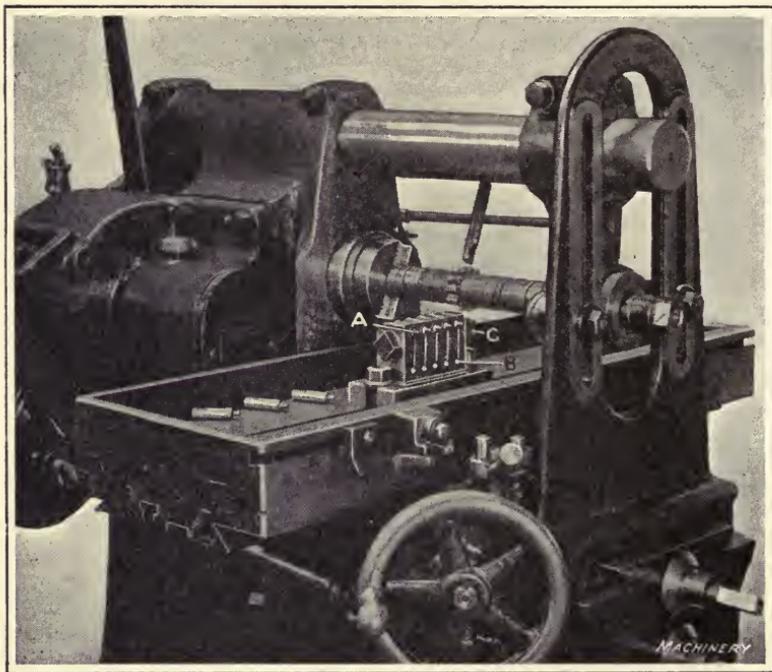


Fig. 12. Manufacturing Milling Machine equipped with String Fixture for milling Rack Teeth in Index-pins

reduced to slightly over the actual amount required to traverse the work past the cutters.

Milling Index-pin for Front Plate of Universal Dividing Head. — Figure 12 shows one of the 12-inch manufacturing millers employed for milling rack teeth in index-pins for the front plate of 10-inch universal dividing heads. There are five 24-pitch teeth to be milled, which have a face width of $\frac{3}{8}$ inch. The material is machine steel, and it will be seen that

the operation is performed by a special form of cutter which is $2\frac{1}{4}$ inches in diameter and runs at 88 revolutions per minute, which corresponds to a cutting speed of 52 feet per minute. The rate of feed is 0.022 inch per revolution of the cutter, which corresponds to a rate of 1.93 inches per minute. The actual production time on this job is 1.7 minutes per piece, which represents the time from floor to floor and corresponds to an hourly production of $35\frac{1}{5}$ pieces.

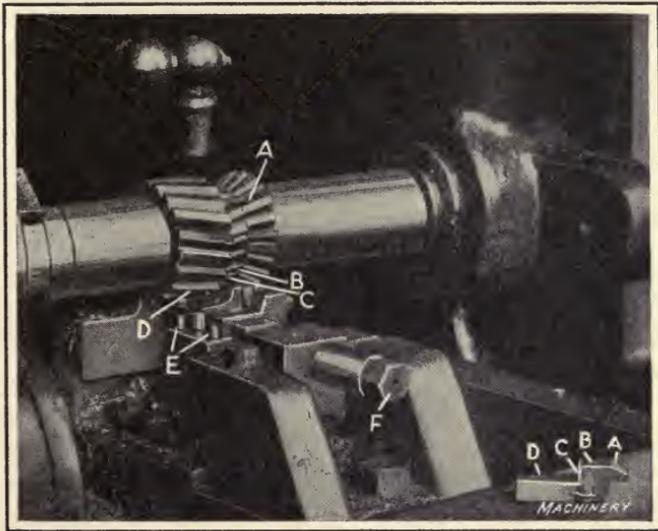


Fig. 13. Manufacturing Milling Machine equipped with Gang of Cutters for milling Four Top Faces of Typewriter Margin Stops

Design of Index-pin Milling Fixture. — It will be apparent from Fig. 12 that provision is made for setting up five pieces of work at a time on this machine, a string type of fixture being used for the purpose. This fixture is of rather unusual design. The entire fixture body is made from a single block of steel, in the upper part of which five holes are drilled to receive the work *A*. In the lower part of the fixture there are five smaller holes *B*, and slots are sawed down from the top, passing through the work-holding holes and projecting down as far as the holes *B*. At the time they are delivered to this machine to have the rack teeth cut, the pieces of work are

cylindrical in form, with the exception of the pointed end. Consequently, they can be slipped into place in the fixture, with the rear end projecting out to pass under the form cutter that mills the rack teeth. After the five pieces have been set up, nuts *C* are tightened on a bolt which projects through the body of the fixture. Tightening these nuts closes in the slots and thus affords a firm grip on the work.

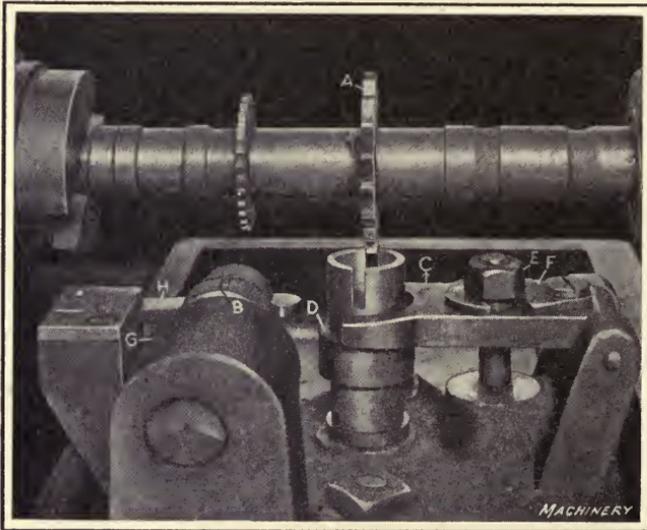


Fig. 14. Manufacturing Milling Machine equipped with Two Cutters and Duplex Fixture for First and Second Operations on Valve Tappet Guides

Milling Right- and Left-hand Margin Stops for Typewriters.

— Figure 13 shows the use of a 12-inch manufacturing miller to mill right- and left-hand margin stops for Royal typewriters. These parts are made from forgings, and one right- and one left-hand stop are set up together, ready to have the milling operation performed simultaneously. The operation consists of milling faces *A*, *B*, *C*, and *D* on the work, and for that purpose it will be seen that a gang of three cutters is provided on the arbor, two of which are plain cutters with spiral teeth, while the third is an angular cutter to provide for milling inclined face *A* on the work. In Fig. 13, the cutters are lettered

to correspond with the faces of the work which are finished by them. Following the usual practice in setting up a gang of cutters, it will be seen that the mills on the arbor of this machine are arranged with the spiral angles of the teeth opposed, in order that the thrust exerted by the angular teeth may be neutralized as far as possible. The forgings to be milled are held in a special form of vise, and endwise location is obtained from the previously milled ends of the forgings, which are placed in contact with the pins *E*. After this location has been accomplished, screw *F* is turned in order to tighten the sliding jaw of the vise against the work. The rate of production obtained on this job is 700 stops in a nine-hour working day.

Milling Valve Tappet Guides for Automobile Engines.—

At the plant of the Continental Motors Corporation, one of these manufacturing millers is equipped with a fixture which adapts it for two different milling operations on valve tappet guides for motor car engines. One of these consists of milling a slot $\frac{1}{4}$ inch in width by $\frac{3}{4}$ inch in depth across the end of the guide, this being the operation performed by the cutter shown at *A*, Fig. 14. The diameter of the work on which this slot is milled is $1\frac{7}{8}$ inches, and the thickness of the walls is $\frac{1}{8}$ inch. The second operation is to mill a pin-slot *B*, which is located at an angle of 90 degrees from the slot milled by cutter *A*. This pin-slot is $\frac{5}{32}$ inch in depth by $\frac{5}{8}$ inch long.

In performing these two operations on valve tappet guides, the slot is first milled across the end of the work, because it is utilized as the locating point for milling the pin-slot *B*. For taking the first cut, the work is dropped into place over a pilot on the fixture and is held down by a pivoted strap *C* which comes into engagement with a flange *D* on the work. Strap *C* is furnished with a hole of sufficient size to clear nut *E*, and after the strap has been dropped into place on the work, pivoted C-washer *F* is slid under nut *E*, preparatory to clamping the work in place.

For taking the second cut, one end of the work is slipped

into the horizontal cylindrical hole in block *G*, after which the work is located in the desired position for milling pin-slot *B* by means of a pivoted bar *H* that is of just the right width to fit into the first slot which was milled across the end of the work by cutter *A*. For each traverse of the milling machine table, one piece is completely machined. After each table traverse, the piece in which the end-slot was milled during the preceding operation is set up in the second station of the fixture, ready for milling pin-slot *B*, and a fresh casting is set up in the first station under cutter *A*. On this operation, the cutting speed employed is 149 feet per minute for the small cutter and 211 feet per minute for the large cutter. The table is fed by hand and the rate of production obtained is sixty completely milled valve tappet guides per hour.

Pratt & Whitney Automatic Milling Machines. — The automatic milling machines built by the Pratt & Whitney Co. have been evolved from the Lincoln type of milling machine, and are equipped with an intermittent table feed and fast traversing mechanism, and an automatic quick return for the table. These table movements are controlled by means of adjustable tripping dogs mounted on a plate which is conveniently located at the front of the machine. With this arrangement for controlling the table, provision is made for having the work approach the cutter at the fast traverse speed, and when the cutter is about to engage the work, the regular rate of feed is automatically thrown into operation. After the cut has been completed, the direction of table movement is automatically reversed and the table is rapidly traversed back to the starting position. While returning to the starting point, the table is automatically lowered in order to prevent the milling cutters from dragging over the work and marring its finished surface; and at the end of the return movement, the table is automatically raised to the cutting position. This receding movement of the table does not impair the rigidity of the supporting members or accuracy of the table movement.

Increased Production Due to Automatic Control. — By having the feed and traverse movements of the table automatically

controlled, the amount of nonproductive time of the machine is substantially reduced. The operator's work is also simplified, as he is merely required to remove milled pieces from the work-holding fixture and set up fresh blanks in their places. As a result, one man is able to look after several machines, the exact number being dependent upon the length of time required to complete a single operation. Automatic table control is of value in reducing production costs when milling work on which there are several lugs or bosses to be machined, which are spaced some distance apart, or where a number of small parts are set up at intervals along a string fixture. In such cases, the intermittent feed arrangement permits the table to be rapidly traversed from one cutting position to another, thus reducing the machining time. In its loading position, the table must also carry the fixture far enough away from the cutters to permit the work to be easily set up, and the power rapid traverse then permits the table to be advanced quickly to its cutting position. To obtain the highest rate of production on these machines, the feed movement of the table should be used only during the actual cutting period; at all other times, the fast traverse is employed.

The Pratt & Whitney automatic milling machines are made in four different sizes with a table traverse of 5, 8, 10, and 12 inches, respectively. Each size of machine is furnished with a range of spindle speeds and rates of feed that are suitable for the classes of work that will be done on a machine of this size. In many plants, a machine adjuster, who is a skilled mechanic, is made responsible for the setting up and sharpening of cutters used on anywhere from twenty to thirty machines, while the machine operator is a semi-skilled man who may be trained quickly to perform his part of the work. During the last few years, girls have been successfully employed as operators of these machines.

Work-holding Fixtures for Automatic Millers. — As in the case of work-holding fixtures used on other types of machines, there are several general principles which must be adhered to in making fixtures for holding the work on automatic millers,

if the maximum production is to be secured. The two following are most essential: First, in order to obtain accurate results (and if accuracy is a requirement, it must be secured at any cost) the work must be held rigidly. Second, in order to obtain the maximum production, the fixture must operate rapidly. As far as possible, all of these milling fixtures should be so designed that they are locked and unlocked by a single movement of an operating handle. To carry this principle out in practice often imposes a difficult task upon the tool designer, yet, with few exceptions, it may be successfully accomplished. In many cases, it will add to the cost of the fixture, but it becomes a paying investment if a great number of pieces are to be machined. If the expenditure of an extra hundred hours of work in making the fixture will save a thousand hours in production time, the economical solution of the problem of fixture design is to add this time to the making of the fixture.

Work-holding Fixture for Small Parts. — For holding a large variety of small-sized pieces of work to be milled, a satisfactory and inexpensive work-holding fixture is made by applying special jaws to a standard milling machine vise. A line of quick-action manufacturers' vises have been developed which carry out the two basic principles stated previously; namely, rigidity and quick operation. These are made in both single and double types. In the case of the double vises, the position of one vise is made adjustable, so the work in either vise can be independently set up in relation to the cutters.

Grouping Milling Operations According to Time Required to Perform Them. — In order to secure the maximum production, where one operator handles several automatic milling machines, care must be exercised in grouping the operations. The actual machining time of the operations handled by one man should be the same as or even multiples of each other. To make this point clear, suppose there are several milling operations which it is desirable to group. The time per operation on the first is three minutes; on the second, four minutes;

on the third, eight minutes; and on the fourth, nine minutes. If there are a sufficient number of parts requiring any one of these operations to be performed on them, to keep one man busy, the planning department would naturally group them together. If not, the next best method is to group three of the three-minute operations with one requiring nine minutes; and two of the four-minute operations with one requiring eight minutes. In this way, it will be possible to maintain the

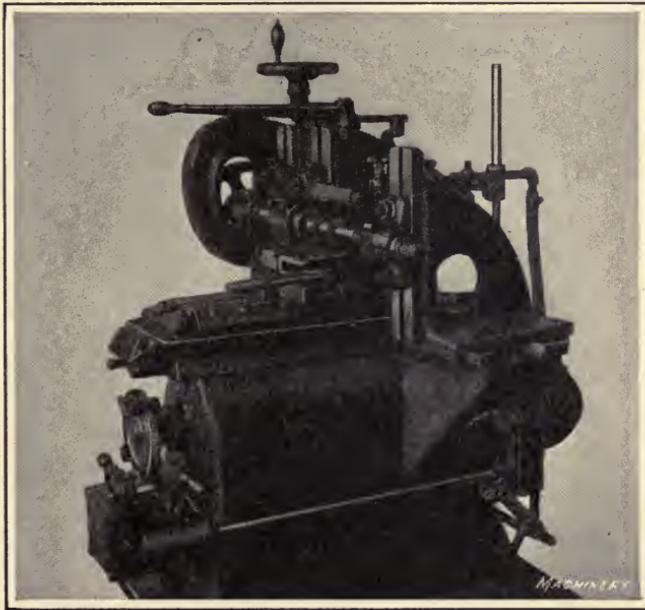


Fig. 15. Eight-inch Automatic Milling Machine for rough- and finish-milling Base of Back Sight Beds for Guns

maximum rate of production. In many cases, the variety of milling operations to be performed is so small that it does not leave a wide choice in grouping. Under such conditions, the grouping should be arranged to reduce to a minimum lost time of both the operators and the machines. In cases where maintaining rates of production is of paramount importance, the machines should be kept busy, even at the cost of an excessive amount of idle time of the operators.

Automatic Miller Equipped for Rough- and Finish-milling Operations. — Figure 15 shows an 8-inch automatic milling machine equipped to provide for rough- and finish-milling the base and groove of a gun part known as a “back sight bed.” Figure 16 illustrates the cutters, work-holding fixtures, and pieces *A* to be milled, in greater detail. In performing this milling operation, a roughing cut is first taken on the work

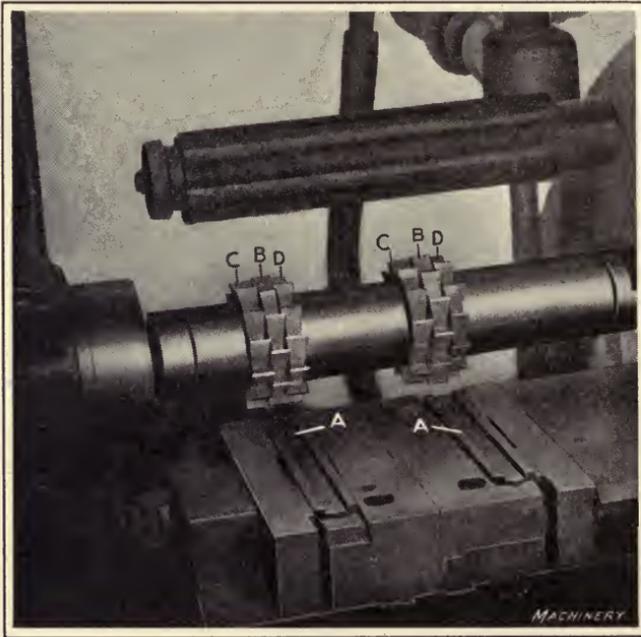


Fig. 16. Rough- and finish-milling Base of Back Sight Beds for Guns on 8-inch Automatic Milling Machine

held in the left-hand fixture; then the rough-milled part is transferred to the right-hand fixture, in which it is held while the finishing cut is taken. It will be apparent that after the rough-milled part is placed in the right-hand fixture, a fresh blank will be set up in the left-hand fixture, so that for each traverse of the milling machine table, one finished part will be obtained. If the desired rate of production were greater, a similar set-up could be employed, except that two roughing

operations would be performed on one machine and two finishing operations on another. With such an arrangement, two pieces would be secured for each cycle of movements of the milling machine table.

It is evident from Fig. 16 that there are two gangs of similar cutters used for performing the roughing and finishing operations on these parts. Cutter *B* mills the groove in the work,

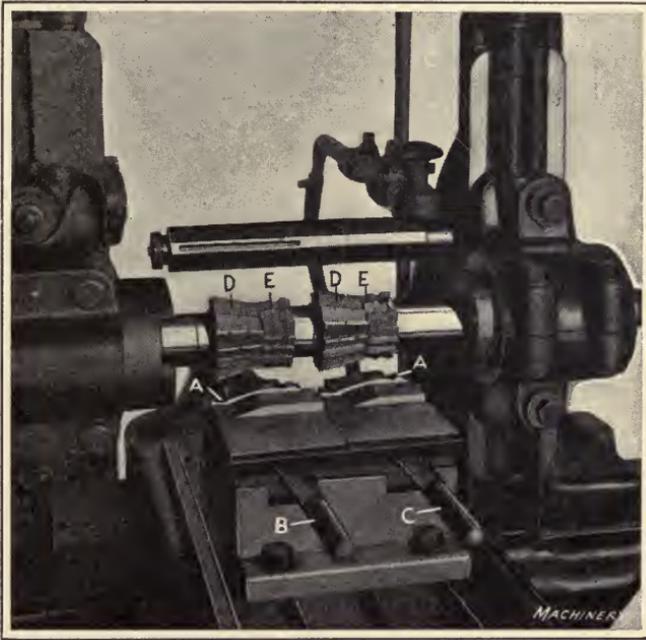


Fig. 17. Rough- and finish-milling Formed Top of Back Sight Beds for Guns on 12-inch Automatic Milling Machine

and cutters *C* and *D* mill the surface at each side of the groove. The work-holding fixture consists of special jaws mounted in a standard quick-action manufacturers' vise. This work-holding fixture is operated by a single motion of the clamping handle, thus greatly reducing the nonproductive time of the machine. The cutting speed is from 65 to 75 feet per minute, with a feed of 2.14 inches per minute. The pieces *A* to be milled are made of steel. The actual cutting time is 2 minutes

10 seconds per operation, and the loading and unloading time is 37 seconds, making the total operating period 2 minutes 47 seconds. One operator is able to take care of a group of three machines working on this job.

Rough- and Finish-milling Work to Desired Contour.— Figure 17 illustrates one of the 12-inch automatic millers set up to rough- and finish-mill the top of back sight beds for guns,

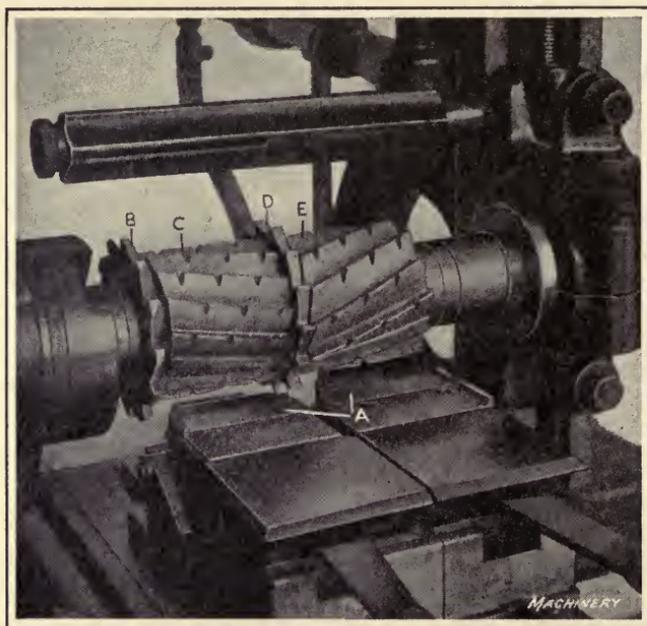


Fig. 18. Twelve-inch Automatic Milling Machine milling Top, Bottom, and Ends of Back Sight Leaf

and shows clearly the cutters, work-holding fixture, and the form to which parts *A* have to be milled. As in the case of the rough- and finish-milling operation which has just been described, the roughing cut on the present job is taken with the work held in the left-hand fixture; and after this preliminary operation has been performed, the work is reset in the right-hand fixture ready for the finish-milling operation. At the time each piece is finished-milled at the right-hand

side of the table, another piece is rough-milled at the left-hand side, so that one piece is finished for each cycle of table movements. The work-holding fixture consists of special jaws applied to a standard milling vise; and to clamp or release the work at either side of the table, it is merely necessary to give a single movement to lever *B* or *C*.

To provide for obtaining the desired contour, two gangs of milling cutters are mounted on the arbor, each gang consisting of two cutters *D* and *E*. It will be seen that cutters *D* are

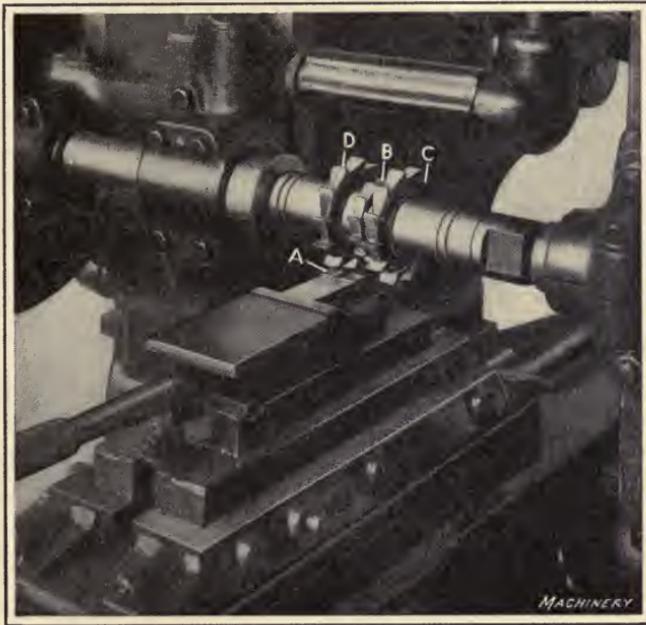


Fig. 19. Five-inch Automatic Milling Machine facing Ends and milling Groove in Back Sight Leaf Slide

angular mills which provide for finishing the inclined face of the work, while cutters *E* are formed to produce the desired contour at the right-hand end of each piece. On this job, the cutting speed is 73 feet per minute, and the feed is 1.86 inches per minute. The actual cutting time per piece is 1 minute 11 seconds, and the loading time is 40 seconds, making the total time per operation 1 minute 51 seconds.

Machine Equipped for Milling Top, Bottom, and Ends of Work. — In producing the back sight leaf for a certain type of gun, it is required to finish the top, bottom, and both ends of the work. Figure 18 shows a 12-inch Pratt & Whitney automatic miller which is equipped for performing all of these operations. At the left-hand side of the machine there is a fixture in which the work is held to allow the top and both ends of the work to be milled; and after this cut has been completed, the piece is transferred to the fixture at the right-hand side of the milling machine table, in which it is held while the bottom of the work is being milled. The fixtures consist of standard vises equipped with special jaws; and each of the two vises can be tightened or loosened by manipulating a single handle. These gun sight leaves are machined from bar stock $\frac{13}{8}$ inch by $\frac{1}{2}$ inch in cross-sectional area by $3\frac{1}{2}$ inches in length.

A gang of three cutters *B*, *C*, and *D* performs the first operation. The angular mill *B* finishes the inclined left-hand end of the work, and the plain mill *C* faces off the top, while the narrow side milling cutter *D* finishes the right-hand end of the work. Cutter *E*, which performs the second operation, is not fully shown in Fig. 18. From this illustration the impression would be gained that this is a plain mill, but at its right-hand end, this cutter has an angular face which provides for milling the inclined shoulder at the right-hand end of the work. The cutting speed is from 80 to 95 feet per minute, with a feed of 1.22 inches per minute. The actual machining time is 1 minute 58 seconds, and the loading and unloading time is 43 seconds, making the total production time per operation 2 minutes 41 seconds. On this job, the operator looks after a group of two machines.

Milling Ends of Work and Groove in Top Face. — To provide for simultaneously milling both ends and a groove in the top face of a gun part known as the "back sight leaf slide," a 5-inch automatic milling machine is used, which is equipped as shown in Fig. 19. The piece *A* to be milled is made from bar stock $\frac{3}{8}$ by $\frac{9}{16}$ inch in cross-sectional area by $1\frac{1}{8}$ inches in

length. In this case, the work-holding fixture provides for setting up only one piece for the milling operation. This fixture has a pair of special jaws mounted in a single quick-action vise of standard design. The arrangement of milling cutters is quite simple. It consists of a gang of three side mills, cutter *B* being utilized for producing the shallow groove in the work, while cutters *C* and *D* face off the ends. On

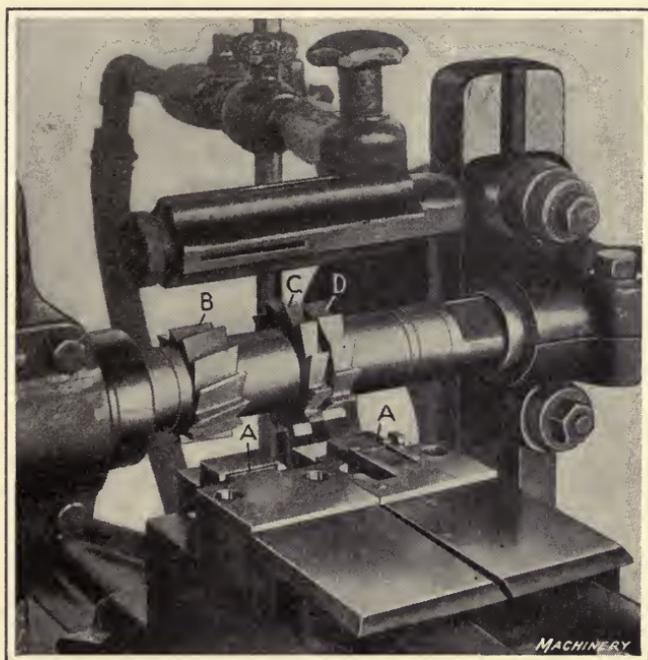


Fig. 20. Five-inch Automatic Milling Machine milling Top, Side, and End of Back Sight Leaf Slide Dog

this job, the cutting speed is from 80 to 105 feet per minute with a feed of 1.18 inches per minute. The machining time per cut is 1 minute 39 seconds, and the loading time is 27 seconds, making the total time per operation 2 minutes 6 seconds. One operator handles three machines working on this job.

Milling Top, Side, and End of Work. — Figure 20 shows another 5-inch size of automatic milling machine equipped

for milling the top, one side, and one end of a gun part known as a "back sight leaf slide dog," which is shown at *A*. A facing cut is taken on the top of this piece, while it is held in the fixture at the left-hand side of the machine, and both the end and a groove in one side are milled with the work held in a fixture at the right-hand side of the table. The work is held in a standard double milling vise provided with

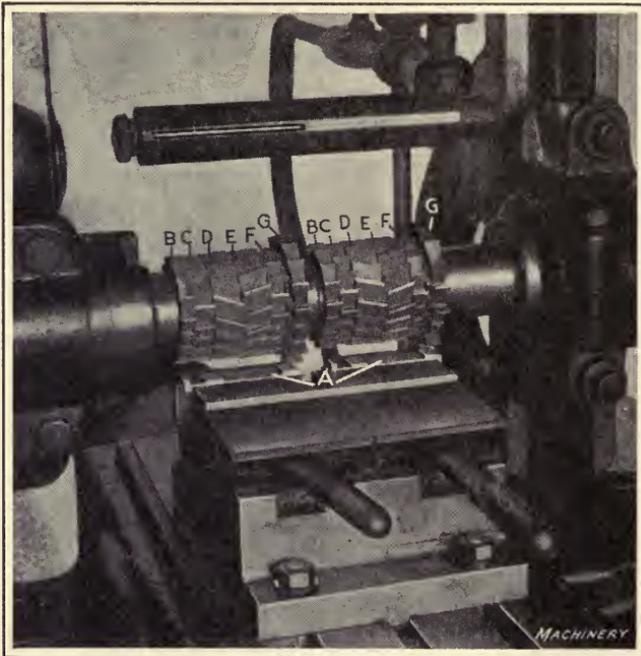


Fig. 21. Twelve-inch Automatic Milling Machine rough- and finish-milling Nine Faces on a Follower

special jaws. A plain milling cutter *B* provides for taking a facing cut on the top of the work, while a gang of two cutters *C* and *D* performs the second operation. Cutter *C* faces off the end of the work, while cutter *D* mills the groove in the side. This job is performed with a cutting speed of 95 feet per minute, and a feed of 1.18 inches per minute. The actual machining time is 57 seconds, and the loading time is 33 seconds, making a total production time of 1 minute 30 sec-

onds. This cut is so short that the operator is able to handle only a single machine.

Rough- and Finish-milling Work to Desired Form. — On the 12-inch automatic milling machine shown in Fig. 21, it will be seen that two gangs of six cutters each are utilized for rough- and finish-milling a gun part *A* known as a "follower," which must have the form shown in this illustration. As in

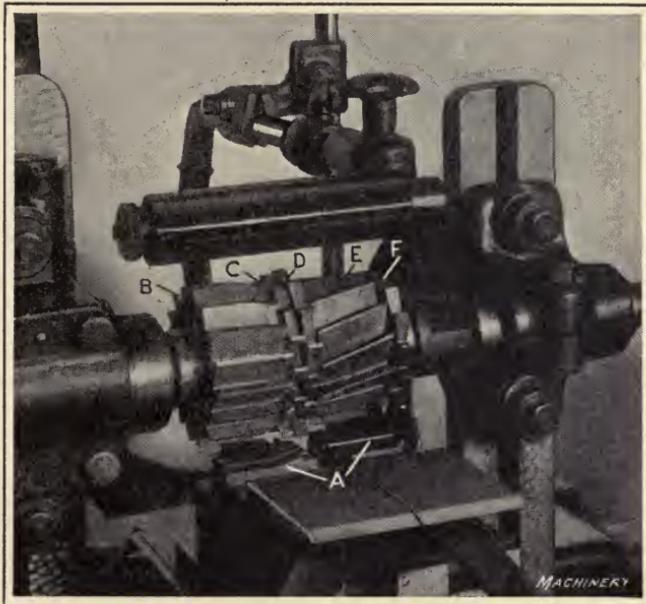


Fig. 22. Eight-inch Automatic Milling Machine milling Top, Bottom, and One End of the Forging for a Lower Band Spring

preceding cases, the roughing operation is performed with the work held in the left-hand fixture, and the finishing operation with the same piece in the right-hand fixture. The method of setting up the work is also the same as that previously described, so that one finished piece is produced for each cycle of table movements. Each gang of cutters consists of six mills *B*, *C*, *D*, *E*, *F*, and *G*, each of these cutters being made of the proper diameter to mill one face of the work in the correct relative position to other finished surfaces. Cutter *G* is of

sufficient size so that it overhangs the end of the work and provides for milling it at the same time that the five top faces of the piece are machined. These followers are made from steel bar stock $\frac{7}{8}$ by $\frac{7}{8}$ inch in cross-sectional area by $3\frac{1}{2}$ inches in length. The cutting speed is from 69 to 89 feet per minute with a feed of 1.86 inches per minute. On this job, the actual machining time is 1 minute 51 seconds, and the loading time is 1 minute 8 seconds, making the total production time per operation 2 minutes 59 seconds. One operator is able to handle two machines working on this job.

Milling Top and Bottom Faces and One End of a Forging. — The part shown set up on an 8-inch automatic milling machine in Fig. 22 is a lower band spring for a gun. This part is made from a forging, and it is required to mill the top and bottom faces and one end of the work. The bottom face of work *A* must be machined to an irregular contour, and to obtain this result, a gang of three cutters *B*, *C*, and *D* is used. Cutter *B* is formed to correspond with the irregular contour of the curved section, while cutters *C* and *D* provide for milling the square shoulder and the end of the work, respectively. After this cut has been completed, the work is placed in the right-hand fixture and two cutters *E* and *F* are utilized for facing off the flat surface of the work and for straddle-milling the wall at the right-hand end. The cutting speed on this job is from 73 to 85 feet per minute, with a feed of 1.86 inches per minute. The actual machining time per operation is 1 minute 24 seconds, and the unloading and loading time is 53 seconds, giving a total production time per operation of 2 minutes 17 seconds. Sufficient time is allowed by the cut to enable one man to operate two machines working on this job.

Milling a Slot with Non-parallel Sides. — An interesting operation is shown in Fig. 23, which consists of milling the non-parallel sides and bottom of a slot in the end of a bayonet, to receive the locking bolt. Two pieces of work *A* are set up in the fixture, one behind the other, in such relative positions that one side and part of the bottom of the slot are milled in the first piece; and when the second piece is carried up to the

cutter, the opposite side and remainder of the bottom of the slot are milled. Two plain cutters *B* and *C* are used in order that the spiral angles of the teeth may be opposed to each other to neutralize the end thrust; otherwise, a single cutter could just as well be employed. After each traverse of the table, the partially milled piece is removed from the first station of the fixture and reset in the second position. A fresh

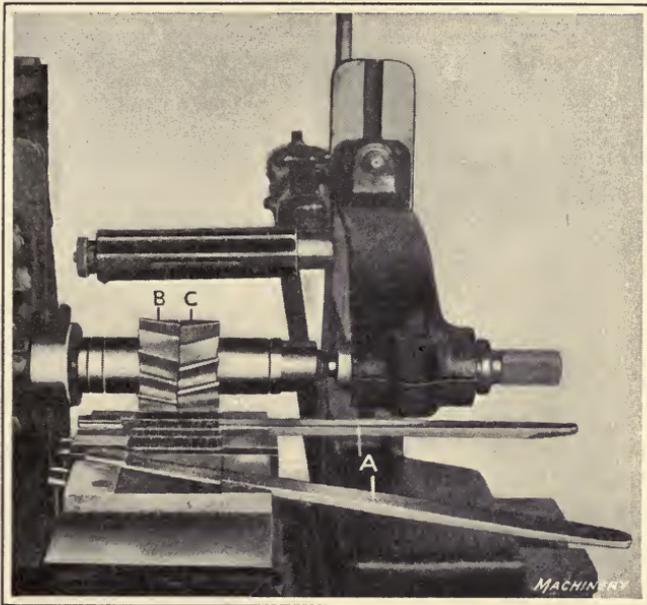


Fig. 23. Eight-inch Automatic Milling Machine milling the Non-parallel Sides and Bottom of the Lock Groove in a Bayonet

blank is then set up in the first station. With this arrangement one piece is completely milled at each cycle of movements of the milling machine table.

Design of Work-holding Fixture Used.—The construction of the fixture used for performing this operation is shown in Fig. 24. It has a clamping mechanism that is operated with a single cam-lever *A*, the cam being attached to a sliding member *B*, and acting against a sliding block *C*. This results in drawing back the sliding member *B* and pushing forward

block *C*. Sliding member *B* carries a jaw at the front of the fixture, and the rear jaw *E* is operated through a rocker arm *D* which is actuated by sliding block *C*. With this arrangement, the single clamping lever provides for securing both parts under an equal pressure. It will be noted that, in both positions, the work is held by fixed jaws acting against the

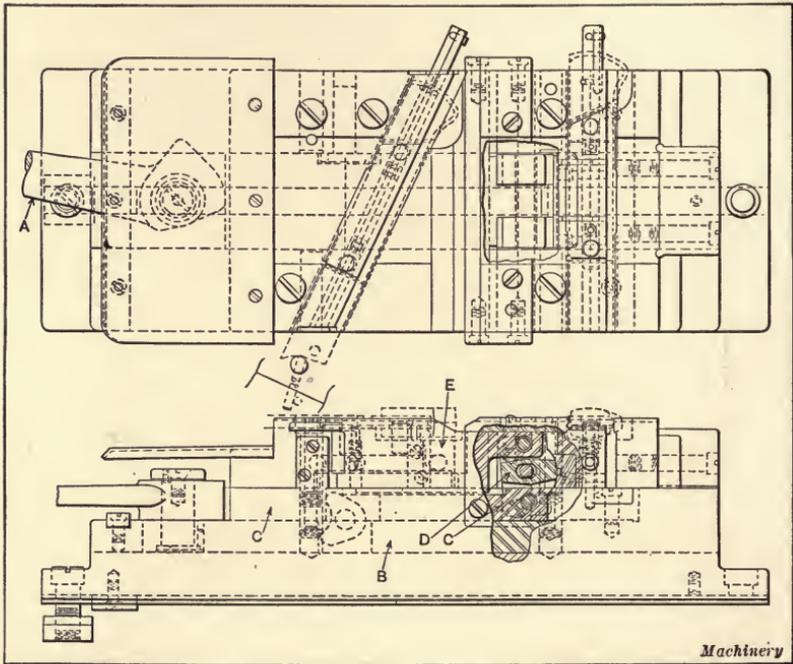


Fig. 24. Design of the Work-holding Fixture used on the Machine shown in Fig. 23

cutter and clamped from the front. Attention is also called to the fact that there is a solid metal support under the cutter in both positions where the work is held. Thus, the maximum rigidity is secured for the fixture. On this job, the cutting speed is 67 feet per minute with a feed of 1.86 inches per minute. The actual machining time is 2 minutes 58 seconds, and the unloading and loading time is 1 minute 14 seconds, giving a total production time for this operation of 4 minutes 12 seconds. One operator looks after two machines on this job.

Milling Top and Ends of Four Pieces of Work and Cutting them off the Bar. — Figure 25 shows a 5-inch automatic milling machine equipped to mill the top and ends of four bayonet locking bolts *A* which are made from a single piece of bar steel $\frac{5}{16}$ by $\frac{5}{8}$ inch in cross-sectional area, by $4\frac{1}{4}$ inches in length. The work-holding fixture used for this job consists of a quick-acting vise, provided with special jaws and equalizing clamps operated from a single cam. A double “whiffle-tree” construc-

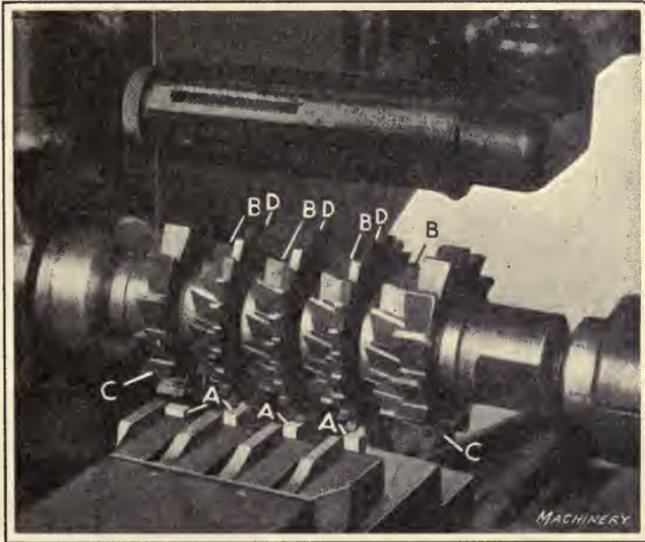


Fig. 25. Five-inch Automatic Milling Machine milling Top and Ends of Four Bayonet Locking Bolts, and cutting them off from the Bar of Stock

tion is employed for operating the equalizing clamps, which holds each part under an equal pressure, so that there is no danger of the work sliding at the time it is cut off. It will be seen that a gang of nine cutters is required for the performance of this operation. Four plain cutters *B* mill the sides of the shoulders and face the surfaces to the right of the shoulders. Two side milling cutters *C* face the ends of the work, and three cutting-off saws *D* divide the single blank into the four parts which are required. On this job, the cutting speed is from 90 to 116 feet per minute, with a feed of 0.87 inch per

minute. The actual cutting time is 2 minutes 1 second, and the unloading and loading time is 36 seconds, making the total time per operation 2 minutes 37 seconds. One operator is able to attend to two machines working on this job.

“Ohio” Tilted Rotary Milling Machine. — In the “Ohio” tilted rotary milling machine, built by the Oesterlein Machine Co., provision has been made to enable it to be operated on either the continuous rotary or the indexing principle. When used as an indexing machine, two or more working-holding fixtures are mounted at the periphery of the circular table of the “Ohio” miller, and a suitably arranged mechanism provides for alternately indexing the table to bring the next piece of work into the operating position, and then feeding the cutter-head in toward the center of the table, so that the cutters are fed across the work. Such an arrangement enables a high rate of production to be obtained, because a number of pieces of work may be mounted around the periphery of the table, and the table may be indexed at high speed to bring the successive castings or forgings into the milling position. The cutter-head is also withdrawn from the work at high speed, the slow-feed movement being utilized only during the actual cutting. The operator of this machine is only required to remove the finished pieces of work from the fixtures and set up fresh blanks, so that there is virtually no idle time of either the machine or its operator.

Milling Yoke Forgings. — Figure 26 shows a machine equipped with two work-holding fixtures arranged for operation on the indexing principle. This machine is used at the plant of the Stuebing Truck Co., for straddle-milling the outside faces of cast-steel yokes. The advantage secured by the indexing principle of operation is quite apparent in this case, because if the machine were used as a continuous rotary miller, a great deal of time would be lost in moving the table through practically a complete semicircle between each of the milling cuts. As the cuts are quite short, the percentage of idle time would be very high, especially in view of the fact that a low rate of feed must be used in milling these steel castings. The

illustration shows the machine just as it is about to commence the straddle-milling operation. The spindle head carrying the straddle-mills will feed radially toward the center of the table until the cut is completed, after which a dog will automatically trip the feed movement and engage a rapid return mechanism which will carry the cutters quickly out of engagement with the work. At the same time, the table indexing

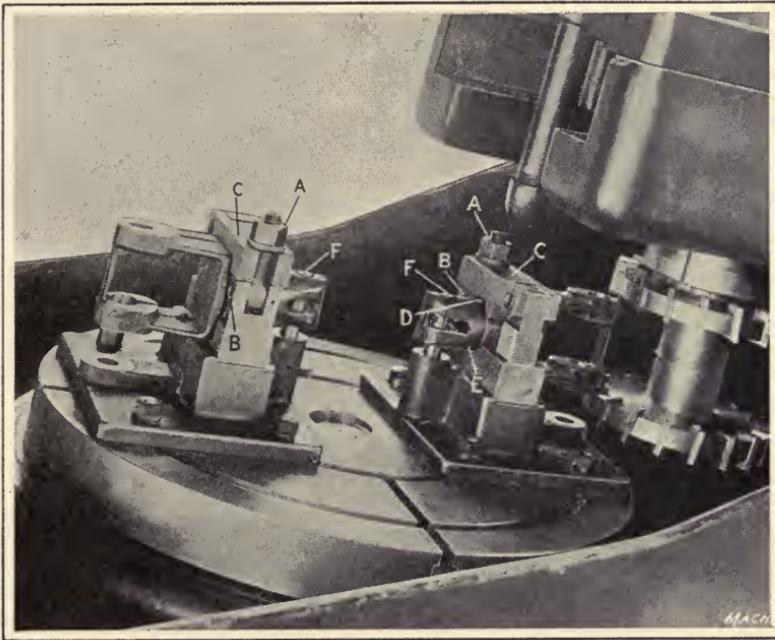


Fig. 26. Straddle-milling Yoke Forgings on Tilted Rotary Milling Machine operated on Indexing Principle

mechanism will be automatically engaged, causing the table to be quickly moved through a half revolution, ready for milling the next casting which has been set up in the fixture at the opposite side of the table. While this piece is being milled, the operator will remove the finished piece and substitute a fresh blank in its place.

Work-holding Fixtures for Milling Yoke Forgings. — On this job, it is of great importance to provide work-holding fix-

tures with a quick-acting clamping mechanism, because the time required to take the cut on these forgings is quite short, so that the operator has only a limited period in which to remove the milled yoke, and to set up a rough forging in its place. For this purpose, it is merely necessary for the operator to turn nut *A* through about half a revolution, after which the bolt may be swung on pivot *B* to enable strap *C* to be raised. On the under side, it will be seen that this strap carries a V-block *D* that fits over the top of the forging; and on its under side, the forging is supported by a similar V-block *E*. Endwise location of the work is provided by a pilot *F*, which fits through a hole that has previously been drilled in the inner end of each forging. After the milled piece has been removed from the fixture, the operator sets up a new forging by merely slipping it over pilot *F* and then dropping strap *C* into place on top of the forging. The clamping bolt is next swung up into the slotted end of strap *C*, after which nut *A* is tightened. Very little time is required for unloading and reloading the fixture. On this operation, the time taken in milling one forging is forty seconds; that is to say, the rate of production is ninety forgings per hour.

Straddle-milling and Slitting Pinion Flanges. — The “Ohio” tilted rotary miller as described, has been designed in such a way that the table may either be rotated continuously to provide for feeding work to the cutters, or so that the indexing principle may be utilized, whereby the table brings a piece of work into position opposite the cutters and then stops while the ram, by which the cutter-spindle is carried, moves forward to feed the cutters radially across the work.

Fixture for Straddle-milling and Slitting Pinion Flanges. — Figure 27 shows a close-up view of the table, cutters and work-holding fixture of an “Ohio” tilted rotary miller which has been equipped for milling pinion flanges, utilizing the indexing principle. Obviously this is necessary because only two pieces of work are set up on the table at a time and because the cutter must be fed into and not over or through the work, as is essential in continuous milling. Referring

first to the work shown at the left-hand side of this illustration, attention is called to the fact that the operation to be performed consists of straddle-milling the ends *A* of a boss on the work, and of cutting a slit at the center. By comparing the arrangement of the milling cutters and slitting saw with the form of the work, the nature of this operation will at once become apparent. Air-operated work-holding fixtures are employed, these fixtures being tightened by throwing lever

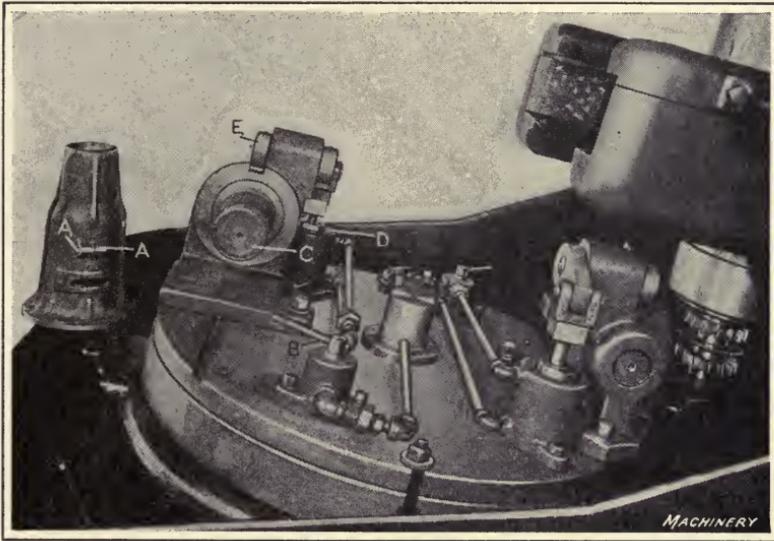


Fig. 27. Two-station Air-operated Fixture for straddle-milling and slitting Pinion Flanges

B in one direction while the work is released from the fixture by an opposite movement of the valve lever. After a milling operation has been completed the table indexes through 180 degrees to provide for bringing a casting which has already been set up in the second fixture, into the operating position, while the other fixture is carried around to the loading position so that the operator may remove the milled pinion flange and set up a fresh casting in its place.

At the time the work comes to this machine it has been bored and the flange has been turned and faced, so that these

surfaces may be utilized as locating points. Arbor *C* enters the bore of the pinion flange and the face of the flange goes back against the finished vertical surface of the fixture. With the work located in this way, valve lever *B* is thrown over to admit air to cylinder *D*, so that the piston in this cylinder will rise and rock latch *E* on its pivotal support to enable this latch to drop over the flange on the work, and hold it back in place on the fixture. It will be apparent that with a casting

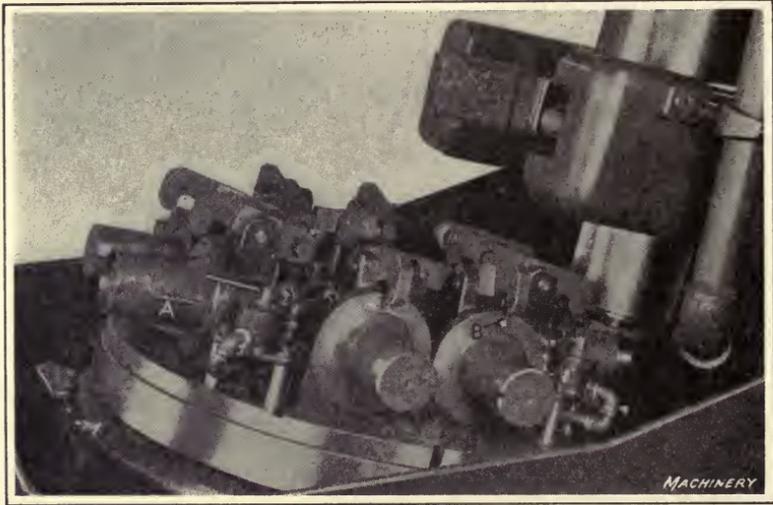


Fig. 28. Work-holding Fixture of Similar Design to that shown in Fig. 27, except that there are Four Stations, with Two Pieces of Work mounted at Each Station

in the operating position, the ram by which the cutter-spindle is carried moves forward to provide for feeding the milling cutters across the ends *A* of the boss to be milled on the work and dropping the slitting saw into the middle of the boss. On this job the rate of production is 120 pieces in one hour.

Straddle-milling a Boss and Making a Saw-cut in Pinion Flanges. — Figure 28 shows a job which is quite similar to the one described in connection with the previous illustration. The operation consists of straddle-milling a boss, and dropping a saw-cut into automobile pinion flanges; but as this machine

has been equipped, it will be evident that provision is made for simultaneously taking these three cuts on two castings, thereby effecting a substantial reduction in production time. The arrangement of each individual work-holding fixture is essentially the same as that on the preceding machine, except that the table has been provided with four stations instead of

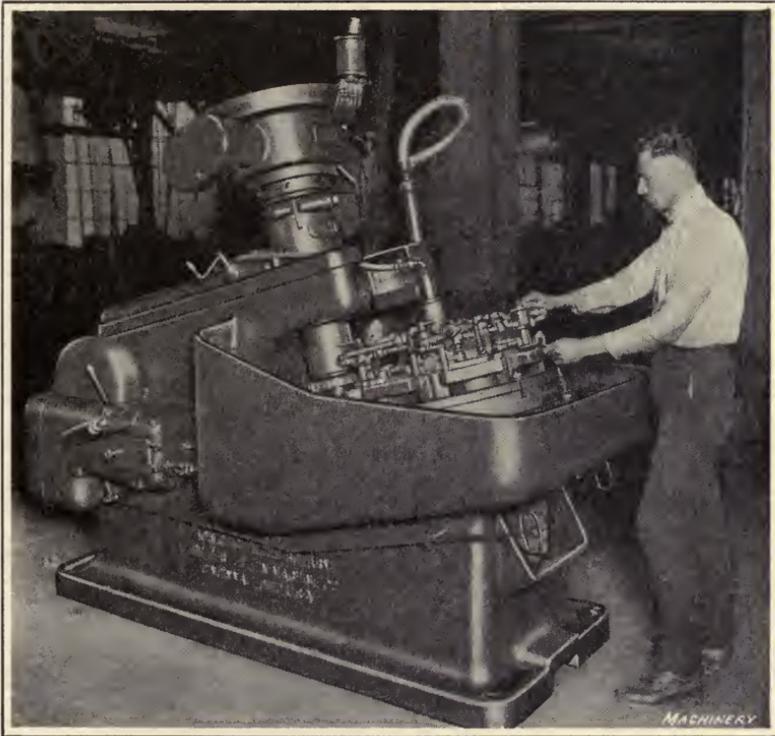


Fig. 29. Tilted Rotary Miller equipped with Air-operated Fixtures and Two Straddle Cutters for milling Anchor Clips

two, and two pieces of work are set up at each station, instead of one as in the previous illustration.

From the piece of work shown at *A* it will be seen that the pinion flange has already been bored, turned and faced, and the finished bore and face of the flange are utilized as locating points, an arbor entering the bore in the work while pin *B* enters one of the drilled holes in the pinion flange to afford

the desired location. As each station comes into operating position, the ram feeds the cutters and slitting saw radially inward toward the center of the table, so that the two milling cutters can straddle-mill a boss on each of the castings between which they are fed, while the saw carried between the cutters provides for slitting each of the castings. On this job the rate of production is 240 pieces per hour. On account of the automatic operation of the machine, it acts as a pace-

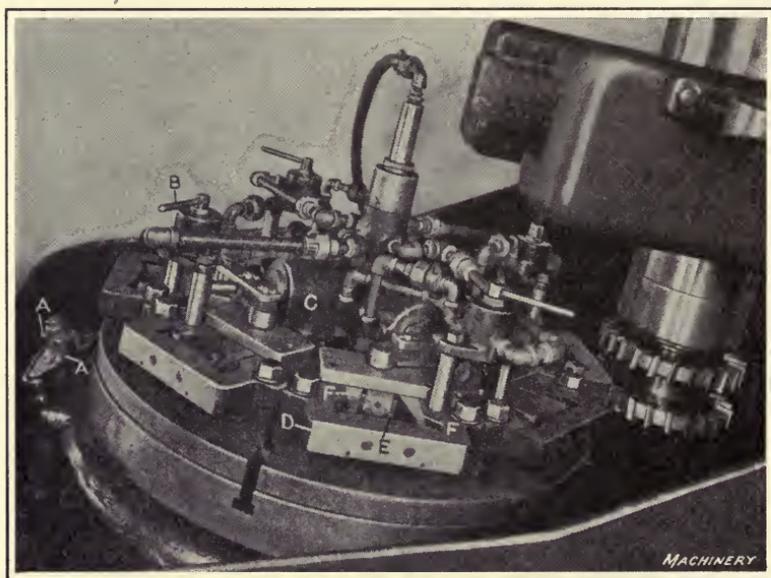


Fig. 30. Close-up View of Work, Fixtures and Cutters on the Milling Machine illustrated in Fig. 29

maker for the operator so that a steady rate of output is secured.

Straddle-milling Anchor Clips. — Figures 29 and 30 show an "Ohio" tilted rotary miller equipped with fixtures for a straddle-milling operation on anchor clips. It will be apparent that pneumatic fixtures are used for holding the work and Fig. 29 shows the operator manipulating the air valve with his right hand while he holds one of the anchor clips in his left hand. From the close-up view of the table, cutters and

work-holding fixtures illustrated in Fig. 30, a better idea will be obtained of the tooling of this miller. In this illustration attention is first called to the fact that it is the surfaces *A* at opposite sides of the work which have to be straddle-milled. Nine fixtures are distributed around the circumference of the rotary table. To provide for clamping or releasing the air-



Fig. 31. Fixture for Continuous Milling of Universal Joint Forgings

operated fixture at each station of the table, it is merely necessary for the operator to throw valve lever *B* in one direction to secure the work, or to move this lever in the opposite direction to release the grip upon a piece which has been milled. It will be seen that there is an air cylinder *C* located behind each of the work-holding fixtures, and that the frame *D* of the fixture is made of sufficient width so that when a piece of work is clamped in place, surfaces *A* will project above and

below the top and bottom of frame *D* so that they can be reached by the straddle-milling cutters.

A fairly accurate location is accomplished by V-block *E* that receives the cylindrical boss on the work, and when valve *B* is opened to admit air to the cylinder, two sliding clamps *F* are pushed forward to hold the work securely in place against a pad, the contour of which conforms to the work. A fixture of this kind can be loaded and unloaded with great rapidity. The automatic station principle of milling is employed, so that the table is constantly indexing pieces of work to the cutting position, and the operator is able to devote all of his time to setting up blanks and removing milled pieces of work. For this reason and also because of the fact that the fixture has been designed to facilitate loading and unloading, the rate of production obtained is 240 anchor clips per hour.

Milling Universal Joint Forgings. — An example of continuous milling on an "Ohio" tilted rotary milling machine is illustrated in Fig. 31 which shows the fixture developed for straddle-milling universal joint forgings. It will be apparent that the fixture is divided into twenty-two stations so that a practically continuous ring of forgings is carried, thus reducing the percentage of time lost while the table is traversing between successive pieces of work. Referring to the piece of work, it will be seen that shank *A* has been turned and this shank is used as the locating point, a bushing of the proper size to receive the shank of the work being provided on each station of the fixture. The operation to be performed consists of milling the faces of the yoke, and a suitable gang of cutters is provided in order to finish these faces simultaneously.

Bearing in mind the fact that this fixture rotates in a clockwise direction, it will be evident that lugs or brackets *B*, which are provided at each station, come into contact with the back side of the yoke and prevent any tendency for it to twist out of position. Of course, it will be apparent that lugs *B* are made thinner than each horn of the yoke, so that the brackets do not interfere with the operation of the milling

cutters. A screw-operated clamping mechanism secures the work in this fixture, and it is merely necessary for the operator to use the T-head wrench to release each milled piece of work, and tighten a fresh forging in its place. On this job, where the finish must be exceptionally good, the rate of production obtained is 90 pieces per hour.

Cross-slotting Bevel Gear Blanks. — At the plant of the Goodell-Pratt Co., Greenfield, Mass., an automatic milling ma-

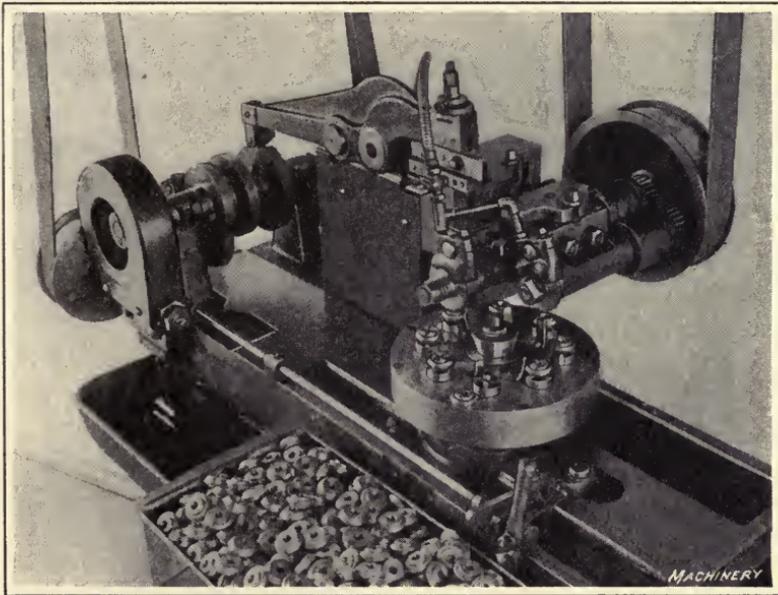


Fig. 32. Slotting Small Bevel Gear Blanks

chine built by the Bilton Machine Tool Co. is used in milling two slots at 90 degrees to each other across the hub of small bevel gear blanks. Figure 32 shows a close view of the fixture and cutters that are provided on the machine used for this purpose. It will be seen that this miller has two spindles mounted in such relative positions that the cutters are located at a quarter of a revolution of the work-holding table from each other. The table revolves intermittently and the work-holding fixture is of very simple design, consisting merely of

pilots to enter the drilled and reamed hole in each bevel gear blank, and a spring clip at the side of each pilot to provide sufficient frictional resistance to keep the work down in place on the fixture. It is evident that very little power is required for this purpose because the cutters are fed down on the work.

Sequence of Operations in Cross-slotting Bevel Gear Blanks.

— On this job, the cycle of operations is as follows: The operator stands beside the machine, and in the position where one pilot is shown with a blank lying beside it, he lifts the milled piece of work off the pilot and substitutes a fresh blank in its place. Movement of the table is intermittent, a sufficient dwell being allowed while the blanks are under the two cutters so that these cutters can feed down to mill slots in the work. These two synchronized movements of the cutter-heads and work-holding table are obtained from a camshaft at the back of the machine, the cutter-head being mounted on a vertical slide and the work-holding table provided with a ratchet and pawl mechanism to give the desired results. A fresh blank has the first slot cut in it when it reaches the first cutter, and after the table has carried this blank around through an interval of 90 degrees, the second slot is cut while the work is under the other milling cutter. One completely slotted blank is thus obtained for each index-movement of the table, or one travel of the cutter-head.

On this job the slots to be milled are $\frac{1}{8}$ inch by $\frac{1}{8}$ inch, and the hole through the work is $\frac{1}{8}\frac{3}{4}$ inch in diameter, while the diameter of the boss in which the slots are milled is $\frac{7}{8}$ inch. The milling cutters are 3 inches in diameter, and they are driven at a speed of 202 revolutions per minute, which corresponds to a cutting speed of $158\frac{1}{2}$ feet per minute. The rate of production obtained is 6000 completely milled parts in a ten-hour working day.

Operations on Potter & Johnston Indexing Milling Machines. — Before describing the methods of handling those milling operations for which the indexing type of machine built by the Potter & Johnston Machine Co. is adapted, it

will be well to study the features of this miller. From Fig. 33 it will be seen that two parallel work-holding tables are provided, which are mounted at a fixed height from the floor on a circular indexing turntable that provides for bringing the two work-holding tables alternately into the operating and

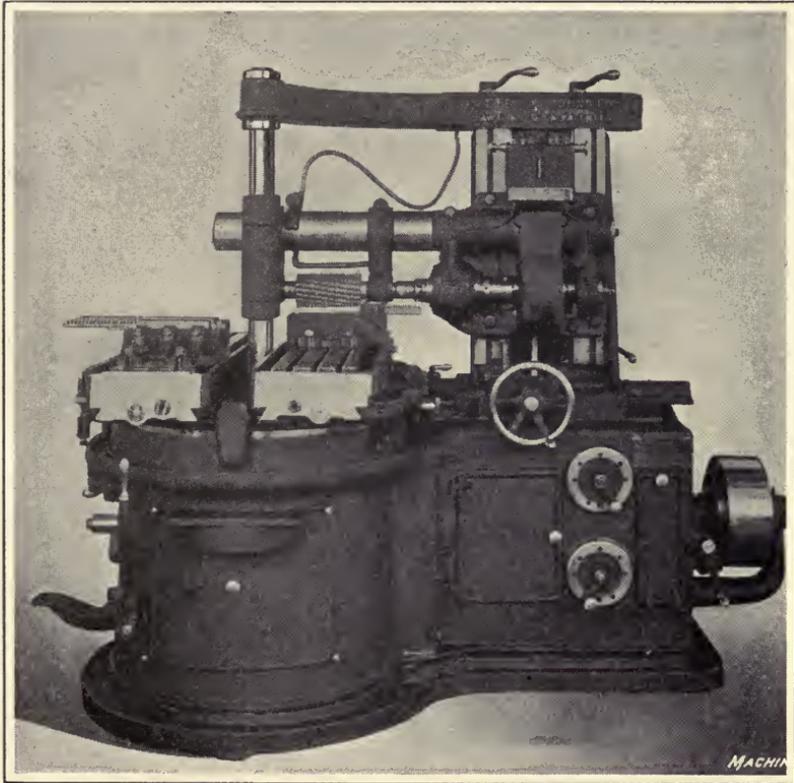


Fig. 33. Automatic Indexing Type of Milling Machine

loading positions. The operator loads the work in the fixtures mounted on one table while the cutters are working on pieces held in fixtures on the other table, so that both the machine and the operator are kept constantly employed, except for the brief intervals during which the machine is indexing. The finished work is not moved back under the milling cutters, hence there is no danger of marring the finish of the work in

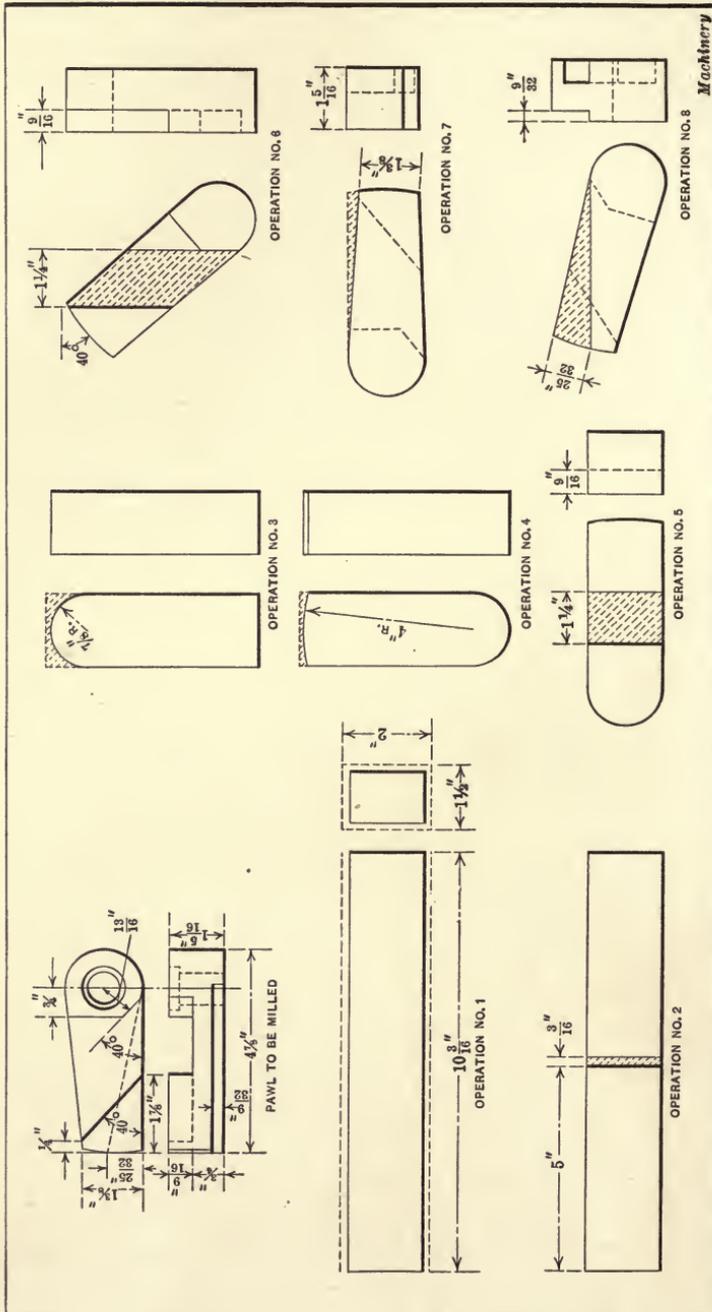


Fig. 34. Turret Revolving Pawl to be milled, and Diagrams showing Successive Milling Operations to be performed on this Part

making such a return movement of the table. By mounting the spindle on a slide carried by the column, provision is made for obtaining vertical adjustment of the position of the spindle; and the column is carried by a horizontal slide which affords transverse adjustment for the spindle, so that any desired position on the table can easily be reached.

Milling a Turret Revolving Pawl. — Figure 34 shows two views of the finished turret revolving pawl after being milled, and also diagrams indicating the manner in which successive milling operations are performed in making this part. There are nine operations required for the production of each of these pawls. The first eight are milling operations, and these will be discussed in detail; but as the final operation consists of drilling and counterboring a hole in the pawl, no consideration will be given to this part of the work. The machine steel from which these pawls are made is delivered to the milling department in blocks measuring $10\frac{3}{8}$ inches long by 2 inches high by $1\frac{1}{2}$ inches thick. Each of these pieces of steel contains sufficient material for making two pawls, a piece 5 inches in length being required for each pawl, while $\frac{3}{8}$ inch is allowed for the kerf removed by a parting tool. The reader will obtain the best idea of the way in which the successive operations are performed on these parts by referring to Fig. 34, which shows in diagrammatic form the successive steps that are involved. Operation 1 consists of squaring up the four sides of each steel blank, so that they are at accurate right angles to each other. After this has been done, the second operation is to part the blanks at the center, in order to produce two pieces, each of which is 5 inches in length.

Methods of Tooling up for Milling Operations on Turret Revolving Pawls. — Some of the methods employed in tooling up for the milling operations on these pawls are quite unusual. A case in point is seen in the provision made for performing Operations 3 and 4, as indicated in the diagrams shown in Fig. 34. The machine used for the performance of both of these operations is illustrated in Fig. 35, where it will be noticed that provision is made on a single machine for

simultaneously performing two operations. Two concave or formed milling cutters are used to finish the upper and lower edges of the blanks to a radius of $\frac{7}{8}$ inch and 4 inches, respectively.

The fixture mounted on each of the work-holding tables provides for holding two rows of five pieces each, so that at every traverse of the table ten pieces are milled, five on the upper end and five on the lower end. Then the turntable is

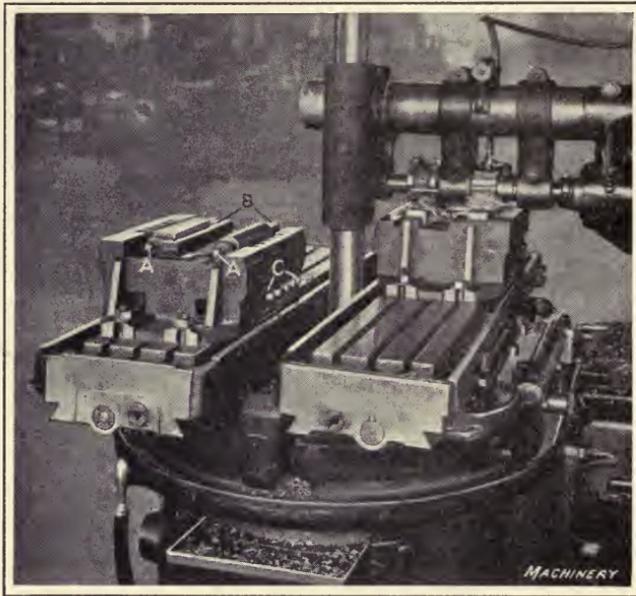


Fig. 35. Indexing Milling Machine equipped for performing Third and Fourth Operations on Turret Revolving Pawls

indexed to bring the fixture carrying these milled pieces around to the loading position. Five of these pieces are milled at both the top and bottom, while the other five are milled only at the top. As a result, five finished pieces are removed from the fixture, and the other five, which have been milled only at the top, are taken out of that side of the fixture in which they were held for the third operation, turned over end for end, and replaced in the opposite side of the fixture, on the same table, ready for performing the fourth operation. Then

five other pieces are set up in the other side of the fixture ready to have the third operation performed on them. After milling operations have been performed on the pieces carried by the fixture mounted on the other work-holding table, the machine will be indexed to provide for milling the pieces that have just been set up.

The fixtures for holding the work for milling are of quite simple design. It will be recalled that the blanks have already

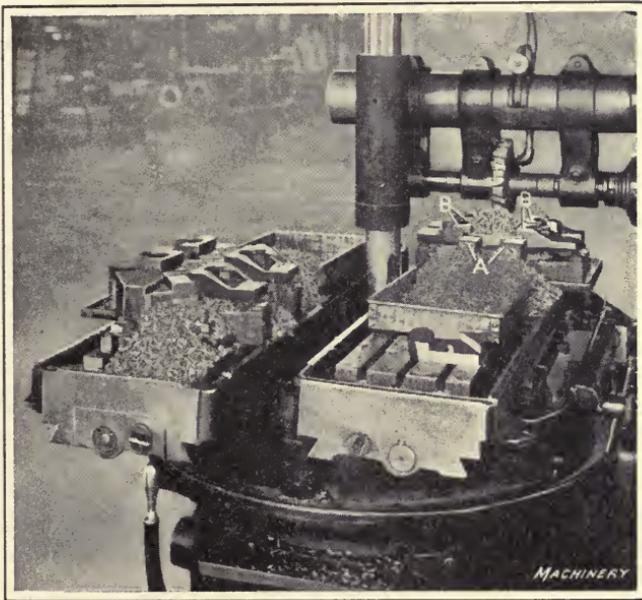


Fig. 36. Indexing Milling Machine equipped for performing Fifth and Sixth Operations on Turret Revolving Pawls

been faced off on all four sides, and in setting them up for the third and fourth operations, five blanks are secured in each side of the work-holding fixture. By tightening set-screws *A*, these pieces of work are pushed back against blocks *B*, which support the thrust of the milling cutters. Then as an additional means of steadying the work and holding it down in the fixture, five set-screws *C* provided at each side are tightened against the work.

Forming One Side of Pawl. — As in the case of Operations 3 and 4, a single indexing type of milling machine is employed for the performance of Operations 5 and 6. The fifth operation consists of milling a transverse slot $1\frac{1}{4}$ inches wide by $\frac{9}{16}$ inch deep across one side of the work; and after this has been done, a diagonal slot of the same depth and $1\frac{1}{4}$ inches in width is milled at an angle of 40 degrees to the sides of the blank. The result produced by the combination of these two

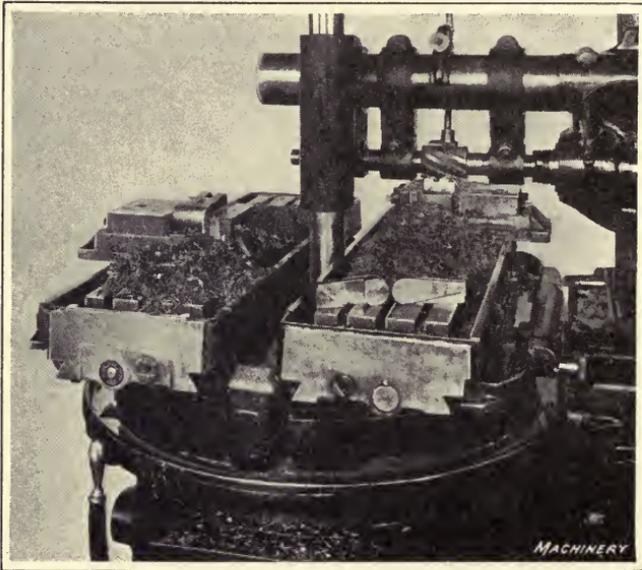


Fig. 37. Indexing Milling Machine equipped for performing Seventh Operation on Turret Revolving Pawls

milling operations is to form one side of the pawl, as shown at the upper left-hand corner of Fig. 34. A milling machine equipped for performing Operations 5 and 6 is illustrated in Fig. 36, but the provision made in this case for handling two successive operations on a single machine is somewhat different from that which was shown in the preceding illustration. In the present instance, only one milling cutter is required on the arbor, and the performance of the fifth and sixth milling operations with this cutter is accomplished by setting the

work at different angles for handling the two operations. On the work-holding table shown at the right-hand side of the machine in Fig. 36, it will be seen that the fixture provides for holding the pieces at right angles to the direction of travel of this table, so that a straight slot is milled across the work, as indicated diagrammatically for the fifth operation in Fig. 34. At the left-hand side of the machine, a similar form of work-holding fixture is provided, except that this fixture holds the pieces inclined at an angle of 40 degrees to the direction of travel of the table. The pieces milled while held in the fixture mounted on the right-hand table are taken out when this table is indexed to the loading position, and they are then set in the fixture on the other work-holding table, ready for the performance of the sixth operation, as indicated in Fig. 34. It will be apparent from Fig. 36 that the work-holding fixtures provided at both sides of the machine are of simple design. They have thrust blocks *A*, which serve the double purpose of supporting the work against the pressure of the milling cutter, and also locating the pieces to be milled at the proper angle to the direction in which the table travels. The thrust block will be at right angles to the direction of table travel for the fifth operation, and inclined at an angle of 40 degrees for the sixth operation. After the pieces of work have been located against these thrust blocks, they are held down by means of straps *B*, which are made of sufficient width so that each strap holds two pieces of work. Four pieces are held in each fixture, so that the milling operation can be performed on all of them at a single setting of the work.

Milling One Side of Pawl to Slight Taper Angle. — Operation 7 consists of milling one side of the turret revolving pawl to a slight taper angle, and for the performance of this operation the milling machine is equipped as shown in Fig. 37. It will be evident that the fixture carried by the work-holding table at each side of the machine consists of a milling vise of standard design, which holds two pieces of work. The only special feature of each of these vises is that a tapered block is placed between the jaws, and the work to be milled is laid on

this block before the jaws are tightened. In this way, provision is made for inclining the sides of the two pieces of work at such an angle that the regular horizontal movement of the table results in milling off one side of the work to the desired angle of taper.

Milling Opposite Side of Pawl to Required Angle. — The eighth and final milling operation performed on these pieces, consists of milling the opposite edge of the pawl in the manner

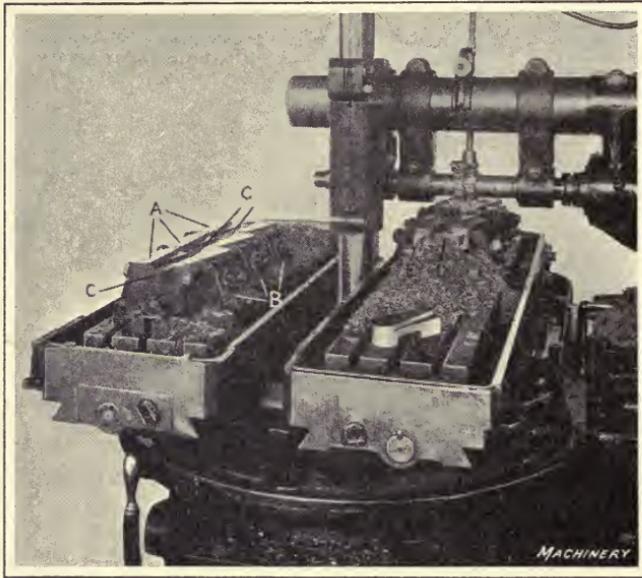


Fig. 38. Indexing Milling Machine equipped for performing Eighth Operation on Turret Revolving Pawls

indicated in Fig. 34. Here it will be seen that the cut to be taken is $\frac{9}{32}$ inch deep, and that it is taken at an angle to the parallel edge of the work, thus sharpening the wedge-shaped form of the highest portion of this side of the pawl. Figure 38 shows the equipment for this operation. It will be seen that the work-holding fixture mounted on each of the tables is so designed that provision has been made for mounting six pieces of work in each fixture. The fixtures on both tables are of identical design, and it will be apparent that each has two

rows of work *A* mounted in it. Two rows of straps *B* hold these pieces; and the proper location of the work is obtained by means of center blocks *C* against which the work is clamped, to obtain the proper inclination with the direction of travel of the work-holding table.

It will be seen that two inserted-tooth milling cutters are mounted on the arbor, and these are located in such a way

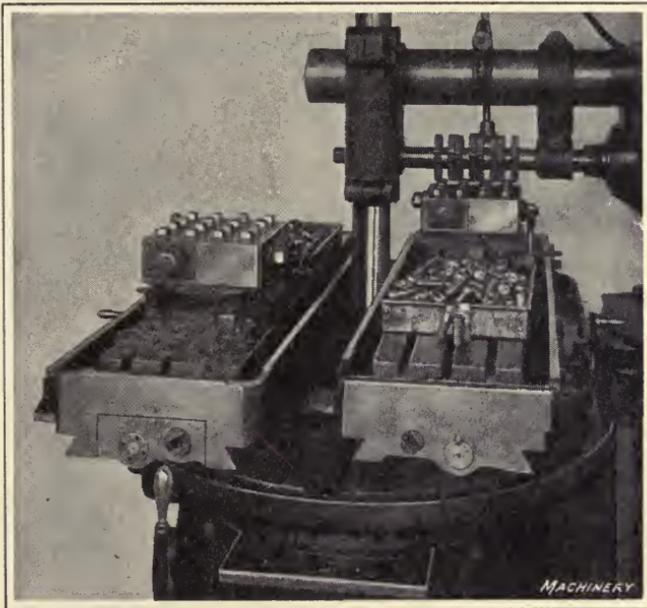


Fig. 39. Indexing Rotary Milling Machine equipped for squaring Heads of Cap-screws

that a single traverse of the table provides for milling the two rows of pieces of work on their inner edges. In order to perform the operation in this way, it will be evident that the work must be set up in the fixture with the ends of the pieces in one row facing in the opposite direction to the ends of the pieces in the other row held by the same fixture. On each fixture there are a block *D* and a pin *E*, which support the pieces of work at the ends of the two rows, so that the thrust of the milling cutters will not have a tendency to cause these pieces to alter their position in the fixture.

Rate of Production in Milling Turret Revolving Pawls. — Individual production times for the eight successive milling operations have not been tabulated, but the rate at which fully milled turret revolving pawls are produced is three per hour. The material is machine steel, and in accordance with the usual practice, the cutters and work are supplied with a copious flow of a cutting emulsion made of soluble oil and water. This is an important point in milling steel, because the tendency of the work to become heated will make it impossible to operate under maximum conditions of production, unless such a precaution is taken.

Straddle-milling Bolt Heads. — Figure 39 illustrates one of these machines set up for straddle-milling bolt heads. It will

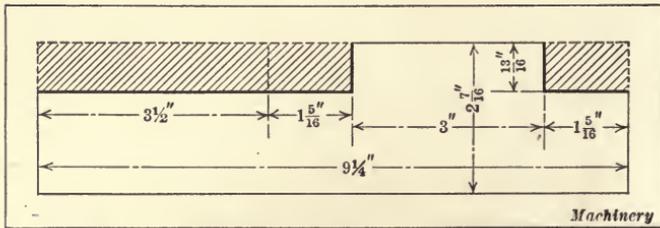


Fig. 40. Turret Revolving Pawl Block on which Milling Operations are performed by Machines shown in Figs. 41 and 42

be apparent from this illustration that each work-holding table is provided with a fixture that carries sixteen bolts in four rows of four bolts each. On the arbor of the milling machine there is mounted a gang of eight cutters with spaces left for traversing the four rows of bolts between them, to mill the flats on opposite sides of the heads. After this has been done, the turntable is indexed to bring the opposite work-holding table and fixture into the milling position. The bolts which have already been fed between the cutters have been milled on two sides of their heads, and to provide for milling the other two sides, each work-holding fixture is mounted on a pivot and provided with an index mechanism, so that it may be swung through an angle of exactly 90 degrees.

When the operation has been completed on the work mounted in a fixture on one side of the turntable, the machine is indexed

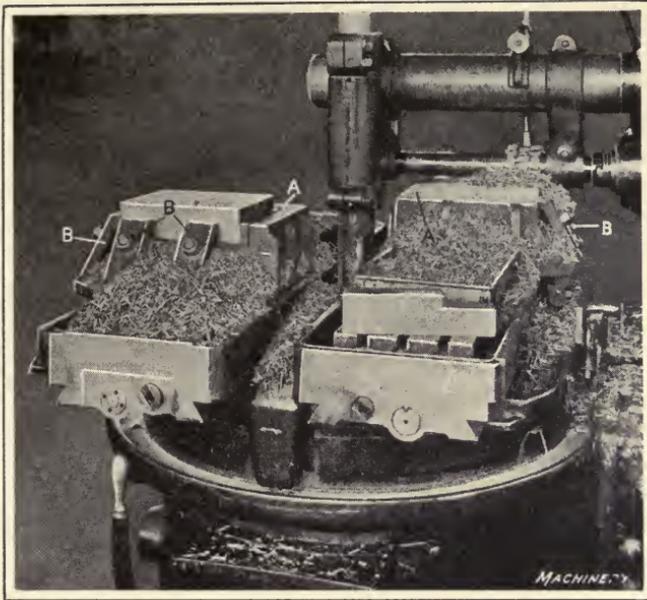


Fig. 41. Indexing Rotary Milling Machine on which the First Operation is performed on the Turret Revolving Pawl Block

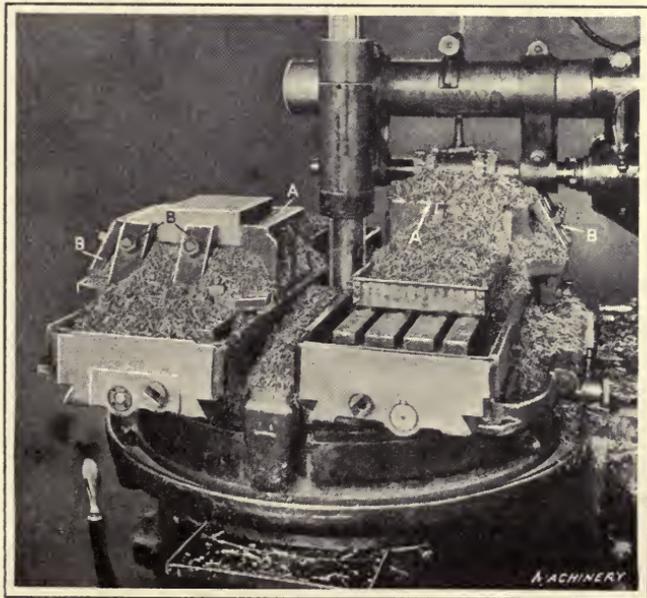


Fig. 42. Indexing Rotary Milling Machine on which the Second Operation is performed on the Turret Revolving Pawl Block

to bring the opposite fixture into the milling position. By feeding the bolt blanks between the cutters a second time, the remaining two sides of the heads are milled, thus finishing the operation. The possibility of indexing the entire fixture in order to provide for milling the second pair of sides on the bolt heads, instead of having to remove all of the pieces from the fixture and reset them in the required position for the second operation, is naturally the means of effecting a substantial saving in the amount of time required for milling these parts. With the equipment illustrated in Fig. 39, the rate of production attained is 160 milled bolts per hour.

Milling Turret Revolving Pawl Blocks. — Figure 40 shows a piece known as a turret revolving pawl block. Figures 41 and 42 show machines equipped for the performance of two successive milling operations on this piece. For the first cut taken on the machine shown in Fig. 41, it will be evident that the work-holding table at each side of the turntable is equipped with a fixture that provides for holding four of the steel blanks from which these turret revolving pawl blocks are made. This first cut consists of removing a section of metal from one end of the blank, which is $3\frac{1}{2}$ inches long by $\frac{1}{8}$ inch in depth.

It will be seen that on the machines shown in both Figs. 41 and 42, the work-holding fixtures are of essentially the same design, and that each fixture provides for holding four of the blanks for turret revolving pawl blocks. The fixtures are of simple design, consisting of two walls *A* at right angles to each other, against which the four blanks are located to bring them at exactly right angles to the direction of travel of the table. One of these two walls of the fixture also serves to support the four blanks against the thrust exerted by the milling cutters. It will be seen that at each of the other two sides of the fixture, there are two straps *B* which are tightened to locate the work firmly against the two opposite walls, to which reference has just been made. These straps are placed at an angle, so that they serve the additional purpose of forcing the work firmly down on the bed of the fixture.

Referring to Fig. 41, it will be seen that the arbor of the

milling machine carries three inserted-tooth cutters, which are of sufficient width to provide for taking the preliminary cut that is $3\frac{1}{2}$ inches in length by $\frac{1}{8}$ inch deep. The position of this cut is indicated by dotted lines in Fig. 40. For the second operation on these parts, the work is set up in the machine shown in Fig. 42, where it will be seen that two pairs of inserted-tooth milling cutters are mounted on the arbor to provide for taking a cut $1\frac{5}{8}$ inches in width by $\frac{1}{8}$ inch deep at each end of the high portion that still remains on the blank, thus bringing it to the condition shown in Fig. 40. In setting up these two machines, it will be noticed use is made of two gangs of two milling cutters, in Fig. 42; and of a gang of three cutters, in Fig. 41. The reason for using these gangs of cutters with interlocking teeth, instead of employing a single cutter in each case, is that the spiral angles of the teeth of cutters comprising such a gang can be opposed to each other, thus neutralizing much of the end thrust on the work; and in addition, such a method of setting up cutters on an arbor allows the action of the milling machine to be smoother than would otherwise be the case. The rate of production is fourteen completely milled turret revolving pawl blocks per hour.

CHAPTER III

CONTINUOUS ROTARY MILLING

IN shops where there are a large number of duplicate parts on which one or more surfaces have to be milled, satisfactory rates of production can often be obtained through the use of so-called "continuous" rotary milling fixtures. The work-holding fixture is so named because it rotates continuously to provide for feeding successive pieces of work under the milling cutters on the machine. The fixture is constructed to hold a number of pieces, and is carried on a revolving table. As the operator is constantly employed removing finished pieces of work and substituting fresh blanks, a high rate of production may be obtained by this method. Production may also be increased in many cases by employing two or more cutters for straddle-milling. Furthermore, a two-spindle machine may be used to good advantage for milling opposite ends of the work. The increased production obtained by continuous rotary milling is due to reducing the non-productive time of the machine by avoiding the necessity of stopping to set up work and then restarting the machine, by avoiding the need of returning the table to the starting point after each traverse, and by overcoming the necessity of having the machine idle while the operator is setting up work, or the operator idle while the machine is running.

Continuous rotary milling is adapted for handling a considerable range of work, as indicated by the illustrations. Generally, the best results are obtained with continuous rotary milling where the pieces to be machined are of rather small size, so that several parts may be mounted in the fixture at one time. For machining automobile crankcases, it is probable that just as satisfactory a rate of production would be obtained by handling the work on a planer-type milling machine, on

which a number of castings could be set up and all of them milled at a single traverse of the table. For milling small parts such as the armature cores, however, the continuous rotary process is the best method.

Importance of Correct Design of Work-holding Fixtures. — When working out the details of continuous rotary milling fixtures, regardless of the special nature of the operation required, the designer should observe certain general principles, particularly the following: As the rate of production is usually limited by the operator's ability to remove finished work and substitute fresh castings in the fixture, the action of the clamping devices should be made as simple and rapid as possible. Also, clamps should be so designed that they will grip the work securely without producing distortion. Another important point is to have the pieces of work held as close to each other as possible, because the table rotates at a uniform speed, so that the total non-productive time for each complete revolution of the fixture is represented by the amount of time wasted while the cutters are passing over gaps between adjacent pieces of work. The output is not dependent upon the number of pieces which the fixture holds, but upon the rate at which these pieces are fed to the milling cutters. This rate of production is, of course, independent of the diameter of the fixture, and generally the circle should be made as small as is consistent with the shape and size of the pieces to be milled, as this will reduce the cost of the fixture. Where there are several parts of the same general design but slightly different sizes, it is often practicable to design a single fixture for milling two or more pieces of work, thus substantially reducing the incidental expense for special equipment. Unless it cannot be avoided, fixtures should never be designed in a way which will make it impossible for the operator to remove milled pieces and replace fresh blanks as rapidly as the table of the machine revolves. Two or more operators can often be employed to load and unload the fixtures, thus allowing the feed and rate of production obtained to be greatly increased.

In designing a fixture to be used for clamping work on the rotary table of a continuous milling machine, and estimating the rate of production to be obtained, careful attention must be given to the design of the mechanism by which pieces are clamped in the fixture, and to the probable length of time which will be required for securing each piece in position ready to be milled. Otherwise, it will frequently happen that the setting-up time is greater than the actual machining time, and as a result rates of production will be retarded. This condition will also make the production estimates erroneous. In such cases the designer of the fixture may select a rate of speed and feed for operating the machine which will prove satisfactory in practice, but his calculation of rates of production based on these rates of speed and feed will prove incorrect because attention has not been given to the length of time consumed in setting up blanks and removing finished pieces from the fixture. It will, of course, be understood that such a complication arises only in those cases where the time taken in setting up the work is greater than the time required for the milling operation.

Davis & Thompson Continuous Rotary Milling Machine. — In order to obtain maximum efficiency in the continuous milling of parts having approximately the size of automobile engine cylinder blocks, crankcases, transmission cases, etc., Davis & Thompson have designed a new type of machine especially adapted for machining pieces of considerable size. In this book, we are chiefly concerned with the design of fixtures, methods of operation, and rates of production which are obtained in handling various typical classes of work, it being assumed that the reader is familiar with the general features of design of standard milling machines. In the case of the Davis & Thompson machine, which is not of the standard type, a general description will doubtless prove of interest. The machine has four main parts, namely, a rotating table on which the work is carried, two duplex cutter-heads, and a bed upon which the cutter-heads and support for the rotary table are carried. Each cutter-head is equipped with two spindles

which have independent longitudinal adjustment to provide for locating the cutters on these two spindles in such a relative position that a roughing cut is taken with the first, and a finishing cut with the second cutter. Usually about 0.020 inch is left for the finishing cut. In addition to the adjustment of the spindles in each head, the heads themselves are

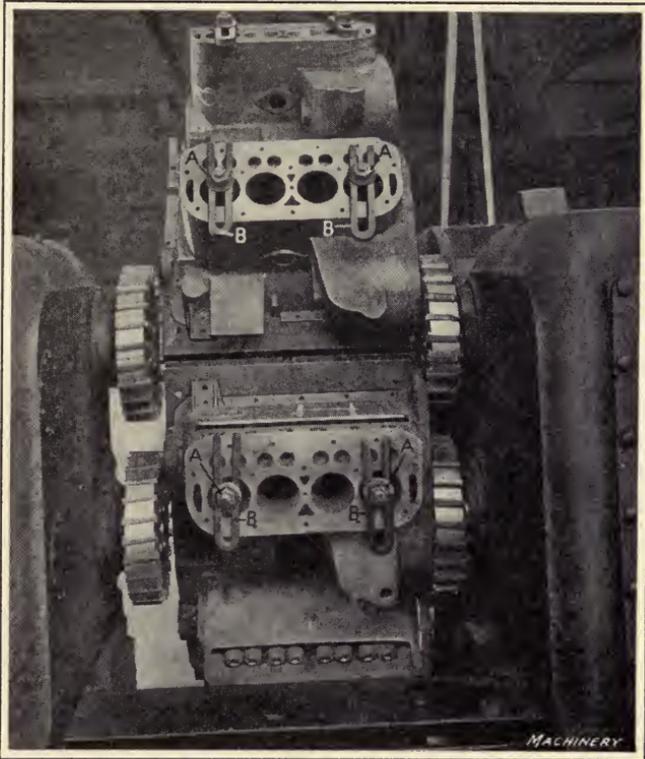


Fig. 1. Continuous Rotary Milling Machine set up for milling Opposite Ends of Cylinder Blocks for Tractor Engines

provided with longitudinal adjustment on the bed of the machine in order to leave the required amount of space between the cutting edges of the tools mounted on these opposed spindles. It will be seen from the illustrations showing typical machining operations on this machine, that the cutters carried by the two heads may be used to mill opposite ends of the same piece of work, as in the case of the cylinder blocks shown

in Fig. 1; or two rows of castings may be set up on the table to provide for rough- and finish-milling a single face on each casting, an example of such a set-up being shown in Fig. 2.

Provision for Increasing Production.— In order to reduce the non-productive time of the machine to a minimum and thus obtain the greatest possible output, provision has been made for feeding the work past the cutters at a suitable rate, and then rapidly traversing the table through the space between adjacent pieces of work. If this were not done, a serious loss of time would result through using the slow feed movement to bring the next piece of work up to the operating position. The mechanism for this intermittent feed and rapid traverse movement is designed similarly to the index mechanism of the Cleveland automatic screw machine, so a detailed description need not be given. Alternate engagement of the rapid traverse and of the proper rate of feed is accomplished automatically by means of tripping dogs mounted on a drum which rotates with the table and engages the fast or slow movement according to whether the cutters have just come into engagement with, or passed out of contact with, the work. Standard sized milling cutters are always used on these machines, which are 12 inches in diameter; and the gear drive between the single pulley on each head and the two spindles is so worked out that the proper cutting speed is obtained for the class of work on which the machine is to be used.

A rotary table is usually designed for each special job to be done on the machine, although it is frequently possible to arrange interchangeable work-holding fixtures to adapt the same table for milling several different pieces. Where this machine is used for milling a number of different pieces of work, it will often be found economical to have a separate table with suitable fixtures for holding each class of work, if the different pieces are milled with sufficient regularity to pay a satisfactory return on the tool investment. It will be seen from Fig. 3 that a tapered nose is provided on the spindle which carries the rotary table. With such a construction, it

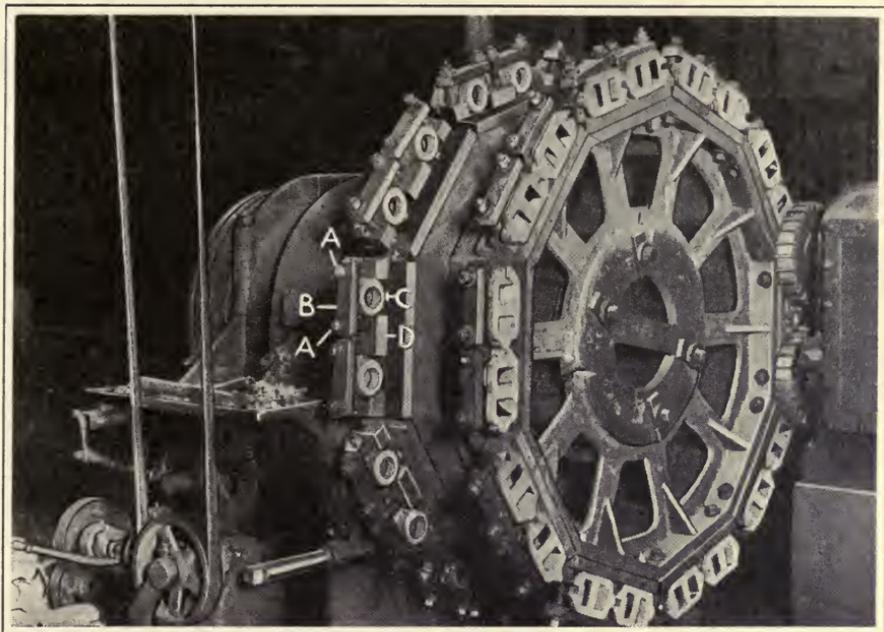


Fig. 2. Milling Water Connections for Tractor Engines. The Same Operation is performed on Pieces at Both Sides of Table

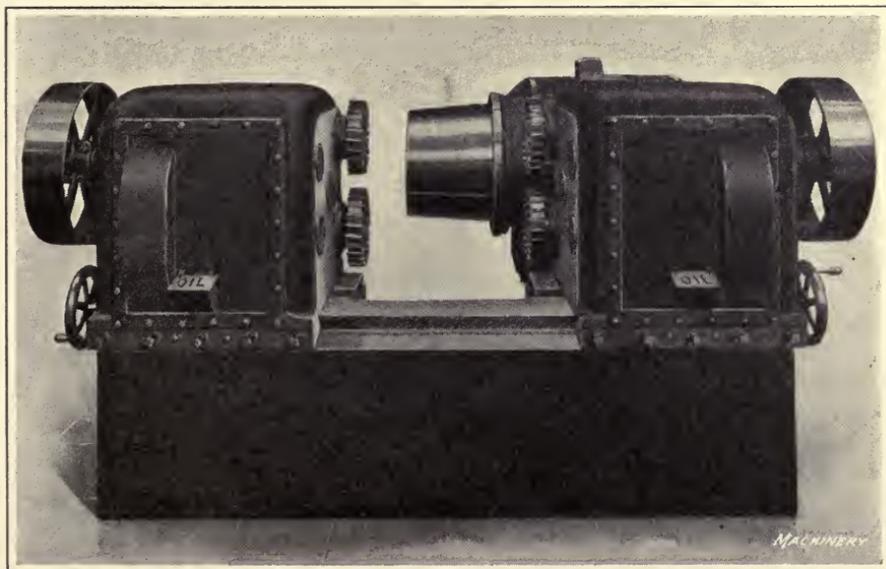


Fig. 3. Rear View of Continuous Rotary Milling Machine, showing Adjustable Duplex Cutter-heads and Tapered Spindle Nose for Work-holding Table

is easy to bore the different tables to the required fit, and then their accurate location on the machine is easily and rapidly accomplished. Changing tables in this way is shorter than setting up a whole new set of work-holding fixtures on the table. The milling operations performed on these machines are similar to those described in connection with the application of continuous rotary milling on knee-type machines, so it is merely necessary to describe one or two typical jobs, and the rates of production obtained. These machines are especially adapted for handling heavy work, and in order that the high-speed steel inserted-tooth milling cutters used may be run at a rate of speed and feed approaching their maximum capacity, all members of the mechanism have been liberally proportioned to withstand severe stresses. On account of the rapidity with which the work may be fed to the cutters, it will frequently be found desirable to employ two or more men to remove milled pieces from the fixtures and to set up fresh blanks in their places. Otherwise, the setting-up time is so much longer than the actual milling time, that it is necessary to slow down the machine for the operator to perform his part of the work.

Milling Opposite Ends of Cylinder Blocks. — Figure 1 shows one of these continuous automatic milling machines in use at the plant of the Avery Co., Milwaukee, Wis., where it is employed for simultaneously milling the opposite ends of tractor engine cylinder blocks. In this case, ten castings are mounted on the table, and the cutters, carried by spindles in the opposed heads of the machine, rough- and finish-mill both ends of the same piece of work. The fixtures, or more properly faces of the table on which the work is carried, are of simple design. Dowel-pin holes have been drilled in the lower face of the cylinder blocks, and pins on each station of the table enter these dowel holes and locate the work ready for milling. There are two bolts *A* extending up through the cylinders at opposite ends of each block. These hold the work, and the utilization of the U-clamps *B* under the washers on these bolts makes it unnecessary to do more than loosen the nuts in order to

remove the milled cylinder blocks as they come around to the loading position. The rate of production obtained is 200 cylinder blocks in a ten-hour working day.

Milling Water Connections for Tractor Engines. — In Figures 2 and 4 there are shown views of one of these continuous milling machines engaged in facing off the joint on water connections for a motor. It will be seen that the pieces are of rela-

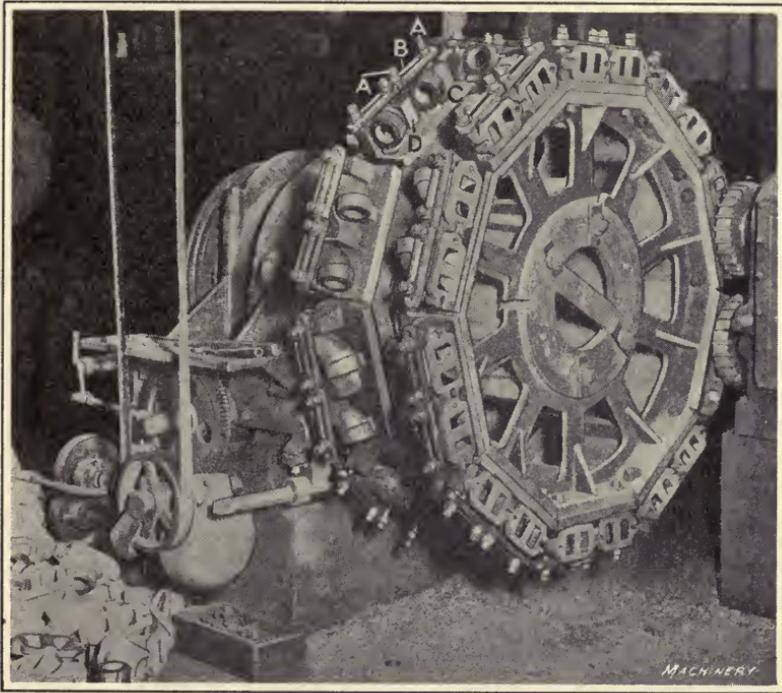


Fig. 4. Milling Another Type of Water Connection for Tractor Engines

tively small size, and that there is only one surface to be milled instead of two surfaces, as in the case of the cylinder blocks shown in Fig. 1. For this operation, extreme accuracy in the location of the work is not absolutely essential, so the rough outer surface of these malleable iron castings may be safely utilized as a locating point. The work is held down in the fixture by bolts *A* and clamps *B*, the arrangement of which is clearly shown. Two operators are employed, one at each side

of the table, to load castings into the fixtures and to remove milled pieces as they come around again to the loading side. The rate of production in each case is 400 castings per ten-hour day.

It will be seen that two different types of water connections are shown in these illustrations and, owing to the form of the work, a slight difference is made in the clamps on the fixtures used for the milling operations. Figure 2 shows that to release the work from the fixture it is merely necessary

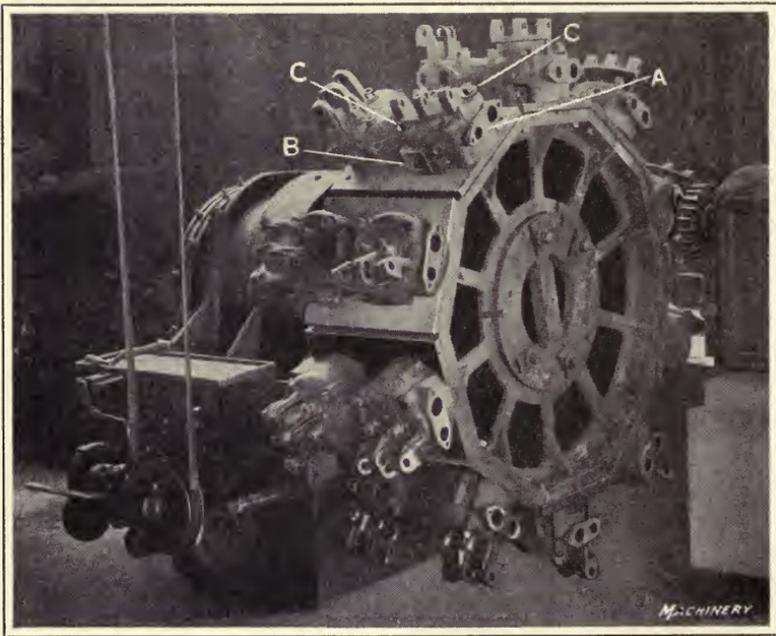


Fig. 5. Face-milling Tractor Engine Cylinder Heads

to loosen the nuts carried by the two bolts *A*. Beneath each clamp *B* there are two springs which raise it out of engagement with the work as soon as the bolts are released, and thus enable the milled piece to be withdrawn from the fixture. The rough cast surface of the work is used as a locating point. At the front, the work is supported by the lower side of the rectangular shaped face, while at the back there is a small pad *C* upon which the round flange of the water connection is carried;

and the side of this flange rests against block *D*. Members *C* and *D* of the fixture form the equivalent of a V-block which supports the thrust developed by the milling cutters and prevents the work from twisting.

For milling the type of water connections which are shown set up on the machine in Fig. 4, the same form of clamping mechanism used on fixtures shown in Fig. 2 cannot be employed, because of the bent form of the work. Consequently, the tool designer substituted U-clamps *B* in place of the combination of straps and springs which have just been described. After the nuts on bolts *A* have been slightly loosened, these clamps can be withdrawn and the work removed without much loss of time. As regards the method of locating and supporting the work in fixtures shown on this rotary table, there is little difference from the method described in the case shown by Fig. 2. At the front end, the method is exactly the same in both cases; at the back, the bent end of the work rests on block *C* and the thrust of the cutters is carried by block *D*.

Face-milling Tractor Engine Cylinder Heads. — Sufficient longitudinal adjustment of the heads is provided on the bed of the Davis & Thompson milling machine so that even in the case of work of considerable size, on which there is only one face to be milled, it is possible to construct a work-holding table of sufficient width to allow two pieces to be set up side by side in order to utilize both sets of spindles for machining the two pieces simultaneously. An arrangement of this kind is illustrated in Fig. 5, which shows a machine for facing off the two surfaces *A* and *B* on a tractor engine cylinder head. It is necessary to have these faces definitely located in relation to each other. Dowel-pins on the fixture, which enter holes drilled in the under side of the head, are used to facilitate locating these surfaces for milling. After obtaining the desired location, the work is clamped by two bolts *C* which extend up through holes in the top of the head. It will be apparent that the first operation, to mill face *A*, is performed with the casting at the right-hand side of the table; and then the work is

set up at the left-hand side of the table for performing the second operation, to mill face *B*. One man is employed to load and unload castings at each side of the table. By operating the machine in this way, the rate of production obtained is 150 cylinder heads per ten-hour working day.

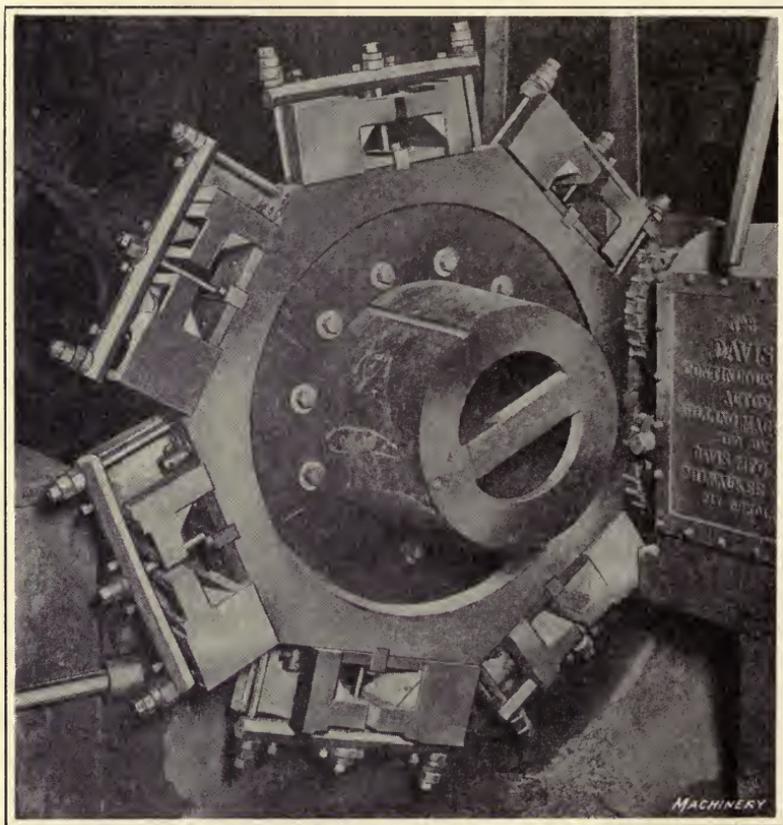


Fig. 6. Face-milling Operation on Main Bearings of Tractor Engine

Machining Main Bearings for Tractors. — Figure 6 shows a continuous rotary milling machine equipped for a facing operation on the main bearing blocks for tractor engines. In handling this work two cuts are taken, the first of which removes $\frac{1}{8}$ inch of metal and leaves approximately $\frac{1}{32}$ inch for the finish-

ing cut. The operation is performed at a cutting speed of 41 feet per minute with a feed of approximately $2\frac{3}{4}$ inches per minute, and the rate of production obtained averages 15 blocks per hour. The work-holding fixture employed on this job is of such simple design that its use will be readily understood from the illustration.

Face-milling Bosses on Bomb-container.— In Fig. 7 the machine is shown equipped for rough- and finish-milling the

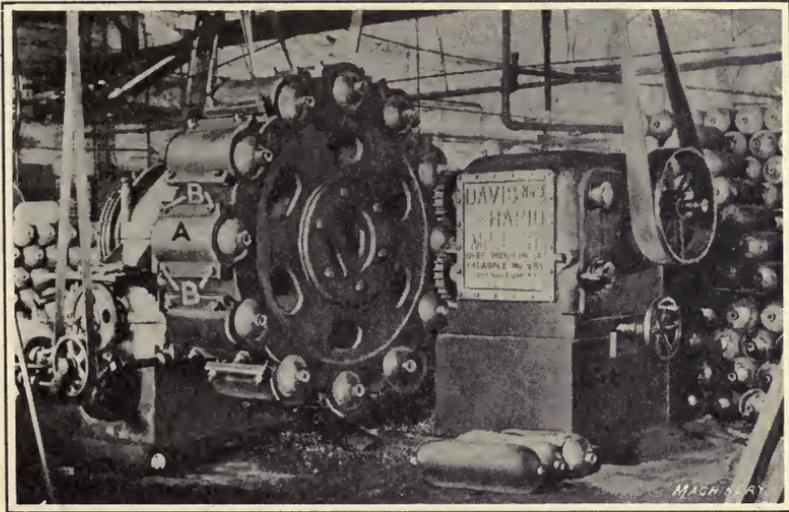


Fig. 7. Face-milling Bosses at Opposite Ends of Bomb-container

face of a boss at each end of bomb-containers of a form which is best shown by those lying on the floor at the front of the machine. These containers are made of steel, and the diameter of the boss to be milled is approximately $2\frac{1}{2}$ inches. Owing to deviations in the form of the steel castings as they come to the machine shop, the depth of cut varies from $\frac{3}{8}$ inch to $1\frac{1}{4}$ inches. In designing the machine table for this milling operation, the geared heads were arranged to drive the cutters at a speed of 43.4 feet per minute, while the rate of feed is 3 inches per minute. Two operators are employed to load and unload the fixtures. Using the machine under these conditions, the rate of production obtained is seventy milled cast-

ings per hour, or 700 in a ten-hour working day. The rotary table used on this machine is made in such a way that it is adapted for only this one milling operation. Semi-cylindrical seats, of a suitable size to carry the bomb-containers, are formed in the periphery of the table. As each piece of work is put into place, a formed plate *A* is placed over it, and four bolts *B* are tightened to secure the work. On account of the necessity of carefully locating the position of each of these

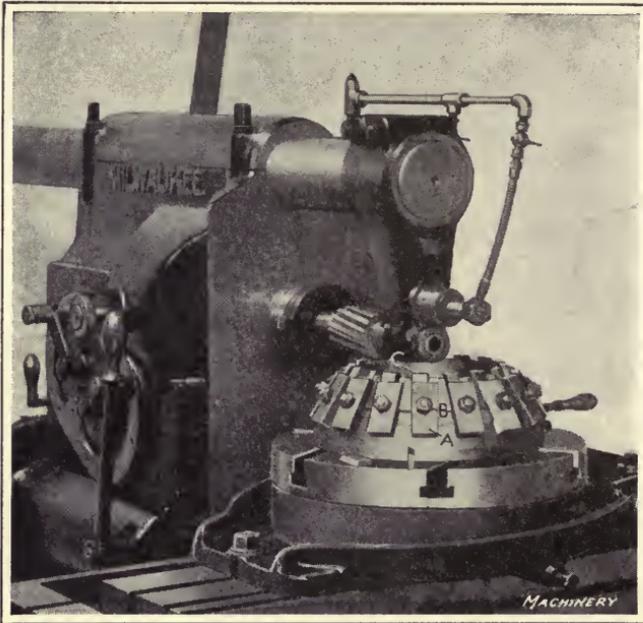


Fig. 8. Horizontal-spindle Milling Machine equipped with Rotary Fixture for Continuous Milling of Inserted-tooth Cutter Blades

pieces in its fixture by means of a gage, two operators were employed so that the machine could be kept going at a rate of feed approaching the full capacity of the milling cutter.

Continuous Rotary Fixtures Used on "Milwaukee" Milling Machines. — Both the horizontal- and vertical-spindle milling machines built by the Kearney & Trecker Co. may be equipped with rotary tables and suitably designed work-holding fixtures for use in continuous rotary milling operations. The selection

of machine will be governed chiefly by the nature of the work to be handled, but generally it will be found that vertical-spindle milling machines lend themselves better to the peculiarities of continuous rotary milling. The reason will be apparent after looking over the way in which the machines are set up for milling operations described in the following paragraphs. It will be seen that where provision must be made for milling the upper and lower surfaces of work carried by a rotary fixture, or for the performance of similar operations, a gang of cutters can often be mounted to better advantage on the arbor of a vertical machine than on a horizontal machine.

Milling Inserted-tooth Cutter Blades. — Figure 8 shows a continuous rotary milling fixture employed on a horizontal-spindle milling machine for machining a 45-degree clearance angle on inserted-tooth milling cutter blades. This is a simple operation, and requires only one plain milling cutter. The fixture is also of simple design, consisting merely of a ring in which sockets are machined to receive the work and hold it at the proper angle so that the clearance surface behind the cutting edge of the blades will be milled to the required angle of 45 degrees. Each piece of work *C* is held in the fixture by means of a strap or clamp *A* which is tightened by a single bolt *B*. As each piece comes around to the loading station, the operator has only to loosen the bolt, lift the finished piece of work out of the fixture, and substitute a blank in its place, after which the clamping bolt is again tightened. One operator can easily unload and load a fixture of this kind, and produce 2500 of these high-speed steel blades per ten-hour day.

Parts of Different Design Milled in One Fixture. — Where there are a number of different parts of somewhat similar design to be milled, a saving in the investment in fixtures and other special tools can be effected by designing a single fixture for milling several different parts. An example of this class of fixture design is illustrated in Fig. 9 where it will be seen that in addition to the work held in the fixture, there are seven other pieces of somewhat the same general form lying on the milling machine table. This work-holding fixture has

been so made that it is possible to mill all these different pieces by simply changing the positions of the bolts and clamps which secure the work in place. The necessary holes are drilled and tapped so that changes of clamps to provide for milling any of the eight different pieces for which the fixture is adapted may be easily and rapidly accomplished.

The pieces which are shown set up in the fixture are connecting link levers for the knee mechanism of "Milwaukee"

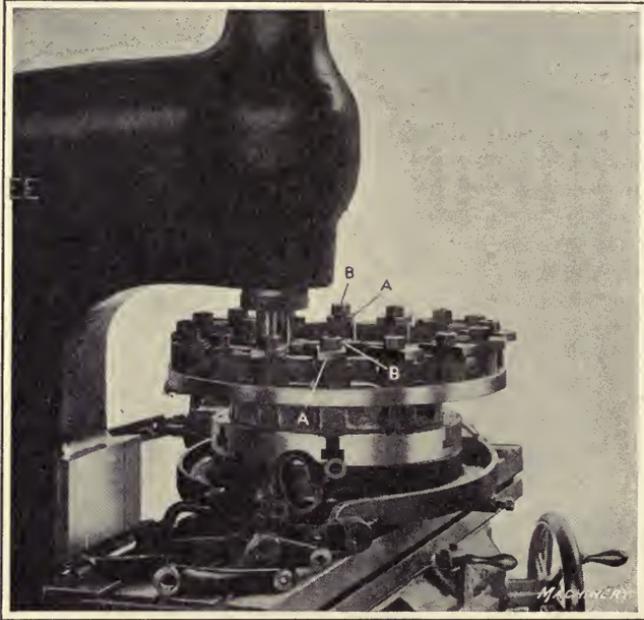


Fig. 9. Continuous Rotary Fixture with Provision for holding Different Pieces of the Same General Form

milling machines. Two operators are employed one of whom loosens the clamps and removes the milled pieces from the fixture, while the other substitutes fresh blanks and clamps them in place, ready for milling. U-clamps *A* hold the work, these clamps being so designed that it is only necessary for the operator to loosen nut *B* to withdraw the clamp. After this has been done, the hole in the work is of sufficient size to enable it to be lifted over the nut. Much time is saved by

avoiding the necessity of screwing the nut all the way off the bolt. The operation in this case consists of spot-milling the round face on an arm on the work. This face is 2 inches in diameter and the depth of cut averages $\frac{1}{8}$ inch. The material is malleable iron, and two operators engaged in loading and unloading the fixture on this machine are able to turn out 10,000 pieces in a ten-hour working day.

Fixture for Performing More than One Operation on the Same Part. — In addition to designing work-holding fixtures

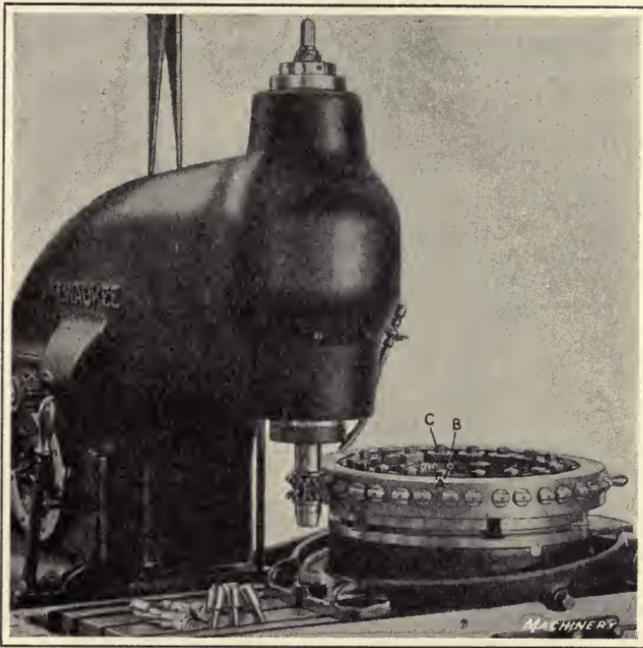


Fig. 10. Continuous Rotary Fixture designed to perform Two Successive Operations. This Illustration shows the First Milling Operation

to provide for milling operations on a number of different parts, it is often possible to use the same fixture for two or more operations on the same part. Where this practice is adopted, it will usually be found most satisfactory to mill several thousand pieces of work; and after these have been milled, it is merely necessary to change the cutters on the

arbor of the machine for the second operation, and to make subsequent changes for any additional operations which are needed to complete the work. An example of the way in which a single work-holding fixture may be utilized for two successive milling operations is illustrated in Figs. 10 and 11. The first operation on the work consists of milling the head to a semi-cylindrical form, as shown in Fig. 10; and after this

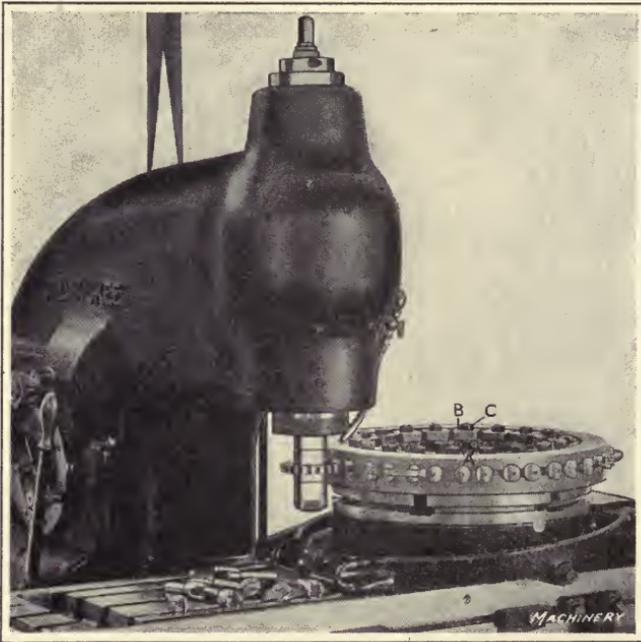


Fig. 11. Pieces milled as shown in Fig. 10 are reset in the Same Fixture at an Angle of 90 Degrees from Original Position, Ready for performing the Second Operation

has been done on all of the pieces, the work is turned through an angle of 90 degrees and set up in the position shown in Fig. 11, ready to have a slot milled transversely across the head.

The first operation is performed with a formed milling cutter, and a narrow side milling cutter is used for the second operation. The ends of the pieces that can be seen at *A* projecting inside the ring body of the fixture show how the work is clamped. Here it will be apparent that a strap *B*, actuated

by a single clamping bolt *C*, engages the inner ends of two pieces of work so that both are secured in place by one bolt. After the milling operation has been performed, it is merely necessary to loosen this bolt about one-half turn, draw the pieces of work out, and push other blanks into the holes which have been made vacant to receive them. On the first operation, the rate of production is 2000 pieces in a ten-hour work-

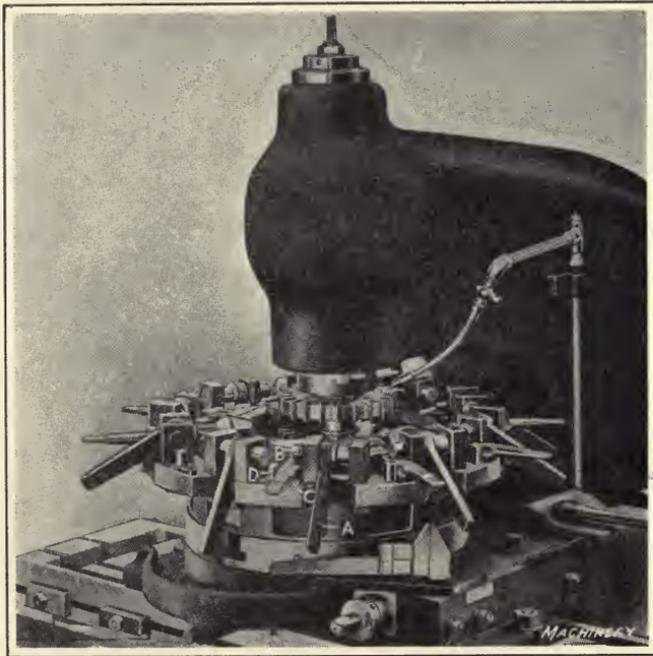


Fig. 12. Straddle-milling Side Faces of the Head and of the Movable Jaw of Adjustable Wrenches

ing day, while the second operation may be run at a higher rate of feed, making it possible to produce 3000 pieces per day. These parts are roller plungers for the feed trip on "Milwaukee" milling machines, and are made of steel. One operator is able to load and unload the fixture.

Straddle-milling Adjustable Wrenches. — In manufacturing adjustable wrenches, one maker forges the head and handle of the wrench in a single piece, and carries machining opera-

tions on the adjustable jaw up to a point where this member and the handle are ready to be assembled together. To produce tools of a satisfactory appearance, it is necessary for the side faces of the head and adjustable jaw to be at the same level. This can be done by using a vertical-spindle milling machine equipped with a gang of inserted-tooth straddle-milling cutters, and a rotary fixture of the design

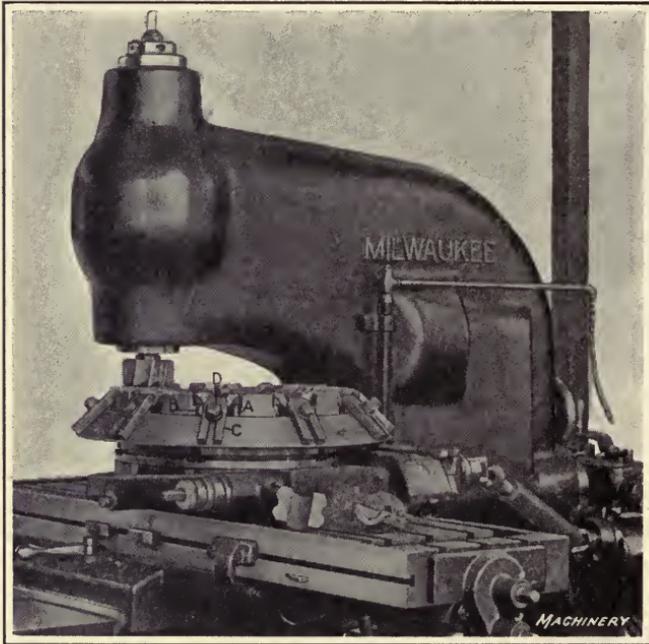


Fig. 13. Face-milling Seat of Crankshaft Bearing Caps

illustrated in Fig. 12. An important feature of the design of this fixture is the provision for extremely rapid operation. As each station on the fixture comes around to the front, after the milling operation, it is merely necessary for the operator to raise lever *A*. This lever is carried by a short stud, on the opposite end of which an eccentric *B* is mounted, this eccentric being utilized to clamp the work down on a hardened block *C*. To prevent the work from being twisted by the torque of the milling cutters, pin *D* supports the work at

one side while at the other side it is prevented from turning by the bracket carrying the stud on which lever *A* and eccentric *B* are mounted. One operator can easily load and unload this fixture because the head of the wrench is a drop-forging which necessitates a slower rate of feed than might otherwise be employed. The depth of cut on the forging does not exceed $\frac{1}{16}$ inch and the rate of production obtained is 3000 wrenches in a ten-hour working day.

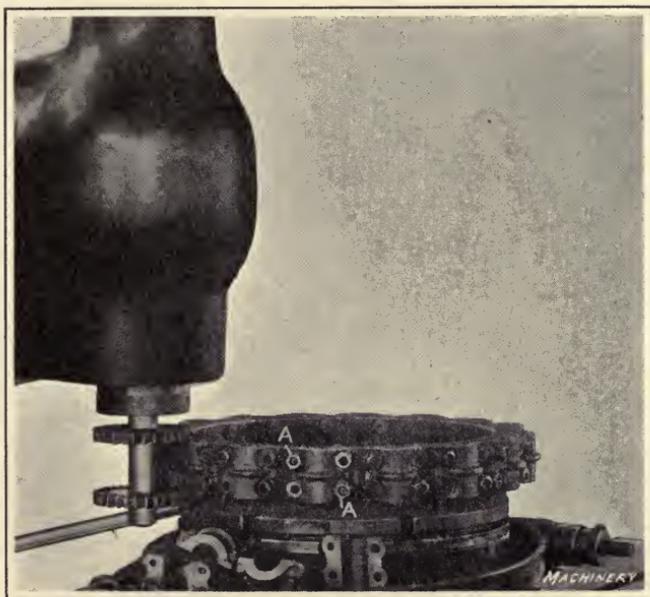


Fig. 14. Straddle-milling Side Faces of Bearing Caps shown in Fig. 13

Face-milling Seat of Crankshaft Bearing Caps. — Figures 13 and 14 show the first and second operations in milling the cast-iron bearing caps for the crankshaft of the Le Roi motor. For these two operations it was not possible to use the same fixture; the surface milled by the machine shown in Fig. 13 is utilized as a locating point in setting up the work for milling the two ends of the cap on the machine illustrated in Fig. 14. In all cases where the continuous rotary milling principle is employed, rapid production is one of the chief objects to be

obtained; and as the setting up time is frequently greater than the actual cutting time, it is desirable to have the clamping mechanism of a fixture operate as rapidly as possible. A good example of the provision for setting up and removing work with the minimum loss of time is shown by the fixture illustrated in Fig. 13. At each station in this fixture there are four pins, two of which are shown at *A* and *B*, and each of these pins supports the work under the flanges at each end. Two U-clamps *C*, which are secured by bolts *D*, hold the

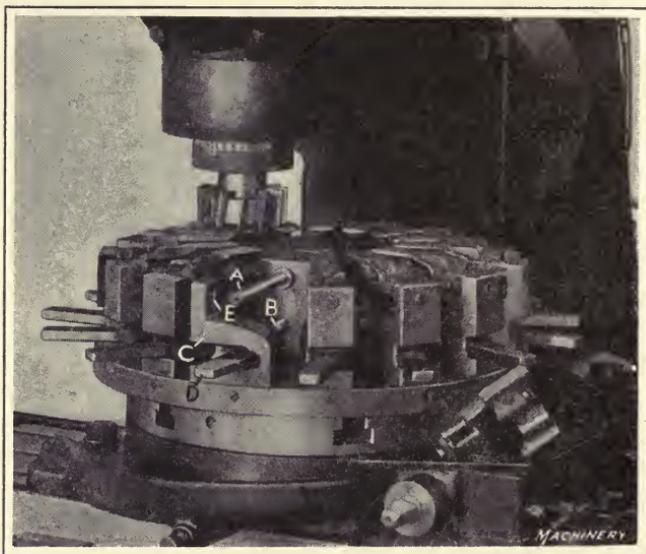


Fig. 15. Face-milling Plunger Pump Bases on Continuous Rotary Milling Machine

work down. The rate of production secured is 5000 castings in a ten-hour day.

After the milling has been done, a half turn of each of the bolts *D* will loosen the clamps sufficiently so that they can be drawn back, thus enabling the milled piece to be removed from the fixture and another casting substituted. The surface milled on the machine shown in Fig. 13 is used as the locating point for the second operation on these bearing caps. It will be apparent that the two ends of the work are simultane-

ously milled by means of a pair of straddle cutters (see Fig. 14), and that the milling fixture consists merely of a ring carried by a rotary table, which is furnished with bolts to secure the castings in place on the fixture. In this case, it was impossible to avoid having the length of time required for setting up and removing the work rather longer than might be expected. The holes through the bearing caps are not large enough to provide clearance for nuts used in conjunction with slotted washers, so the two nuts *A* used for holding the work have to be screwed all the way off the bolts. Even so, the rate of production obtained is 5000 castings per day with a depth of cut averaging $\frac{1}{8}$ inch, taken from each of the end faces.

Face-milling Plunger Pump Bases. — Continuous rotary milling is especially adapted for machining pieces of moderately small size, but frequently face-milling can be done on machines equipped with rotary fixtures. Figure 15 shows a vertical-spindle "Milwaukee" milling machine used at the plant of the Madison-Kipp Lubricator Co., Madison, Wis., for machining the bases of pump bodies. The pieces to be milled have two holes drilled in them, which are utilized as locating points by slipping the work over pilot *A* and pin *B*. At each station there is also a supporting bracket *C*, which is pivoted so that it may be swung around behind the casting and then pushed inward by means of an eccentric at the end of lever *D*. Hole *E* in the bracket receives the outer end of pilot *A*, thus helping to steady the work and eliminating vibration. In milling these faces, the average depth of cut is approximately $\frac{1}{8}$ inch, and the size of surface to be milled is 2 by 3 inches. With one operator engaged on the machine, these gray iron castings can be milled at the rate of 800 per ten-hour working day.

Straddle-milling Shanks of Tappet Valves. — Figure 16 illustrates a vertical-spindle milling machine with a rotary fixture for milling two flats at the end of the shank of steel tappet valves for a motor. The design consists simply of two V-blocks at each station, which receive the shanks of the valves,

and a strap *A* and clamping bolt *B* which hold both pieces of work in place. The maximum depth of cut in this instance is only $\frac{1}{8}$ inch, so the machine can be run at a high rate of feed. The setting-up time, therefore, becomes the determining factor in production, and in order to operate the machine under the most favorable conditions it is necessary to have three operators engaged in removing milled valves and substituting fresh blanks in their places. Used in this way, one machine is able to mill 25,000 valves in ten hours.

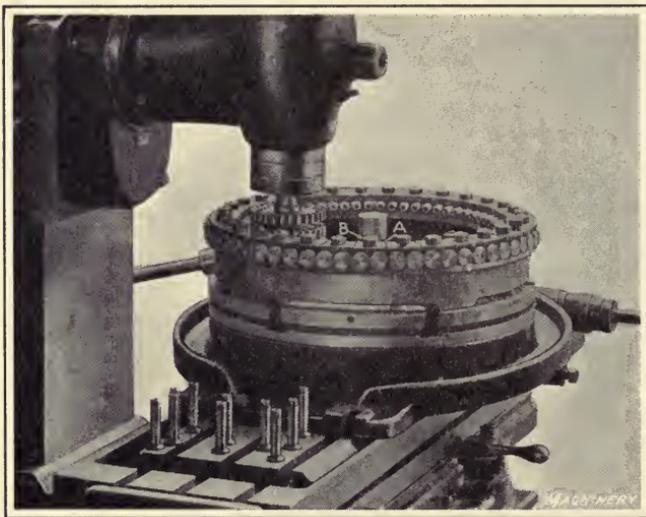


Fig. 16. Straddle-milling Two Flats on Shanks of Tappet Valves

Continuous Rotary Milling on Becker Machines. — Vertical-spindle milling machines built by the Becker Milling Machine Co., are used in many plants in connection with rotary tables for applying the continuous principle to milling operations. Where work has to be milled at both ends, an important feature of the equipments designed and built by this company is that an auxiliary vertical spindle may be provided on the machines, so that it is unnecessary to reset the work for a second operation on the opposite end from that previously milled. Despite careful designing of the clamping mechanism

on work-holding fixtures, it often happens that the setting-up time exceeds the milling time; hence it will be obvious that the possibility of eliminating a second setting of the work is likely to be the means of greatly reducing production costs. In several of the following examples of the tooling up of these vertical-spindle milling machines for operation on the continuous rotary principle, it will be seen that a gang of two or more cutters is mounted on the spindle for milling several surfaces on the work simultaneously. Where an auxiliary spindle is

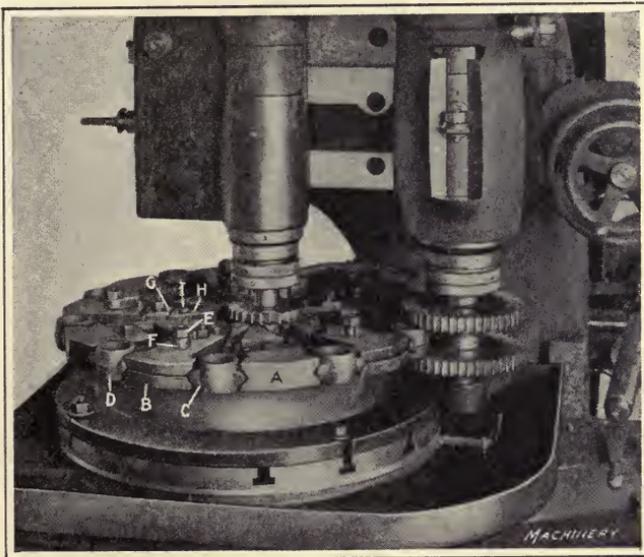


Fig. 17. Continuous Rotary Milling Machine equipped with Auxiliary Spindle for straddle-milling Both Ends of Connecting-rod Forgings simultaneously.

provided on the machine, the application of a gang of cutters on each of the two spindles provides a method of milling many classes of work by which the cost of the production is doubtless kept close to a minimum.

Careful designing of the fixture will often increase the rate of production obtained in the milling operation. For instance, consider the case shown in Fig. 17, where a machine is illustrated set up for milling the faces of bearings at both ends of automobile engine connecting-rods. For handling this job.

the designer adopted the use of an auxiliary spindle on the machine so that both ends of the connecting-rods could be milled simultaneously. Then he went a step further by setting up two milling cutters on each spindle, in order to make provision for milling both sides of the connecting-rods at the same time. The arbors are piloted at their lower ends to maintain accurate alignment and perfect rigidity. After it had been placed in service, the designer made a slight change in working out the details of this fixture as used for machining motor connecting-rods, shown in Fig. 18.

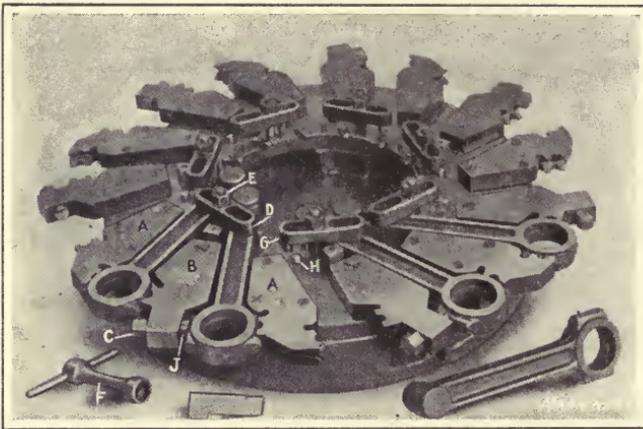


Fig. 18. Fixture for straddle-milling Both Ends of Motor Connecting-rod Forgings simultaneously

Designing Fixtures to Reduce the Load on Clamps. — In the case of the fixture shown set up on the machine in Fig. 17, it will be seen that each connecting-rod is placed in a radial position and the rotary table on the machine is arranged to run in a clockwise direction. Provision is made for carrying ten forgings in the fixture. As the connecting-rod forgings are fed under the cutters, the milling operation on one end of a piece of work is completed before the opposite end is fed up to the cutters. As a result, the cutters exert a thrust on the work first in one direction and then in the other, which imposes an unnecessarily severe load on the clamps. To reduce this load, the equipment was designed as shown in Fig.

18, so that the pieces of work are located tangentially instead of radially. As a result, the two sets of cutters which mill the opposite ends of each connecting-rod come into simultaneous engagement with the same piece of work, thus neutralizing practically all of the thrust which the different cutters impose on the work in opposite directions, and relieving the clamps on the fixture of a great part of the strain to which they would otherwise be subjected. To secure this neutralization of the thrust on the work, it is necessary to have the milling cutters revolve in opposite directions.

A brief description of the way in which the work-holding clamps on each of these fixtures operate will prove of interest. Referring first to Fig. 17, it will be seen that the large ends of the connecting-rods are held at each side by V-blocks which fit around the bosses provided on the forgings to receive the bearing cap bolts. A solid block *A* is rigidly bolted to the body of the fixture, while block *B* is split horizontally through the middle, forming a fixed lower plate and a removable upper plate. In loading this fixture, two connecting-rods, say *C* and *D*, are put in place or removed at the same time. Provision is made for rapidly raising the upper plate of clamp *B* by simply loosening nut *E* about one turn and then swinging back the pivoted C-washer *F*. When this is done, the plate can be raised sufficiently so that the milled connecting-rods *C* and *D* can be lifted out of the vees and rough forgings substituted in their places. After these forgings have been put into position, the upper plate of clamping member *B* is dropped, thus providing for gripping the boss on each side of the new forgings in the V-blocks, and the work is securely held at this end after C-washer *F* is swung into place under nut *E* and the nut is tightened. Each pair of connecting-rods is held at the opposite end by means of a sliding wedge which is pushed between the small ends of the forgings to force them into contact with the sides of blocks which are bolted to the fixture.

Movement of the wedge point is accomplished by means of an intermediate plate which is best shown at *G* in Fig. 17.

This plate is beveled on its inner edge to engage a corresponding beveled face on the outer edge of wedge *H*. Tightening the nut above plate *G* forces the plate downward, and the beveled edge of plate *G* acting against the beveled face of wedge *H* forces the wedge between the inner ends of the connecting-rods, thus holding them firmly in place against the sides of the fixed blocks. Each of the wedges *H* is held on the body of the fixture by a screw *I*, which fits into an elongated hole. This arrangement provides for holding the wedge in place and at the same time allows it the necessary lateral movement.

How Quick-acting Fixtures Increase Production. — On the fixture shown in Fig. 18 two forgings are set up at one time, as in the preceding fixture. Fourteen forgings are carried by the fixture, and the pieces are milled on four surfaces. The machine is operated with a feed of 4 inches per minute and forty forgings are machined per hour. The work is done on a two-spindle machine, with two cutters on each arbor to provide for milling all four surfaces on the work simultaneously. In this case, each pair of connecting-rod forgings is held by two clamp members *A*, which are securely bolted to the fixture, and a pivoted clamp member *B*. The illustration shows that these clamps are made with vees to receive the bosses on the forgings in which the bearing cap bolt holes are to be drilled. When two forgings have been dropped into place in the fixture, bolt *C* is tightened, pushing the connecting-rod forging in front of clamp *B* up firmly into contact with clamp *A*. At the same time, clamp *B* swings back on its pivot to provide for securely clamping the connecting-rod forging behind this clamp against the second clamp *A*. At the inner end the forgings are secured by a strap *D*, held down by nut *E*, which is tightened by a T-wrench *F*. Provision is made for eliminating the possibility of straps *D* being set in a position where they will interfere with the milling cutters. Two forgings are held in place in this fixture by simply tightening bolts *C* and *E*, so that the operation of setting up the work is extremely rapid. The small block *G*

and pin *H*, provided at each station on the fixture, fit into the channel in the connecting-rod forging; block *G* constitutes an end-stop for locating the work, while pin *H* affords a support for the forging to prevent it from being sprung by the pressure of the cutter.

A better idea of the construction of clamping bolts *C* will be obtained by referring to Fig. 19. Here it will be seen that the bolts *C* are threaded into the tapped holes in V-blocks *J*, which slide in holes machined in the pivoted clamps *B*, to

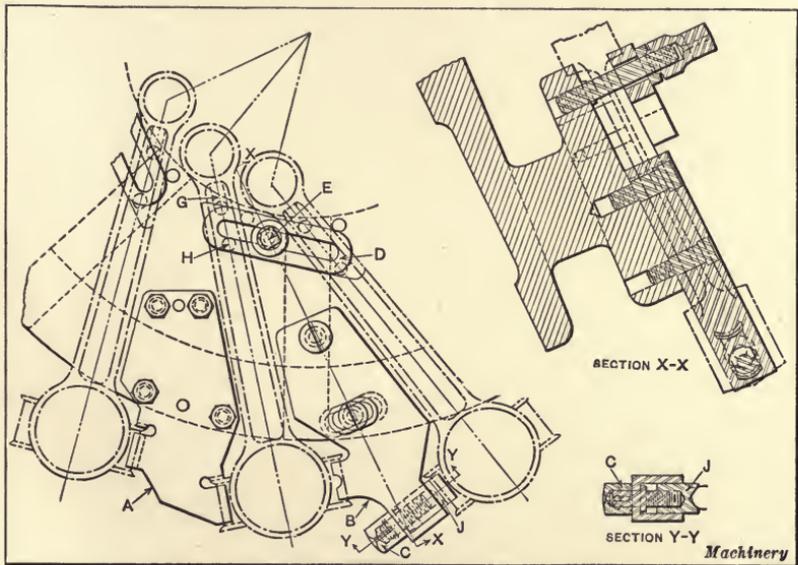


Fig. 19. Details of Work-holding Fixture shown in Fig. 18

come into engagement with the large ends of the connecting-rods and secure them in place in the fixture.

Application of Continuous Rotary Milling Principle to Machining Large Pieces.— Although continuous rotary milling is especially adapted for machining pieces of relatively small size, the method may also be used for larger pieces. Figure 20 shows a fixture designed for machining the differential gear housing for an automobile. The work is malleable iron, and each casting weighs approximately 40 pounds. In this case only two pieces are set up in the fixture at one time, the method

of operation being such that the single large face-milling cutter is working on one casting while the operator is removing the other piece which has just been milled and substituting a fresh casting in its place. Each of the two stations on the work-holding fixtures is equipped with two trunnion cradles

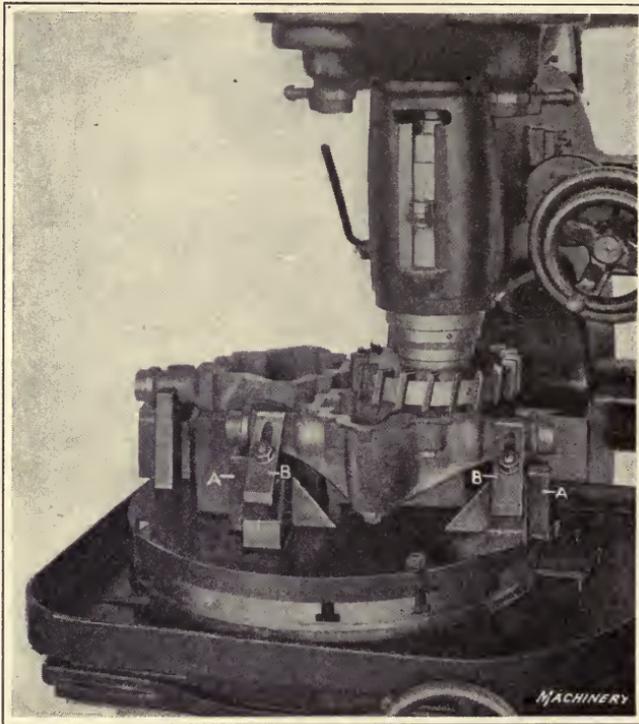


Fig. 20. Milling Differential Gear Housings showing an Application of the Continuous Rotary Principle to milling Large Castings

A, so that the work can be dropped into place and held down by means of straps *B* at each end. In this case the table is arranged to rotate in a counterclockwise direction so that the milling cutter first engages the work at the side nearest to the center of the table. To prevent the work from rotating, each of the castings is supported on the inner side, so that the pressure of the milling cutter cannot cause these castings

to rotate on their points of support. The rate of production is twenty-two pieces per hour.

Face-milling Aluminum Crankcases. — Figure 21 shows a fixture designed for facing off the underside of an aluminum

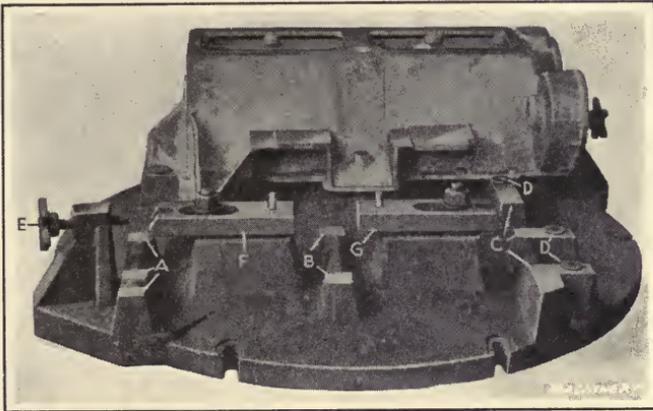


Fig. 21. Continuous Rotary Fixture designed for performing a Face-milling Operation on Aluminum Crankcase Castings

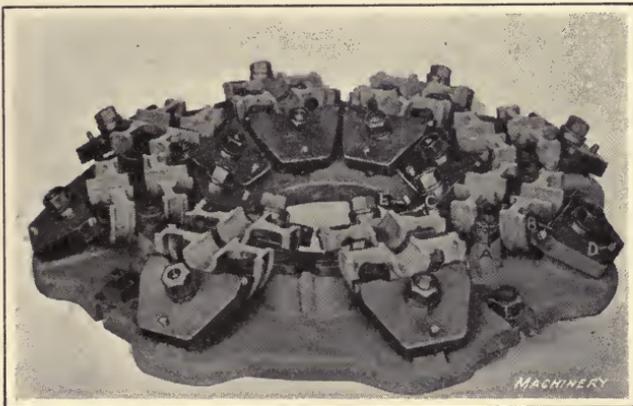


Fig. 22. Face-milling the Joint between Two Halves of Fan Pulley Castings

crankcase on a single-spindle milling machine equipped for operation on the continuous rotary principle. One crankcase casting is shown set up in place, and at the front of the fixture is illustrated the way in which the work is secured in position

for milling. Only two castings are held by this fixture. The underside of the castings has already been face-milled, and this surface is used as the locating point, finished pads *A*, *B*, and *C* on the fixture being employed for this purpose. The casting is dropped into place on these pads and end-stops *D*, which are beveled on the underside, hold the casting down on the locating pads when clamping screw *E* is tightened. When the work has been set up the operator reaches in through

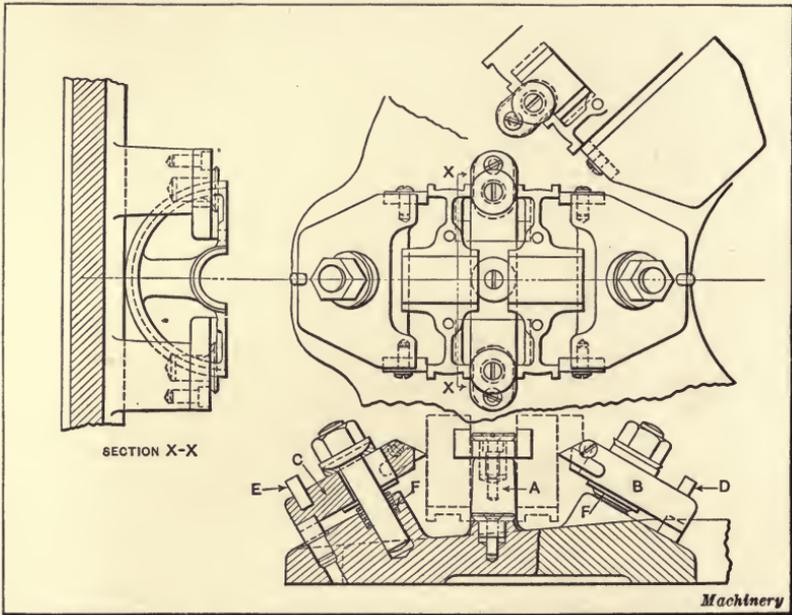


Fig. 23. Details of Fixture illustrated in Fig. 22

holes in the side of the crankcase casting and tightens straps *F* and *G* to hold the work securely down on the fixture for milling. The estimated rate of production is three pieces per hour.

Face-milling Joint between Two Halves of Fan Pulley Castings. — Figures 22 and 23 show a continuous milling rotary fixture designed for use in machining the joint between the two halves of fan pulleys. This fixture holds sixteen pieces of work, and is arranged in a somewhat different manner from those already described. It will be seen that each sta-

tion on the fixture is so designed that two halves of a pulley are supported side by side, and the single-spindle machine used in this case is provided with a face-milling cutter of sufficient diameter to extend over the entire joint surface of both halves of the pulley, as they are fed under the spindle. In this case the method of clamping is quite simple. Located

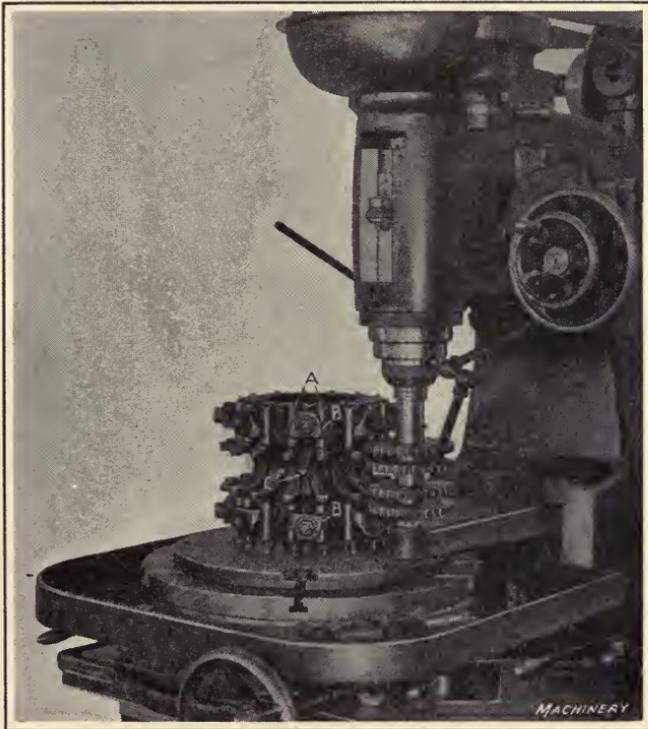


Fig. 24. Fixture designed to hold Automobile Engine Clutch Shifter Yokes for simultaneously milling Four Faces

between each pair of half pulleys there is a fixed clamping member *A* and, in setting up the work in the fixture, the two pieces are placed in contact with this central clamping device. After this has been done, outer clamp *B* and inner clamp *C* are brought up into contact with the work and tightened by means of a bolt on each of these clamping members. In this way the work is forced in against the central clamping block *A*

and held firmly in position ready for the milling operation. Clamps *B* and *C* slide on pins *D* and *E*, respectively, to prevent them from turning, and the clamps are set at an angle to provide for forcing the work down into the fixture. Springs *F* Fig. 23, are placed under the clamps to raise them out of

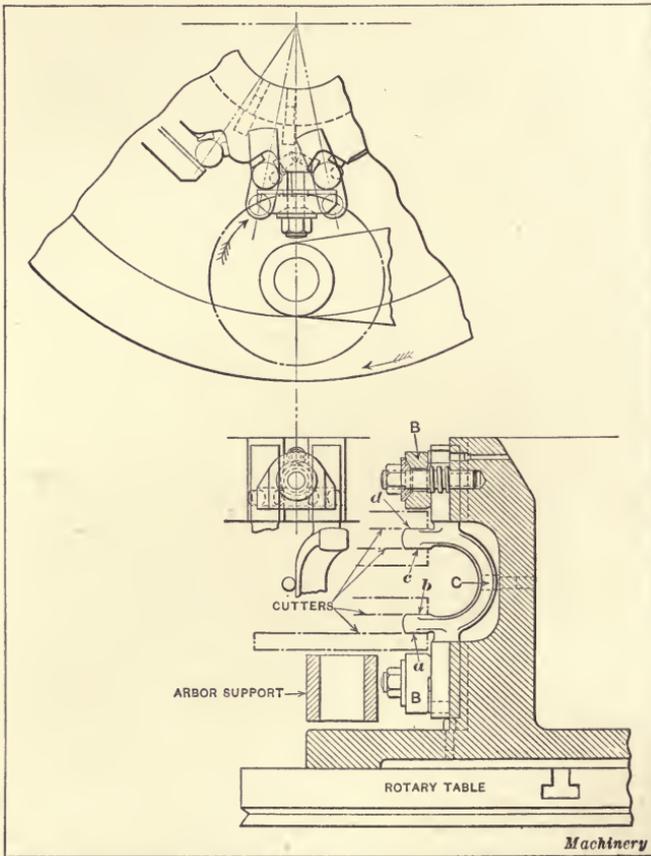


Fig. 25. Details of Work-holding Fixture illustrated in Fig. 24

engagement with the work when the bolts are loosened, thus increasing the speed of operation. By simply tightening two bolts two pieces of work are secured in position on the fixture, so that it is possible to set up the work for milling and remove it without entailing much loss of time. The output is more than sixty pieces per hour.

Simultaneously Milling Four Faces on Clutch Shifter Yokes.

— Figure 24 shows a Becker single-spindle milling machine equipped with a continuous rotary fixture designed for machining a clutch shifter yoke. Here it will be seen that a gang of four face-milling cutters are properly spaced for simultaneously milling off faces *a*, *b*, *c*, and *d* of the yoke, as shown in Fig. 25. The faces to be milled are about $\frac{3}{4}$ inch in diameter

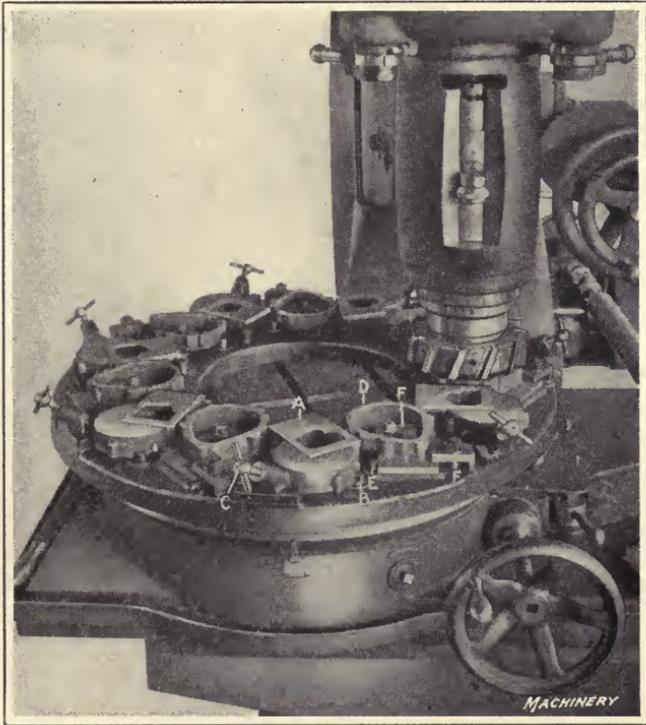


Fig. 26. Fixture for milling Automobile Starter Covers

and the maximum depth of cut is approximately $\frac{3}{16}$ inch. The arbor is piloted at its lower end to maintain accurate alignment and to prevent vibration. Before the work is set up in the fixture illustrated in Fig. 24, the trunnions have been turned and these are used as the locating points in setting up the work for milling. The fixture, which holds sixteen forgings, is provided with upper and lower V-blocks in which

these trunnions are held. Above each pair of vees there is a spring clip *A* which holds the work in position until the clamping device on the fixture has been tightened to secure the work for milling. Two pieces are set up in the fixture and removed at the same time. After the forgings have been pushed under spring clips *A*, clamps *B* are tightened to secure the two forgings in the V-blocks. Rotation of the forgings due to the torque of the milling cutters is prevented by pins *C* against which the sides of the yoke forgings come into contact. By straddle-milling the four faces on these pieces simultaneously, the rate of production is 195 shifter yokes per hour. A better idea of details of the fixture design will be obtained by referring to Fig. 25. Attention is called to the springs for releasing clamps *B* when the bolts are loosened.

Milling Both Sides of a Cover Plate. — In Fig. 26 is illustrated a fixture designed for facing both sides of an automobile starter cover on a machine equipped for continuous rotary milling. In working out the design, it was found that ample production could be obtained from one single-spindle machine. To enable it to be operated continuously without changing the fixtures for milling the two sides of the work, the fixture was designed with provision for milling one side of the starter cover while held at one station and then transferring this piece of work to an adjacent station on the fixture ready for milling the opposite side. The illustration shows that alternate stations are arranged for holding the work for the first and second operations, respectively, and the fixture can hold seven pieces of work in each position.

For the first operation, the work is set up to mill face *A*, and for this purpose the under side of the rough casting is located against three stops *B* which constitute the equivalent of a vee into which the casting is forced by means of clamping screw *C*. This screw is pointed both inward and downward, so that tightening it serves the double purpose of forcing the work into the vee formed by the three locating stops, and of holding the work down on the faces of these stops. After the first operation, the work is turned over, ready for milling sur-

face *D*. For this purpose the milled surface *A*, which was finished during the preceding operation, constitutes the locating point, and the work is clamped down on a pad on the fixture which engages surface *A*. Stop-pins *E* prevent the work from slipping away from the pressure of the cutter, and the work is held down by means of two straps *F*. The locating spots that hold the work for milling face *D* are at a height above the plugs that support the work while milling face *A*, which is equal to the depth of cut taken at the second opera-

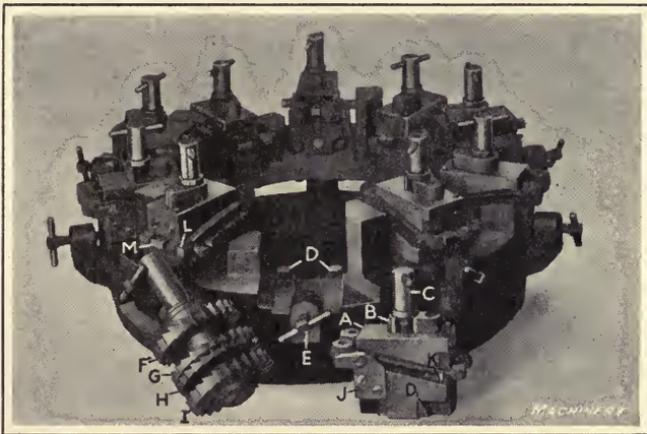


Fig. 27. Continuous Rotary Milling Fixture with Reversible Work-holding Blocks which provide for straddle-milling Opposite Ends of Offset Brake Levers

tion on face *D*. The production is sixty pieces per hour, completely milled on both sides.

Reversing Setting of the Work for Performing a Second Operation. — In Fig. 27 there is illustrated an ingenious method developed for milling the faces of bearings at opposite ends of an offset type of hand-brake lever. This job is done on a single-spindle machine. Here the method of procedure is first to mill both faces of one bearing, after which the work is reversed end for end to mill the faces of the bearing at the opposite end of the levers. The continuous rotary milling fixture has stations for holding twenty of the forgings to be milled. The illustration shows the gang of cutters which is

used for these two milling operations. These cutters are so mounted on the piloted arbor that spaces are left of the proper width for milling the faces at opposite ends of the work. The interesting feature of this fixture is the provision for reversing the work end for end, and still having the milling cutters properly located to take care of the offset on the brake levers. At each station two brake levers are mounted in a block, these pieces of work being held down by a cover plate *A* which is tightened down on the work by first adjusting the position of a C-washer *B* and then tightening clamping screw *C*.

The work-holding block is pushed in against two locating plugs *D*, which are beveled in such a way that they serve the double purpose of locating the block in the desired position and holding it down on the fixture when capstan screw *E* is tightened. The two forgings are located in the block by a wedge *M* which forces them into contact with a pin *K* and lug *J*. Lug *J* and lug *L*, which is at the opposite end of the block, are so placed that they take the thrust of the cutters. The block is first pushed into position with the large end of each brake lever on the inside, so that this end of the work comes into place between cutters *F* and *G*. After the work has been milled at this end and the work-holding block has come around to the loading position, it is released by loosening clamp screw *E*, and the block is next turned end for end and secured in that position in the fixture. Then, when the rotary table has again brought the work around to feed under the cutters a second time, the small end of the brake levers goes between cutters *H* and *I* which are properly spaced to provide for milling the faces at the small end of the work. The work of setting up and milling these forgings can be handled very quickly. The actual output is more than eighty brake lever forgings per hour, which are completely milled on four surfaces.

Fixture for Milling Clutch Shaft Bearings. — Figure 28 shows the use of a continuous rotary milling fixture designed for facing off the base of clutch shaft bearings. This fixture has capacity for holding sixteen pieces of work. In order to

provide for machining the bases of these parts exactly level, which is an essential feature, an interesting form of equalizing device was developed. On each clutch shaft bearing there are two bosses *A* supported by plungers *B* in such a way that they provide for leveling up the work. When the milling cutter faces off the under surface, it will be apparent that this surface will be parallel with bosses *A*. At their lower ends plungers *B* are secured to a block *C* and this block also carries a C-shaped plate *D* which serves as the equivalent of a C-washer for clamping nut *E*. To set up a piece of work

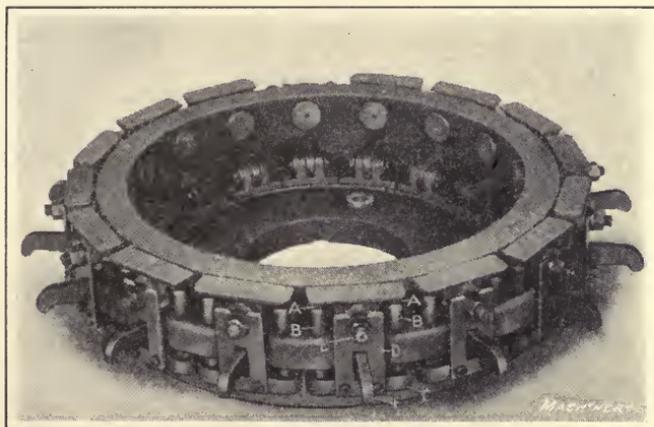


Fig. 28. Continuous Rotary Milling Fixture with Equalizing Device for locating Clutch Shaft Bearings

in this fixture, the casting is dropped into place after which lever *F* is raised, this lever being pivoted at a point on the inside of the main casting of the fixture. As a result of raising lever *F*, plungers *B* level up the work and at the same time plate *D* is slipped under nut *E*. Then by simply tightening this nut about one-half turn, the work is secured in place ready for milling. It is possible to secure a high rate of production with a fixture which can be operated so rapidly. The operation is performed on a single-spindle machine with one face-milling cutter carried on the arbor.

Fixtures for Milling Six Surfaces on Spring Shackles. — In Figs. 29 to 32, inclusive, there are shown two fixtures used for

milling six surfaces on cast-iron spring shackles of the form shown in Figs. 29 and 31. In milling these parts, four steps are required. With the work set up in the fixture shown in Figs. 29 and 30, using two straddle-milling cutters mounted on a single-spindle machine, the first step is to mill faces *A* and *B*. Then the shackle on which these faces have been milled is turned over in the fixture and again carried between the milling cutters for facing off surfaces *C* and *D*. The next step is to take the partially milled shackle to machines equipped

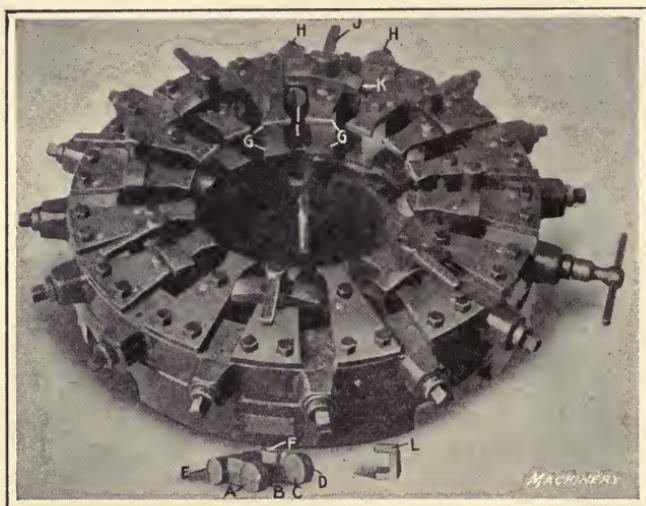


Fig. 29. Fixture designed for straddle-milling Faces *A*, *B*, *C*, and *D* of Spring Shackles

with fixtures of the type shown in Figs. 31 and 32. These single-spindle machines are equipped with one facing cutter, and at the first revolution of the fixture, surface *E* is milled. The work is then turned over, and at the second revolution of the fixture, surface *F* is finished, thus completing the milling operations.

The details of the design of the work-holding fixtures and method of handling the work are as follows: Figures 29 and 30 show that the fixture holds sixteen spring shackles. Each shackle is dropped into one of the stations of this fixture with

the arms projecting inward, and steel plates *G* are arranged to bear against the sides of the upper and lower bosses on which it is required to mill four surfaces, *A* and *B* or *C* and *D*, with the work set up in this fixture. Endwise location is accomplished by having either surface *E* or *F* rest against the bed of the fixture. Two shackles are dropped into place in the fixture or removed at the same time. After two cast-

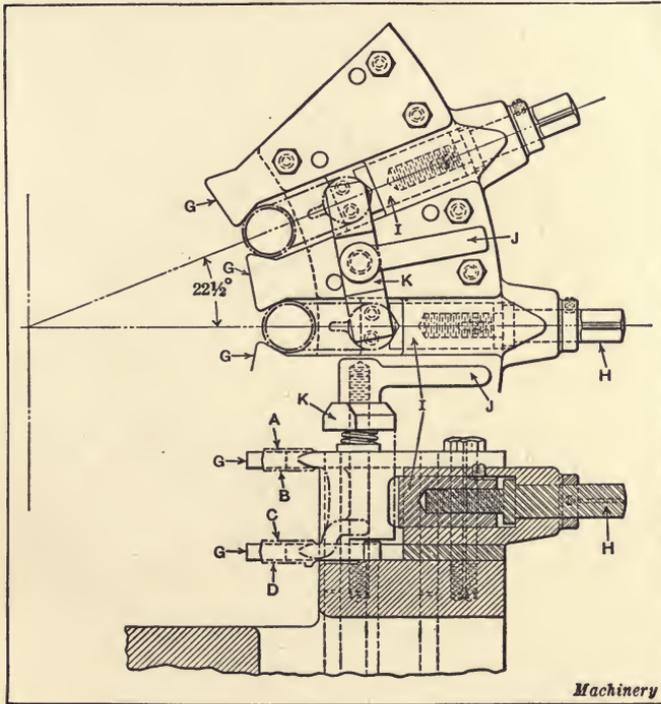


Fig. 30. Details of Work-holding Fixture shown in Fig. 29

ings have been put into place, screw *H* is tightened. Figure 30 shows that each of these screws is threaded into V-blocks *I*; the ends of these V-blocks will also be seen in Fig. 29. By tightening screw *H* the two pieces of work are forced inward so that they are engaged by the tapered ends of plates *G*. Lever *J* is then thrown over. This lever operates a quick-acting cam mechanism which tightens strap *K* down on surface *E* or *F* of the work, as the case may be, thus securing it

in place for milling. After surfaces *A* and *B* have been milled, the work is turned over end for end and surfaces *C* and *D* are milled at the next revolution of the work-holding fixture. The material is cast iron and the fixture is rotated at a speed which feeds the work to the cutters at a rate of 4 inches per minute. The rate of production, milling four surfaces, is more than eighty pieces per hour. At *L* there is shown a gage used for checking the accuracy of the distance between faces *A* and *B* or *C* and *D*, as this dimension has to be held within specified limits. For the two final milling operations on these

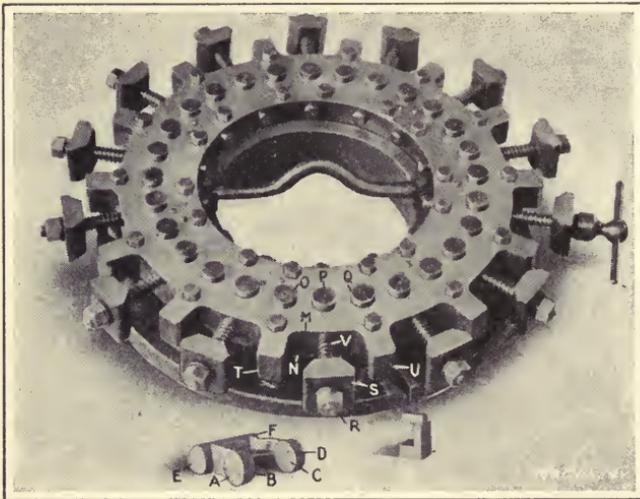


Fig. 31. Continuous Rotary Milling Fixture for milling Faces *E* and *F* of Spring Shackles

spring shackles, surfaces *B* and *C*, Fig. 30, are used as the locating points. These surfaces straddle a finished ring extending all the way around the fixture, Figs. 31 and 32, so that they are in close contact with surfaces *M* and *N* machined on the upper and lower sides of the ring. This provides for end-wise location of the work, to obtain the desired relationship between all of the six milled surfaces. For clamping the work, the spring shackle castings are slid inward until engagement is made with plugs *O*, *P*, and *Q*, which form the equivalent of

two V-blocks. As in the case of the preceding fixture, two spring shackle castings are set up or removed at a time. After the work has been pushed into place between plugs *O* and *P* or *P* and *Q*, nut *R* is tightened to bring strap *S* against the backs of the two spring shackles. This strap is tapered on its inner side so that provision is made for clamping the two pieces of work between the two tapered surfaces on strap *S* and corresponding tapered surfaces on lugs *T* and *U* which

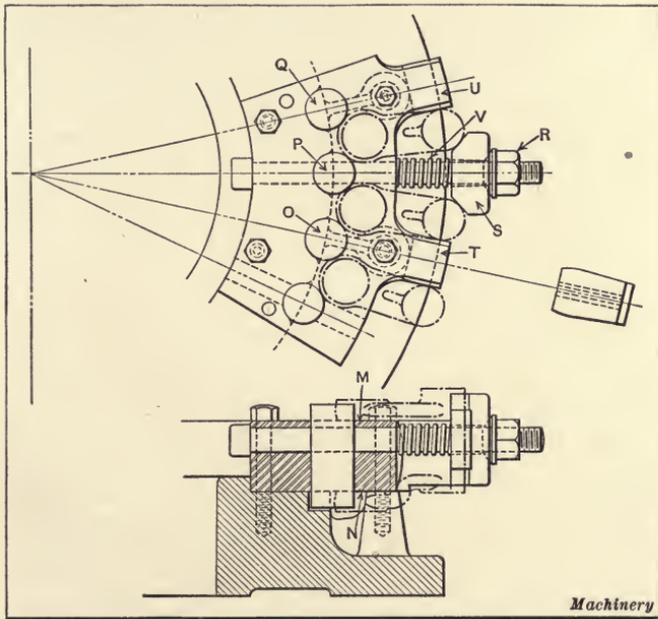


Fig. 32. Details of Work-holding Fixture shown in Fig. 31

project out from the body of the fixture. A compression spring *V* is located behind each of the straps *S*, so that in removing the work it is merely necessary to loosen nut *R*, and the strap is automatically pushed back from the work by the spring. The fixture is designed to hold twenty-eight pieces of work. After surface *E* has been machined the work is turned over end for end to provide for milling surface *F*. The fixture feeds the work to the cutters at 4 inches per minute. In performing these two operations the rate of production is sub-

stantially more than eighty pieces per hour. A single-spindle milling machine is used with one face-milling cutter on the arbor.

Rotary Milling on Gould & Eberhardt Machines. — Continuous rotary milling machines built by Gould & Eberhardt

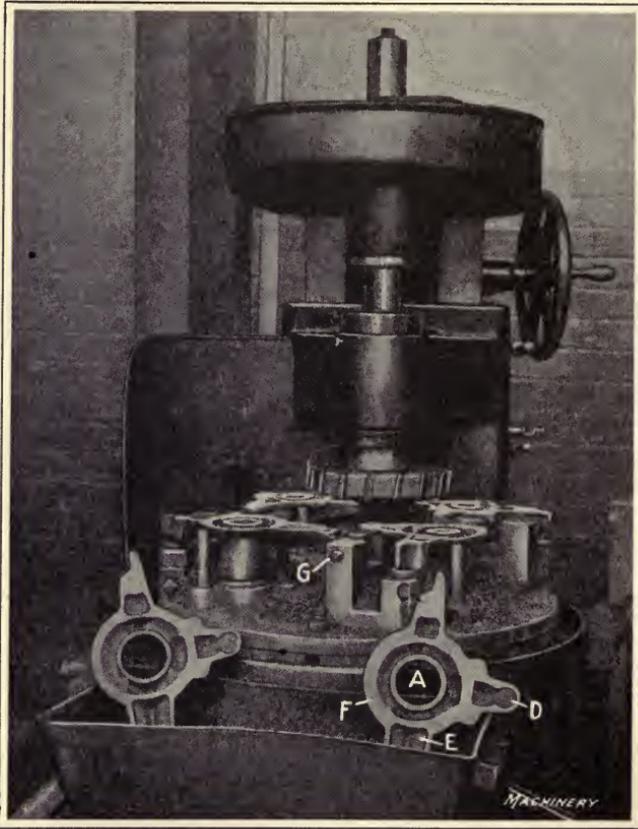


Fig. 33. Fixture for face-milling White Metal Pump Casings

are in a sense an evolution of their gear-hobbing machines. It was necessary to modify many features of the design, but in a general way the first rotary milling machine followed the same general construction as the gear-hobbing machines. For instance, the same patterns were used for molding the

castings for the beds of both types of machine, and other standardized units of the hobbing machine were employed in the milling machine construction. Experience showed, however, that continuous rotary milling machines had to withstand more severe service than gear-hobbing machines, so the

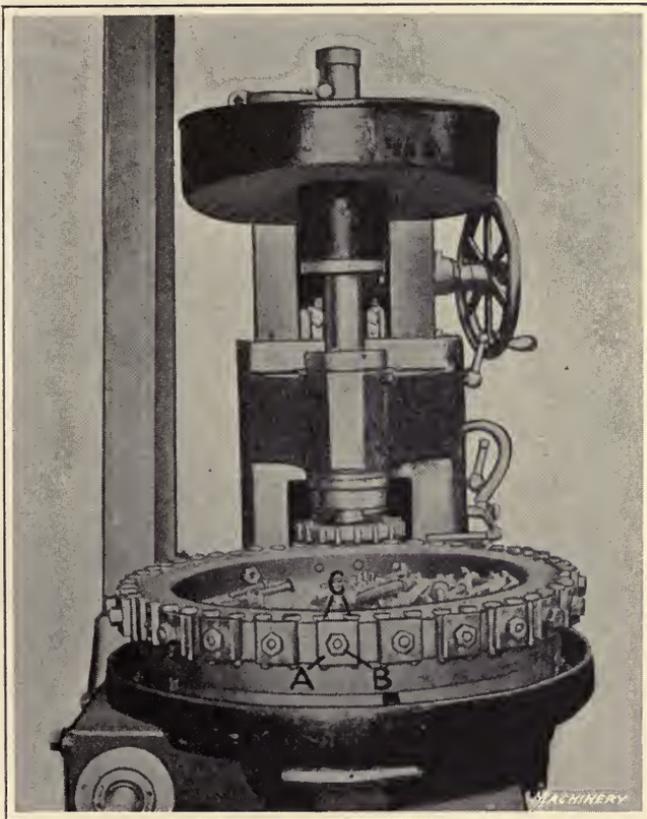


Fig. 34. Continuous Rotary Fixture for straddle-milling the Ends of Wrist-pins

design of the latter was revised to afford the required rigidity at points where unusually severe stresses must be carried.

It will be seen from Figs. 33 and 34 that the spindle head is mounted on the column with sufficient adjustment so that the head may be set in any desired relation to the work for

using a single face-milling cutter, a gang of straddle-milling cutters, or any other combination required for the most rapid production of various classes of work. In place of the work-holding table which supports the gear blank on a hobbing machine, a rotary table was furnished on the milling machine, on which a continuous circular work-holding fixture may be mounted. The method of driving this table and of adjusting its position on the bed of the machine are similar to the method of driving and adjusting the table of the standard gear-hobbing machines of this company's manufacture.

Range of Work Handled. — Figures 33 to 40 will give a good idea of the classes of work which can be handled on this type of continuous rotary milling machines, and also of the methods of setting up and operating. These examples of shop practice have been selected with several ideas in mind. In the first place, they show fixtures used for milling a variety of different sized pieces, ranging from the white metal pump castings shown in Fig. 33, of which only four may be mounted in the fixture at a time, up to the wrist-pins shown in Fig. 34, of which forty-eight can be held at a time. Other interesting features are the variety of methods adopted for holding the work, and the various combinations of cutters used.

The work-holding fixture shown on the machine in Fig. 33 consists of a pilot at each station on the fixture, over which the previously bored work is dropped, and four posts which engage the under side of the various overhanging sections of the work to prevent them from being distorted by the pressure of the milling cutters. Frequently it is desirable to adopt the principle of mounting work on the upper surface of a continuous rotary fixture, but the more generally applied method is to hang the work around the periphery of the fixture so that it may be passed between cutters mounted on the arbor. The latter method is usually applied where there are several surfaces on the work to be milled by means of a gang of straddle-milling cutters. Such a fixture is shown in Fig. 37, where it will be seen that there are four surfaces *A*, *B*, *C*, and *D* on the work to be milled by means of a gang of straddle-milling cut-

ters. In this case sufficient overhang is provided to allow the work to be fed between such a gang of cutters without any danger of interference with the fixture.

Milling White Metal Pump Casings. — In the case of the white metal pump casings shown in Fig. 33, hole *A* has been finish-bored when the castings come to the machine. This hole is utilized as a locating point, the castings being dropped over pilots on the fixture which fit closely into holes *A*. For any face-milling operation, the work must be so supported that there is no danger of the pressure of the milling cutters causing the work to be sprung out of shape, thus producing subsequent trouble in assembling. Support for the work in face-milling operations is especially important in the case of pieces with overhanging arms, flanges, etc., which are likely to be deflected through the application of pressure if poorly supported. The pump casings shown in Fig. 33 are a typical example of such work, because the three arms, *C*, *D*, and *E* and the flange *F* must be supported from beneath. After each casting is dropped over the pilot, it slides down until the arms and flanges of the work are engaged by posts projecting up from the bed of the fixture. Then cap-screw *G* is tightened to clamp the work. As each casting is adequately supported from underneath and the entire pressure of the milling cutters is downward, it is merely necessary for this screw to prevent vibration from having a tendency to raise the work off its supporting points.

Face-milling Connecting-rods on Continuous Rotary Machines. — At the plant of the Ford Motor Co. in Walkerville, Ont., continuous rotary milling machines of this type are tooled up as shown in Fig. 35 for facing off the surfaces of crankshaft bearing yokes, which are left rough at the time the rods are forged. This illustration shows that there are ten stations on the fixture, in each of which two connecting-rod forgings may be mounted so that a total of twenty forgings are set up. To hold two forgings in place it is merely necessary to place them behind strap *A* and tighten bolt *B*. The forgings to be milled will be seen at *C*, and in setting up these forgings

two pins (not shown in the illustration) fit into the wrist-pin bearing at the lower end of each forging. This provides for supporting the thrust of the milling cutter, and when strap *A* has been tightened back on the work, the operator gives the pieces no further attention until they come around to the

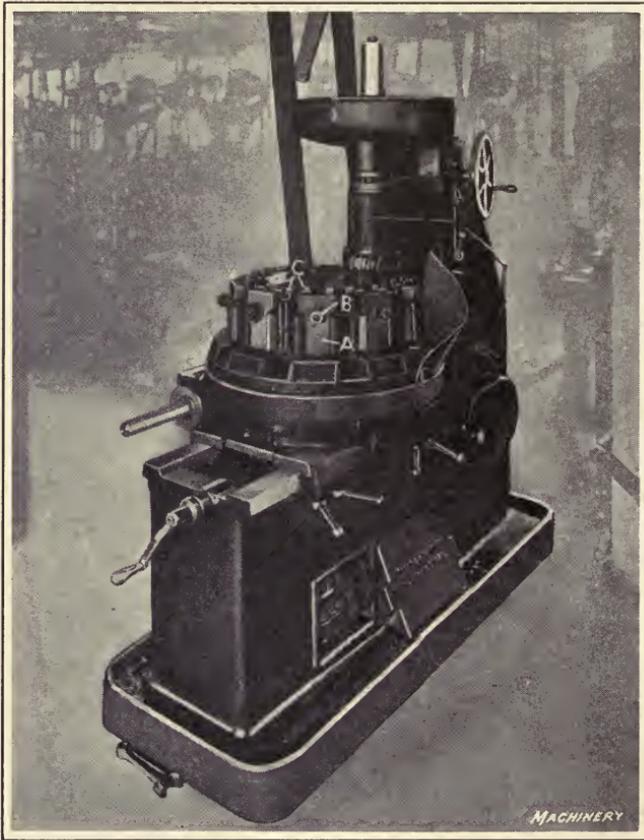


Fig. 35. Continuous Rotary Milling Machine equipped for face-milling Ends of Yokes on Connecting-rod Forgings

loading point again, milled and ready to be removed from the fixture. As it is merely necessary to loosen bolt *B* slightly to remove the work, very little time is consumed.

Rough-milling the Teeth of Bevel Gear Blanks. — Generating planers of the type built by the Gleason Works are used

at the Ford Motor Co.'s plant in Detroit, Mich., for cutting the teeth of ring bevel gears. It was believed that production on this job could be facilitated by first roughing out the teeth of the gears; and for use in this rough-cutting operation, Gould & Eberhardt designed and built continuous rotary mill-

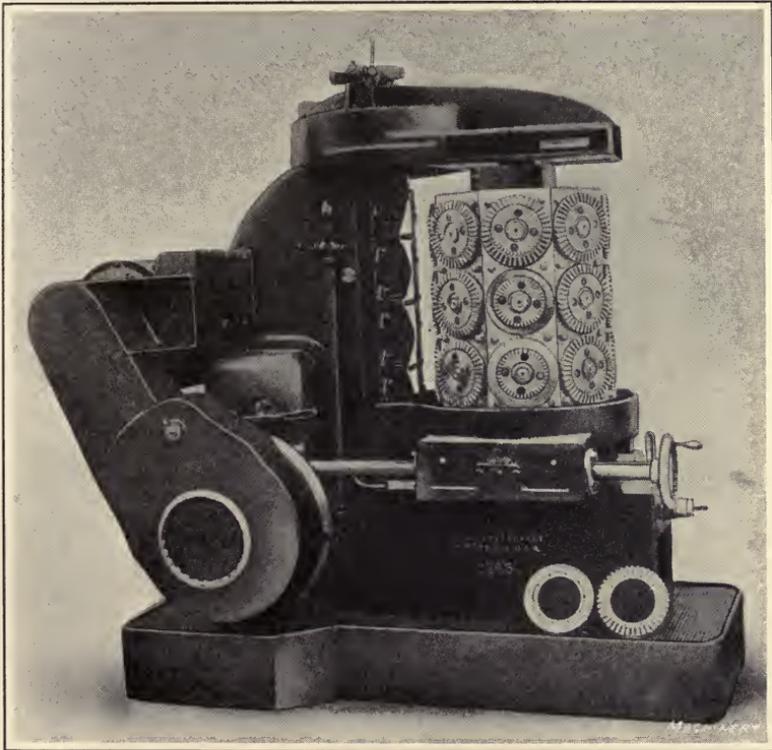


Fig. 36. Continuous Rotary Milling Machine for rough-cutting Ring Bevel Gear Teeth

ing machines of the type shown in Fig. 36. The gear blanks are supported on an octagonal shaped turret with three blanks mounted on each face, giving a total carrying capacity of twenty-four pieces of work. A spindle mounted in the column of the machine carries three rotary gear-cutters for milling one tooth space at each side of each gear blank for every revolution of the turret. After the turret has completed each

revolution, all of the gear blanks are indexed through one tooth space, the entire action being automatic, so that the operator is merely required to load and unload the work-holding fixtures. The amount of time which the cutters are at work represents but a small percentage of the complete circumference of the circle through which the work rotates. Consequently, it is necessary to have a rapid traverse movement of the turret during the idle period, and a suitable feed movement while the cutters are at work.

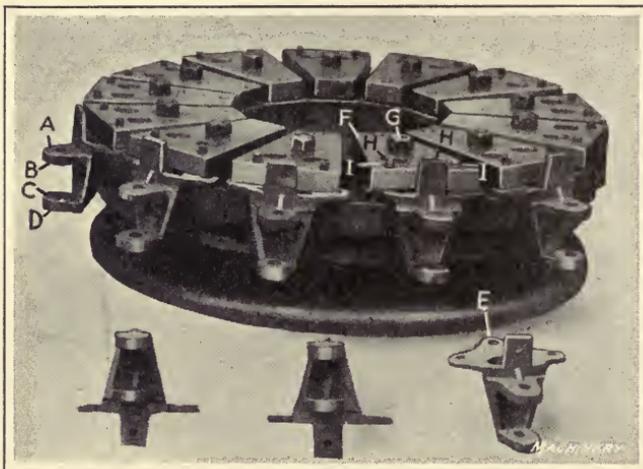


Fig. 37. Continuous Rotary Fixture for supporting Castings on which Faces A, B, C and D are to be milled simultaneously

The work is fed to the cutters at a speed of from 15 to 16 inches per minute, while a speed of 112 inches per minute is employed for traversing the turret during the period that the cutters are passing across the central space of each bevel gear ring or across the space between gears mounted on the adjacent turret faces. The ring gears are 8 inches pitch diameter and have forty 5-pitch teeth with a face width of 1 inch. They are made of vanadium steel drop-forgings. The gear cutters are $5\frac{1}{2}$ inches in diameter and run at a cutting speed of 140 feet per minute. Approximately 0.010 inch of metal is left to be removed from the sides of the teeth by the Gleason gear

tooth planer. In operating the Gould & Eberhardt milling machines, the gear blanks are set up in rotation so that they are finished in consecutive order instead of having all of the twenty-four blanks carried by the turret finished at one time. This keeps the machine operator constantly employed setting up blanks and removing finished gears from the machine, instead of having to shut down the machine while twenty-four finished gears are removed and the same number of blanks set up in their places. One operator is able to attend to two machines used under these conditions, and the rate of production is one rough-cut gear in approximately three minutes.

Straddle-milling Wrist-pins. — For milling wrist-pins for the Ford motor, use is made of continuous rotary milling machines equipped with fixtures shown in Fig. 34, which have a capacity for holding forty-eight pins. There are twenty-four stations on the fixture, each of which is furnished with a clamping strap *A* held against the work by a single bolt *B*. Two wrist-pins *C* are held by the strap, so that both pieces of work may be set up and held in place on the fixture by merely tightening the bolt *B*. Semi-cylindrical shape pockets are machined around the periphery of the fixture to receive the pieces of work, and similar pockets are milled on the inside of straps *A*. As these pockets fall just short of being a full half cylinder, two pieces of work can be clamped between the strap and body of the fixture by tightening a single bolt. As it is merely necessary to loosen bolt *B* about one-half turn in order to lift the two wrist-pins *C* out of the fixture and substitute other blanks, the fixture can be manipulated rapidly.

Supporting Castings for Milling Four Faces Simultaneously. — A fixture is shown in Fig. 37 used in straddle-milling the faces *A*, *B*, *C*, and *D* of two lugs on cast-iron brackets, which are carried on the periphery of the fixture with sufficient overhang to allow the work to come between a gang of four straddle-milling cutters on the milling machine arbor. The piece of work seen lying in front of the fixture in this illustration shows that there is a flange *E* which extends backward, and this flange is used as the supporting member for clamping the work.

Each casting is held in place on the fixture by means of a strap *F*, held down by a bolt *G*. With the strap loosened, flange *E* on the casting is pushed back under the strap until it comes into engagement with two stops carried in holes *H*. Then bolt *G* is tightened to press the strap firmly down on the work. There is a considerable amount of overhang between bolt *G* and the outer end of strap *F*, which might cause trouble through having the strap apply an insufficient amount of pressure on the work. To overcome possible difficulties from this



Fig. 38. Fixture for milling Work of Similar Form to that shown in Fig. 37

cause, two set-screws *I* are tightened down on the work, thus taking up any possible lost motion resulting from the springing of the clamp.

The fixture used in milling surfaces *A*, *B*, *C*, and *D* on cast-iron brackets of the form shown in the foreground of Fig. 38 is of similar design to the one described in connection with the preceding illustration. In this fixture, the work is also supported by means of a flange *E* which is slid under clamp *F*. Each of these clamps *F* has a notch *G* which receives rib *H* on the work to locate the piece properly in the fixture. After each piece of work has been milled, it is merely necessary to loosen bolt *I*; then a spring located beneath the clamping

strap *F* raises the strap out of engagement with the work so that the milled piece may be withdrawn and a fresh casting substituted. The fixture rotates in a clockwise direction, and it will be seen that a pin *J* is located just behind each piece of work, to carry the thrust of the milling cutters as the work is fed between them, and thus prevent the position of the work from shifting, or undue strain from being placed upon the clamps of the work-holding fixture.

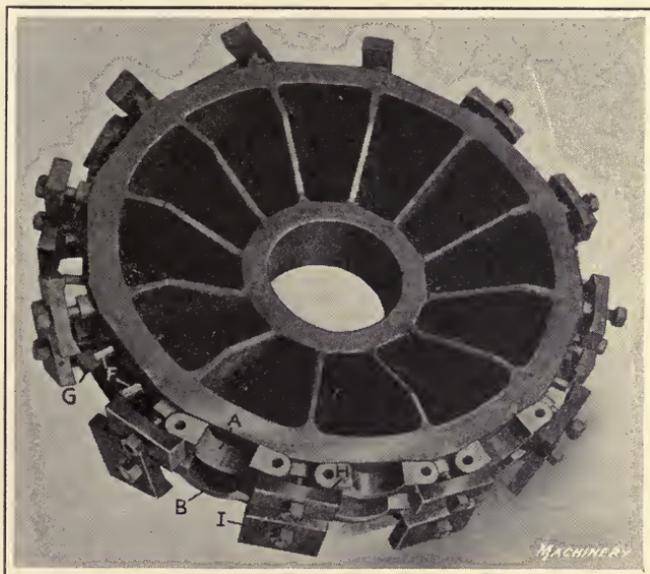


Fig. 39. "Double-deck" Continuous Rotary Fixture used for face-milling the Seats of Bearing Caps shown at *A* and *B*

Milling Bearing Caps. — Continuous rotary milling machines are used at the plant of the Touraine Co., of Philadelphia, for face-milling bearing caps of the forms shown set up on the fixture in Fig. 39. Bearing caps *A* and *B* are of different design, and in order to explain the milling operation performed on them, attention is directed to Fig. 40 which shows the work in more detail. These malleable iron bearing caps are clamped in fixtures mounted around the periphery of the rotary fixture. On casting *A* there are two surfaces *C* and *D*

to be milled, while on casting *B* there is but a single face *E* to be milled. The machine is equipped with a gang of three cutters to provide for straddle-milling the two faces on casting *A* and facing off the upper surface on casting *B*. The supporting and clamping mechanisms are of quite simple design. Castings *A* are supported by two pins *F*, while castings *B* are supported by two blocks *G*. Straps *H* which hold castings *A* on the fixture must be slightly narrower than the work, to

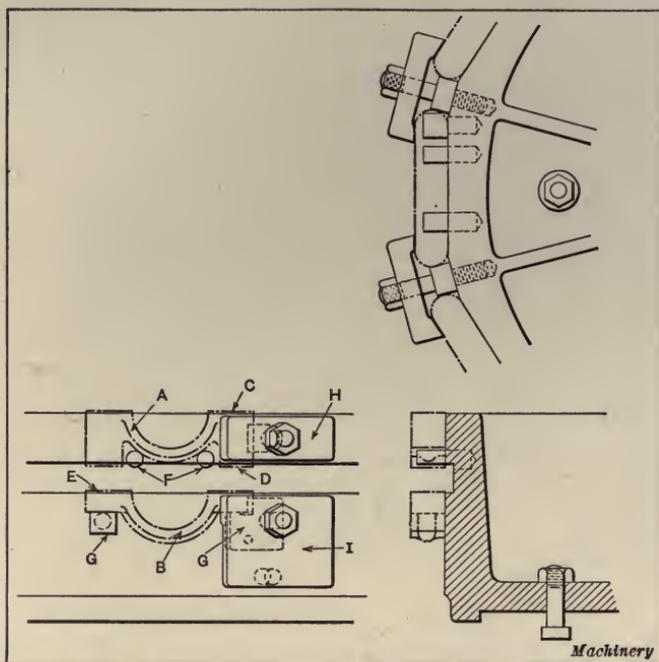


Fig. 40. Details of Work-holding Fixture shown in Fig. 39

allow the straddle-milling cutters to reach both surfaces *C* and *D*. This precaution need not be observed in making straps *I*, because it is merely necessary to have the strap engage the work at points slightly below the level of the upper surface *E*. With this fixture it is only necessary to loosen the bolts slightly that hold straps *H* and *I*, and then the castings may be lifted off their supporting points, *F* and *G*, respectively, and removed from the fixture.

Desirability of Continuous Rotary Milling from the Standpoint of Production Obtained. — In deciding upon the best methods for new milling operations, and in designing auxiliary equipments for the milling machines, decisions will in all cases be governed by the features of the work which indicate that preference may properly be given to some specified method of milling. Where a plant is engaged in the quantity production of duplicate parts, and more especially where these parts are of small or medium size, the continuous rotary milling principle will often afford maximum production. Any experienced mechanic who has studied the nature of the different operations which are explained in this chapter will recognize that in these cases very satisfactory rates of output have been obtained. The instances which have been cited are those where the continuous rotary milling principle has shown up to good advantage. At the same time, the results obtained in these cases are by no means exceptional. They are good enough, however, to warrant giving the continuous rotary method careful consideration at a time when a decision is being reached concerning the method of milling new pieces of work which appear to be of a nature that could properly be handled in that way.

CHAPTER IV

PLANER MILLING PRACTICE IN AUTOMOBILE PLANTS

ALTHOUGH the term "planer type" generally designates milling machines with a long table which conveys a number of pieces of work past milling cutters carried by heads supported on the cross-rail and housings, it is probably more accurate to call such machines multiple-spindle milling machines. They are especially adapted for milling large pieces of work, and are usually designed to meet the particular requirements for continuous use on one class of work. For instance, machines of this type are generally used in milling motor car crankcases, cylinder blocks, cylinder heads, etc., and in almost every case the milling machine builder has been furnished with designs of the parts and detailed information as to the daily production required, the average depth of cut to be taken on the different surfaces that must be milled, etc. With these data, he is able to design a machine which has the necessary number of spindles for milling the different finished surfaces on the work, and which is structurally adapted for the service required.

Data concerning the number of parts per day is needed by the milling machine designer because, if there is a large number of parts to be milled, the rate of production at once becomes an important factor; hence it will be well worth while for the plant investing in multiple-spindle milling machines to obtain equipment designed to mill as many surfaces as possible simultaneously. On the other hand, if the kind of work is limited in quantity, it may be better to perform several independent operations on one or more machines of simpler and less expensive construction. In the latter case, a more complicated equipment might turn out the required production in, say, half of a full working day, but as the machine was

especially designed for a specific class of work, it would lie idle for 50 per cent of the time, resulting in a poor return on a heavy investment.

Features of Multiple-spindle Milling Machines. — Owing to the fact that the work-holding fixtures for multiple-spindle milling machines are usually designed and made in the plant of the milling machine builder, they are generally better adapted for the work than fixtures designed by less experienced men for other types of milling machines. In this treatise, fixtures and methods for milling operations are illustrated and described, with a brief review of the general characteristics of the types of machines on which the work is to be done. As the general characteristics of the standard types of milling machines are matters of general mechanical knowledge, machine design has not been taken up in detail. In the case of fixtures used on other types of milling machines, certain criticisms of the fixture design are sometimes warranted. These fixtures for use on the multiple-spindle machines, however, have been designed by experts and are in practically every case ideal for their work. The classes of work described in this chapter are some of the types which are advantageously milled on multiple-spindle machines used in automobile factories.

In operating multiple-spindle milling machines, a number of fixtures are set up on the table, so that a "string" of castings may be passed between the milling cutters on the machine. Owing to the large size of the pieces to be milled, it is generally necessary to employ a machine operator and a helper to set up and remove the work, and these two men follow a definite routine. It is quite a general practice to start the machine immediately after a casting has been set up in the fixture nearest to the milling cutters. Then the operator and his assistant will proceed to set up castings in each of the other fixtures, starting with the fixture next to the one in which the first piece was mounted. After all of the fixtures have been loaded, one or two of the pieces carried at the front end of the table will have passed under the cutters, so the men immediately remove these milled pieces. Idle

time of the operator is thus eliminated, because he does not first load the fixture and then remain idle while the work is being fed under the cutters, as is the case with some types of single-spindle machines. About the only lost time of the operator is that period during which the last piece of work is being fed past the cutters.

When all of the fixtures have been emptied, the table is quickly returned to its starting position by the power-driven rapid traverse movement. Then the operators immediately set up another piece of work in the first fixture and use the rapid traverse to run this piece up almost into engagement with the milling cutters, after which the feed movement is engaged. The operators then start to reload the remaining fixtures in the order which has already been explained. The idle time of the machine also is thus cut down to a minimum, which comprises the period required to unload the last piece of work, return the table to the starting point, and set up the other casting in the first fixture. Machines of this type, therefore, although they are usually quite expensive, are able to attain a very high rate of production and thus pay a good return upon the investment.

Importance of Care in Designing Work-holding Fixtures. — Equal care must be given to the designing of the work-holding fixtures and the machines on which they are to be used, if maximum operating efficiency is to be obtained. On average classes of work, it is possible to operate multiple-spindle milling machines at a feed of from 8 to 9 inches per minute, and in working out the fixture design, this factor must be constantly borne in mind. In other words, the tool designer must first determine the amount of time it will take to feed each piece of work past the cutters, and then work out the design of all adjustable supporting points and clamping mechanisms on the fixture in such a way that the machine operator and his assistant will be able to set up a piece of work ready for milling within the time required to feed another piece of work past the cutters. Otherwise the setting-up time becomes the limiting factor in determining the quantity of production.

Application of the Three-point Suspension Principle.— Multiple-spindle milling machines are used for both first and second operations on the work, and the design of fixtures will naturally be governed by the nature of the operation to be performed. The pieces milled on these machines are usually of considerable size, so where the first operation is to be performed with the work located on the fixture on a rough-cast or forged surface, it is usual to employ what is known as a "three-point suspension" bearing. This is based upon the familiar principle of geometry that three points determine a plane. To use a simple comparison, a three-legged stool will stand firmly on a floor, regardless of how rough it may be; but a four-legged stool will have one leg off the floor and be liable to rock about, if there is any lack of uniformity in the surface. It is exactly the same way in setting up a rough casting for the first machining operation; with the three-point suspension, the casting is sure to be firmly supported, but if four or more supporting points are used, the casting is likely to tilt out of place. In some cases, the cast surface of the work may be used as a locating point, while in other instances it may be desirable to cast bosses on the work, which come into contact with locating points on the fixture.

The location obtained for a first operation of this character is not extremely accurate, and in almost every case the method of procedure is to use the finished surface milled by the first operation as the locating point in setting up the work for subsequent operations, thus bringing other finished surfaces into an accurate relationship with the one first milled, and consequently with each other. The first finished surface, therefore, should be held within close limits of accuracy. To accomplish this, the work must be fully supported at all points. In the case of such pieces as cylinder blocks, special means of support are not usually necessary, because the form of the work is such that there is little danger of deflection resulting from the pressure applied by the milling cutters. For milling crankcases and other work of this general character, however, where the castings are thin, and where there are flanges and arms on the

work, which have considerable overhang, all such unsupported members must be held in a way which will adequately resist the cutting pressure.

Compensation for Variations in Size of Forgings and Castings. — As the work is being located from a cast or forged surface, and as there may be as much as $\frac{1}{8}$ inch variation in a casting, or $\frac{1}{16}$ inch variation in a forging produced under the best possible conditions, fixed supports cannot be provided on the fixture to come into engagement with the work. The three points of the three-point suspension bearing are fixed, but all other supporting members must be made adjustable, so that after the casting is dropped into place on the three fixed points, these adjustable points can be brought up into engagement with the work and then clamped in this position. Commonly used forms of construction for this purpose are to have either plungers supported by compression springs, or plungers which rest upon a sliding tapered surface at their lower end, with a screw for the purpose of manipulation. Where either of these designs is used, the plunger is brought up into engagement with the section of the work which it is to support and then firmly clamped in position by a screw. After the first operation has been performed, the milled surface may be used as a locating point for subsequent operations. If this surface has been milled without springing the work, there will be a perfectly plane surface to use for locating the piece ready for the next operation; consequently, any required number of points may be provided on the fixture to afford the necessary support. It is usually important to provide for locating the work in certain other directions also, depending on the form of the pieces being milled.

Cutting Speeds for Planer Milling Machines. — Sixty feet per minute probably represents an approximate average of the speeds at which cutters are commonly driven on planer-type milling machines. If the cutters are properly designed, and the necessary precautions taken to provide for the dissipation of heat generated in cutting the metal, it will be found that this figure can be increased. The contention is made that the

chips usually produced by cutters on machines of this type are fine, and that each edge of the tool is usually in action for not more than 5 per cent of the running time; that is to say, each edge on the cutter is working for 5 per cent of a revolution and has the remaining 95 per cent of the revolution during which the coolant can absorb heat. With very high speeds the arbors on which the cutters are mounted should be of ample size and plenty of power should be provided for driving the milling machine. Most of the planer-type milling machines being built today are provided with ample power and strength to enable the best types of high-speed steel milling cutters to be driven to their maximum productive capacity. Users of these machines, however, sometimes overlook the necessity of mounting milling cutters upon an arbor of sufficient size to withstand the severe torsional and bending stresses to which it is subjected. Generally, the capacity of the cutters limits the rate of production obtained by planer-type milling machines; but if an arbor of insufficient size is used, this carelessness on the part of the tool designer places a serious handicap upon the amount of work which the machine can turn out in a specified period of operation.

Beaman & Smith Planer-type Milling Machines. — A multiple-spindle or “planer” type of milling machine built by the Beaman & Smith Co., possesses the usual features of an equipment of this kind and also provides for eliminating the idle time of the machine which ordinarily occurs while the operator is removing the work from the last one or two fixtures, returning the table to the starting position, and setting up a casting in the first fixture on the table ready for starting the next cut. This result is secured through having the table made in sections of just sufficient size to allow a single work-holding fixture to be mounted on each section of the table. Thus, each fixture may be unloaded after the work has passed under the milling cutters and the table is then picked up by a trolley hoist and carried around to the opposite end of the milling machine bed, where it is again lowered into place on the ways. Where a planer-type milling machine is designed and used

on this principle, the operation becomes absolutely continuous. These planer-type milling machines are used to advantage in the plant of the Hudson Motor Car Co., of Detroit, Mich., for milling crankcases and cylinder blocks.

Another feature of the design of these milling machines is the provision for roughing and finishing operations on each piece of work without requiring any resetting. As shown in Fig. 4 and some of the following illustrations, the machines equipped for these combination roughing and finishing operations are furnished with two sets of housings and cutter-heads. The rough castings are passed between the first set of cutters to remove most of the surplus metal, leaving approximately 0.020 inch for removal by a similar set of cutters carried on housings located a short distance further along the bed of the machine. Where considerable accuracy is required on any large surfaces milled on machines of this type, the use of this combination of roughing and finishing cutters improves the quality of workmanship that is secured. At the automobile plant where this method is employed, milled surfaces on cylinder blocks and crankcases do not receive any further treatment, and the work can be done more economically in this way than where castings are rough-milled and then subjected to a subsequent finishing operation by grinding or by some similar method.

Milling Hudson "Super-Six" and "Essex" Crankcases.
— Milling operations in machining aluminum crankcases for both the "Super-Six" and the new "Essex" cars are performed on two planer-type milling machines, each of which is equipped with the subdivided tables and the arrangement of roughing and finishing cutters just described. On the first machine, the base of the crankcase, the pads on the suspension arms, and the seats for the crankshaft bearing caps are rough-milled, and the base and bearing cap seats are also finish-milled by cutters carried by the other set of housings. Then the work is taken to a second machine, which rough-mills both ends of the crankcase and the top surface to which the cylinder block is bolted, and then finish-mills the top surface. The details

of the work-holding fixtures and the routine followed in handling the work will next be described.

Milling Pads on Suspension Arms of Crankcase. — Figure 1 shows that the large inserted-tooth cutters *A* and *B* provide for milling the pads on the suspension arms at each side of the

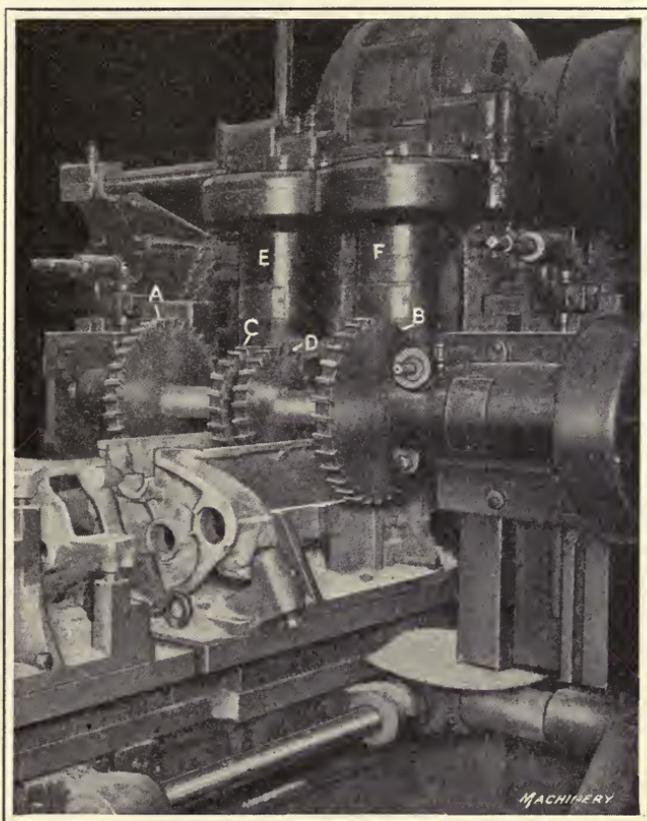


Fig. 1. View of Two Table Sections and Roughing Cutters on Machine milling Automobile Crankcases

crankcase, by means of which the motor is supported on the chassis; and that the two smaller cutters *C* and *D* mill seats for the crankshaft bearing caps. The base of the crankcase is also milled by two other cutters which are not shown but which are mounted on vertical spindles carried in bearings *E* and *F*. After each crankcase passes under this first set of six cutters,

the table which carries the work-holding fixture is traversed along the bed of the machine to feed the work under a second set of four cutters carried on the other housings. These finish-mill the crankcase base and crankshaft bearing cap seats, the roughing and finishing being performed without interruption.

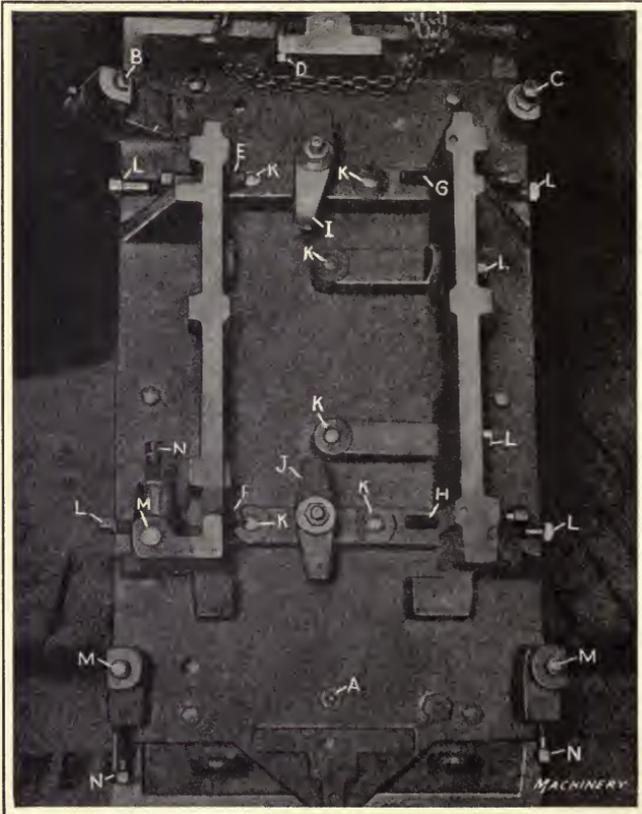


Fig. 2. Close View of Work-holding Fixture of Type used to hold Crankcases on Machine shown in Fig. 1

After these milling operations have been completed, the casting is removed from the work-holding fixture, and four hooks, located at the ends of chains carried by a trolley hoist, are passed through rings at the corners of the table. The table is then lifted off the bed of the milling machine and carried around on a crescent-shaped trolley rail, which brings it back

to the front end of the bed, where it is lowered into place on the ways. Beneath the table there is a rack which meshes with worms carried by a shaft inside the bed of the machine. These driving worms are mounted along the shaft at sufficiently frequent intervals so that each table will be fully engaged by one worm before it starts to run off the preceding worm. In this way, there is always ample power available to drive the work between the milling cutters.

As this is the first machining operation on these crankcase castings, the work-holding fixtures are designed with a three-point suspension bearing on which the work is located from the rough-cast surface. The three suspension points of the fixture will be seen at *A*, *B*, and *C* in Fig. 2. As the work is fed between the milling cutters, a considerable amount of end thrust is developed, and bolt *D*, in the body of the fixture, was designed to carry this load. The end of the casting rests against this bolt so that there is no possibility of its sliding longitudinally in the fixture. Sidewise location is secured by two fixed screws *E* and *F*, against which the casting is forced by means of adjustable screws *G* and *H*. The work is held down by means of straps *I* and *J*.

Adjustable Supporting Points for Thin Castings. — Mention has been made of the necessity of providing adjustable supporting points for engaging the lower surfaces of large castings which are sufficiently thin so that there would be danger of springing the work under pressure developed by the cut. Aluminum crankcase castings require careful support to avoid trouble of this kind. Not only is the work quite thin, but there are long overhanging members which are inadequately supported from the main part of the casting. In designing the work-holding fixture shown in Fig. 2, means have been provided for supporting the work by six adjustable plungers *K* which are raised into contact with the casting after it has been dropped into the fixture. These plungers are manipulated by means of screws *L* which control the movement of wedges that slide under the beveled ends of plungers *K*. As these wedges are held under the ends of the plungers by

means of screws *L*, they not only force the plungers up into engagement with the work, but also hold them rigidly in that position, thus affording adequate support for the pressure exerted by the milling cutters. In addition to plungers *K*, there are three spring plungers *M* which are held in contact with the work when it is placed in the fixture by means of compression springs located beneath these plungers. The plungers are firmly located against the work and then clamped in this position by binding screws *N*.

Gaging Castings before Starting Machining Operations.

— Some foundries make it a rule not to allow credit for any



Fig. 3. Inspection Fixture used for checking up Crankcase Castings to see that Sufficient Metal is provided to "clean up" all Machined Surfaces

defective castings upon which machining operations have been started; but whether or not this is a rule of the foundry which delivers castings to a machine shop, it is a good practice for the shop to inspect all of its castings before work is started. It is, of course, desirable to obtain credit from the foundry for any castings of such poor quality that they cannot be successfully machined, but the saving effected through getting such credit for defective castings often represents but a small percentage of the actual loss which would be suffered by the manufacturer if he proceeded with the machining operations until the work reached a point where the defect in the casting made it impossible to "clean up" some surface.

Recognizing the importance of this point, the Hudson Motor Car Co. uses a crankcase casting inspection fixture as

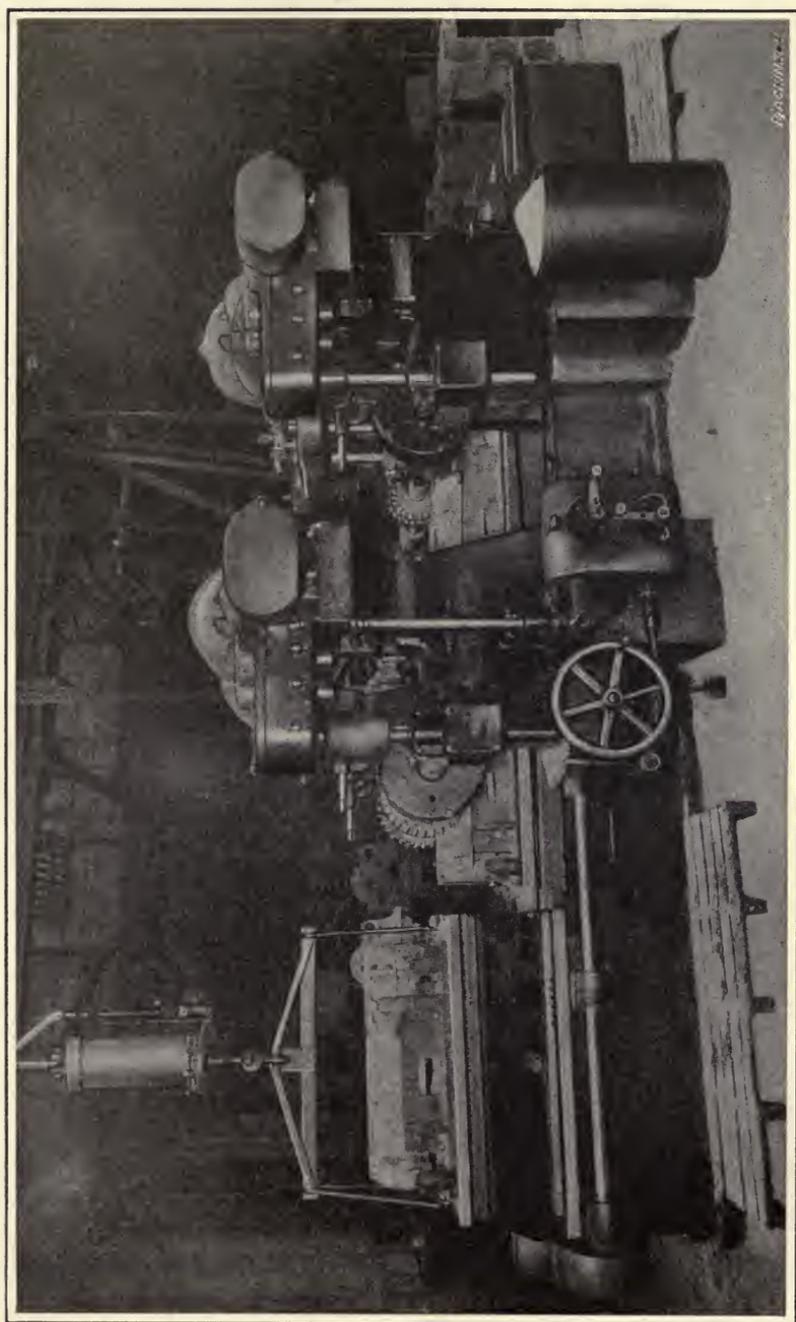


Fig. 4. View of Machine for milling Automobile Crankcases. One Table Section is shown being returned to the Starting End of the Bed

illustrated in Fig. 3, provided with three suspension points *A*, *B*, and *C*, corresponding to the points in the work-holding fixture shown in Fig. 2, on which a preliminary location of the casting is obtained. This fixture is used for ascertaining whether the foundry has allowed sufficient metal on all surfaces of the castings that are to be machined so that they can "clean up" properly. On the bed of the fixture there are eight spring plungers, which come up against the lower surface of the crankcase. These plungers are graduated on their stems to indicate the amount of excess metal which has been left for machining. It will also be seen that gages are provided at each end of the fixture, which have the same outline as the crankshaft bearing cap seats in the castings; and similar gages provide for checking up the surfaces which have to be machined on the suspension arms. Each crankcase casting is inspected on this fixture before it goes on to the milling machine. Not only does this method make it possible to get credit for all defective castings, but it also saves the loss resulting from milling operations on defective castings which could never be machined in a way that would enable them to pass the final inspectors.

Second Operation on Crankcases. — The second operation on these crankcases consists of rough-milling both ends of the crankcase and the face to which the cylinder block is bolted; then a finish-milling operation is performed on the cylinder block face. A multiple-spindle planer-type milling machine, equipped with sectional tables and two sets of housings to carry rough- and finish-milling cutters, is used for this operation. The machine is shown in Figs. 5 and 6. It will be seen that four cutters are used for the roughing operation. An interesting feature of this set-up is that the two large inserted-tooth milling cutters which mill the top surface of the work have interlocking teeth. This arrangement is necessary because, if the teeth on one cutter did not overlap those on the other, there would be a seam left on the work at the point where the two cutters failed to meet. After the castings pass under these cutters, they are carried on to a single inserted-tooth

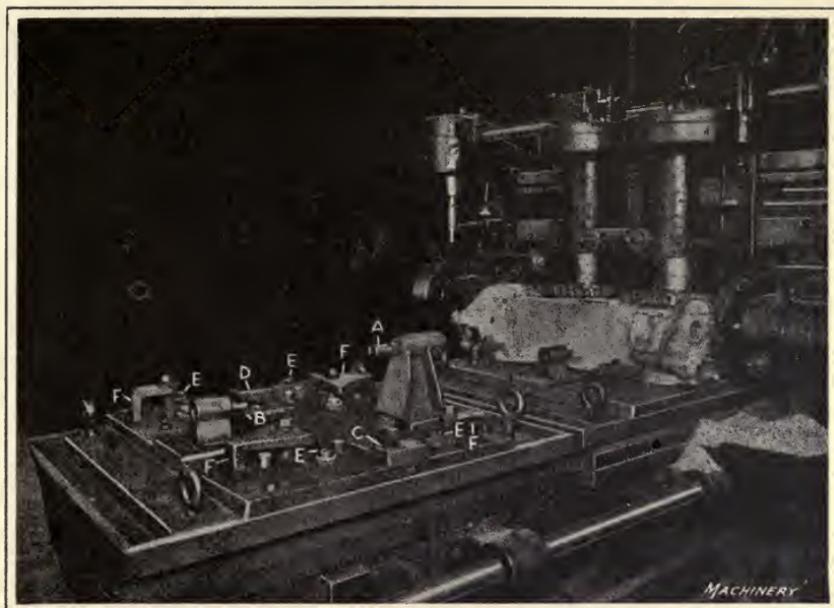


Fig. 5. Close View of Roughing Cutters and Fixture for milling Cylinder Face and Ends of Crankcases

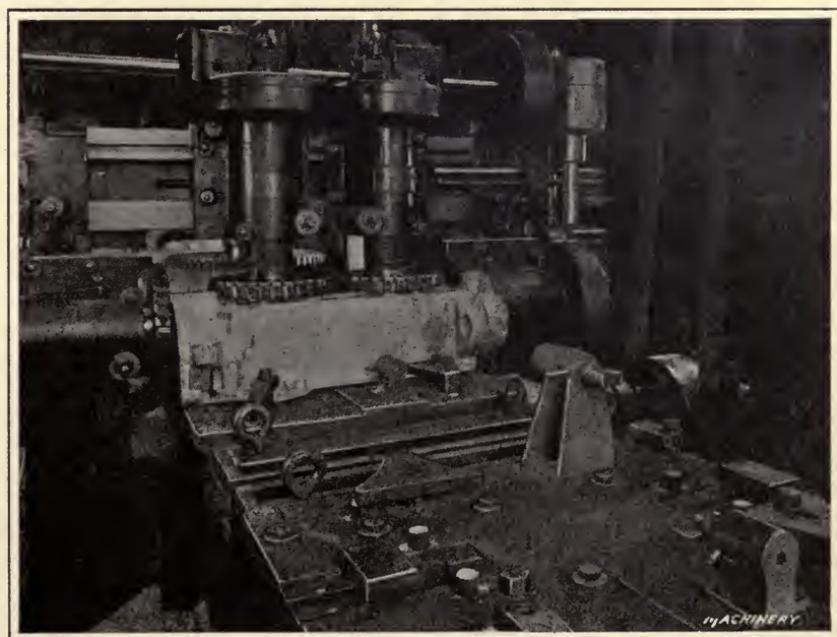


Fig. 6. End View of Machine and Fixture shown in Fig. 5

milling cutter of sufficient size to extend completely across the surface to which the cylinder block is bolted. This large cutter can be clearly seen in Fig. 6, and it is used in place of the two interlocking mills, because greater accuracy can be obtained in finishing the cylinder block seat in this way. The finish-milling operation is not performed on the ends of the crankcase.

Milling Different Crankcases on One Fixture. — In connection with the work-holding fixtures used on this machine, one especially interesting feature of tool design is that the same fixtures may be utilized for milling crankcases for either the "Super-Six" or the "Essex" car. This saves the cost of an additional set of fixtures; furthermore, a machine may be converted from the milling operations on one type of crankcase to the other with less loss of time than would be required if it were necessary to remove one set of fixtures and substitute others in their places.

It will be recalled that the usual practice in designing work-holding fixtures for the performance of second milling operations on large-sized pieces of work is to use a previously milled surface of the work as a locating point for subsequent operations. This is the method followed in designing the work-holding fixtures shown in Figs. 5 and 6; and where this method may be employed, it is usually possible to make a fixture of quite simple design. There are fixed pads on the bed of each fixture, which engage the milled lower surface of the crankcase, and endwise location of the work is obtained by means of a V-block that fits over a projection on the side of each casting. In order to have the ends of the cases milled square with the crankshaft bearings, it is also important to locate the work from these bearings. This is done by using as locating points the seats which were milled during the preceding operation to receive the crankshaft bearing caps. These milled seats drop over blocks on the fixtures, and the work is now located in the desired position. To clamp it down ready for milling, it is merely necessary to tighten up four straps on the flange running around the lower faces of the crankcase.

It will be seen in Fig. 5 that there are two V-blocks *A* and *B*. Block *A* provides longitudinal location for the "Super-Six" crankcase, while block *B* locates the "Essex" case. Blocks *C* and *D* enter the crankshaft bearing cap seats to locate the work so that the ends of the crankcase will be milled square with the crankshaft bearings. These blocks are of the proper size to enter the seats milled in both "Super-Six" and "Essex" cases; but as the "Essex" case is considerably the shorter, it is necessary to provide longitudinal adjustment for blocks *C* and *D* so that they may be set in the desired positions for locating work of two different lengths. The slides for making this longitudinal adjustment of the locating blocks are clearly shown in Fig. 5.

There are nineteen cylindrical shaped locating pads by which the work is supported on the fixture. All of these are not used at the same time, however; there are eight pads placed in the proper positions for supporting the "Essex" crankcase, and eleven situated to engage the previously milled lower surface of the "Super-Six" crankcase. In setting up the machine to mill "Essex" crankcases, it is necessary to remove the four end pads *E* for the "Super-Six" case, because these stops would interfere with the milling cutters that face off the ends of the castings. Pads *E* are bored at the center to receive screws which secure them down upon the bed of the fixture. Straps *F* hold down both the "Essex" and "Super-Six" crankcases.

Production Obtained in Milling Crankcases. — For the first operation on these crankcases, which consists of rough- and finish-milling the crankshaft bearing caps, the suspension arm pads, and the face to which the oil-pan will be bolted, the work is fed to the cutters at a rate of 15 inches per minute, and the largest size cutters are driven at a peripheral speed of 520 feet per minute. The crankcase castings are made of aluminum, and the rate of production obtained is 130 milled cases in an eight-hour working day. For the second operation, which rough- and finish-mills both ends of the crankcases and the face to which the cylinder block will be bolted, the work is

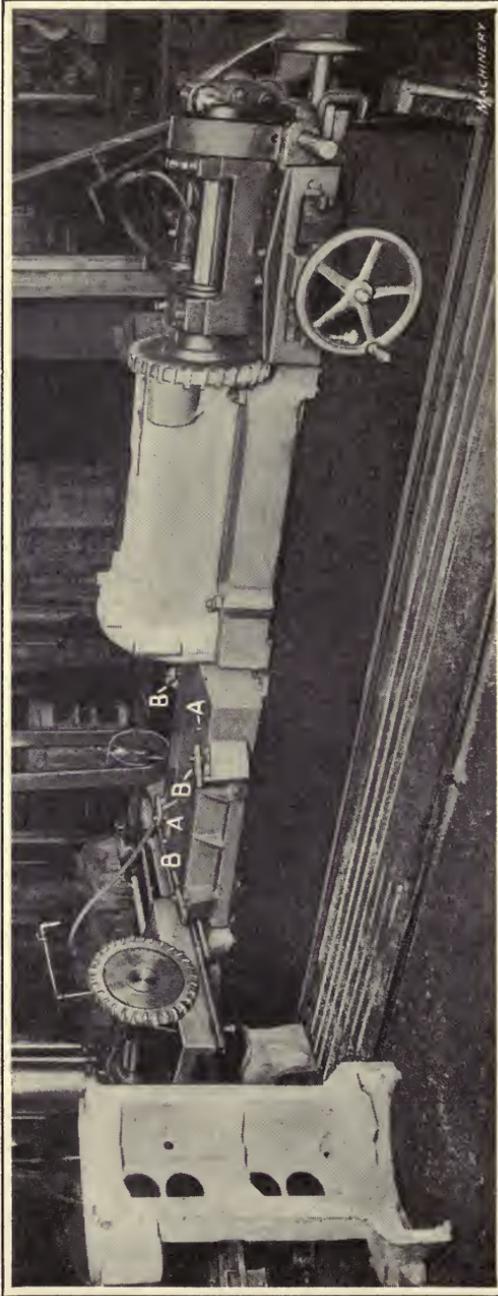


Fig. 7. Duplex Milling Machine used for milling Ends of Crankcases

fed to the cutters at a rate of 30 inches per minute, working day. Four work-holding fixtures and table and the cutters are driven at such a speed that sections are provided for the machines which perform the 32-inch cutter which finish-mills the cylinder form the first and second milling operations on block face is cutting at a speed of 593 feet per crankcases.

minute. On this operation, the rate of production **Milling Ends of Hinkley Crankcases.**—At the obtained is 200 milled crankcases in an eight-hour plant of the Hinkley Motors Corporation, of Detroit,

Mich., use is made of a duplex milling machine of the type made by the Garvin Machine Co., for milling one end of aluminum crankcases for motor truck engines. The opposite end of these cases has already been machined, and the face on which the oil-pan will be bolted has had two dowel-pin holes drilled in its flange. These holes are used as the locating points in setting work up on the milling machine to have the end of the case milled exactly at right angles to the crankshaft bearings. For this purpose, two dowel-pins *A*, Fig. 7, are placed in the table of the machine at each end, so that the crankcases may be dropped over these pins, after which they are held down by means of four straps *B*, which engage the flange running around the work. This operation is performed with milling cutters 16 inches in diameter which run at a speed of 135 feet per minute, and with a feed of 10 inches per minute. Two castings are set up on the machine at a time, each of which is milled at only one end. The rate of production is thirty crankcases per hour.

Simultaneous Performance of First and Second Operations on Crankcases.—In the plant of the Studebaker Corporation, in Detroit, Mich., a work-holding fixture is used which provides for simultaneously performing the first and second milling operations on cast-iron crankcases which are held at opposite sides of a vertical work-holding fixture. Figures 8 and 9 show that the fixture consists essentially of a plate supported edgewise on the table of a multiple-spindle milling machine and furnished with the necessary clamping mechanism to provide for operating on a crankcase held at either side of the fixture. The first operation consists of milling the face of the crankcase to which the cylinder block will be bolted; then the crankcase is removed from the fixture, and after being turned over, it is again set up at the opposite side for milling the oil-pan face of the crankcase. A sidehead is mounted on each housing of the machine to provide for simultaneously taking these two cuts on the work.

For the first operation on the crankcases, the work, held in the fixture shown in Fig. 8, is located from the oil-pan face of

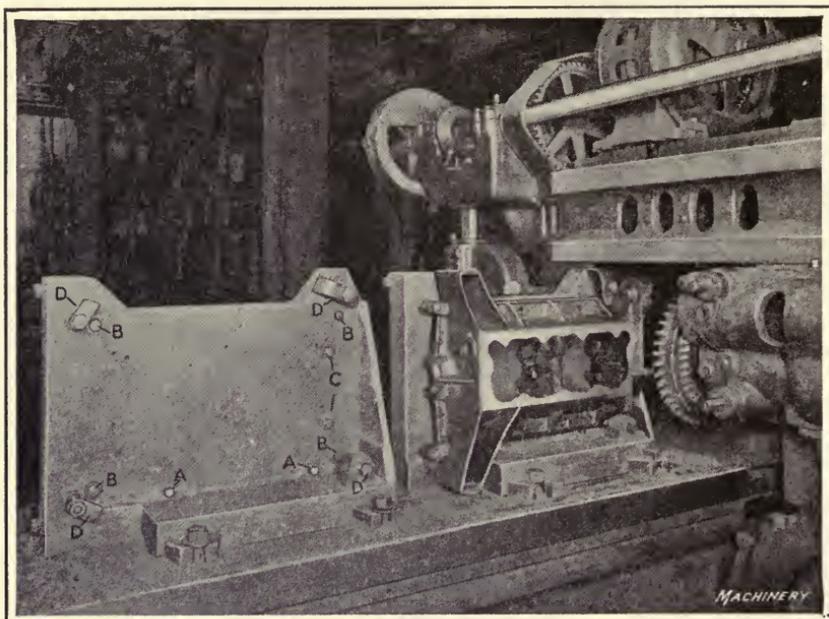


Fig. 8. Fixture used for simultaneously milling Opposite Sides of Cast-iron Crankcases

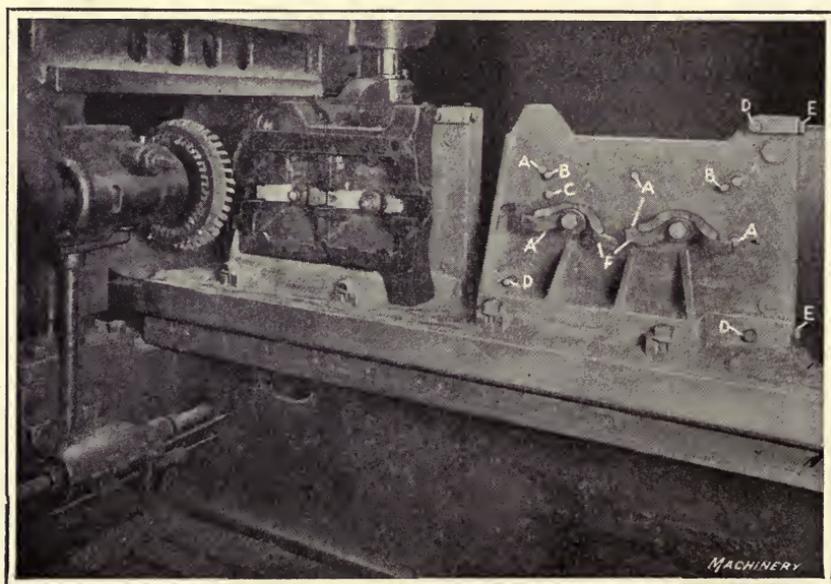


Fig. 9. Opposite Side of Fixture shown in Fig. 8

the crankcase. In locating the rough castings in a fixture, it is usual to employ a three-point suspension bearing, but in this case, such a design did not appear to be practical. Owing to the fact that four corners of the work are used for location, it is necessary for the machine operator first to check up the accuracy of his castings with a gage and, if necessary, grind down one corner with a portable electric grinding machine until the work will rest against the surface plate without rocking.

In setting up a casting on the fixture shown in Fig. 8, the lower edge of the crankcase is set on two pins *A*, after which the case is pushed back against the fixture so that the four corners may be supported by pads *B*. To provide for carrying the end thrust of the milling cutters, the inside of the front end of each casting rests against two pins *C*, and three straps and a clamping screw *D* hold the work back against the four supporting pads *B*. It takes approximately one minute to set up each casting in its fixture for the first operation, and the work is fed to the milling cutters at the rate of 4 inches per minute. The cutters are 16 inches in diameter and run at a speed of 18 revolutions per minute, which corresponds to a cutting speed of 75.5 feet per minute. Four castings are set up at each side of the fixtures for each traverse of the table. The first operation is performed on seven and one-half crankcases per hour.

Each casting carried by the fixture shown in Fig. 8 is fed past an inserted-tooth milling cutter which faces off the cylinder block face of the crankcase, after which the casting is removed from the fixture and carried around to the opposite side of the machine. After the work-holding fixtures have been unloaded at that side, the partially milled castings are set up, with the milled cylinder block seat as a locating point. Six fixed locating pads *A*, Fig. 9, engage the milled face of the work. The casting is slipped over two pins *B* which hold it up in the desired position until the clamps are tightened, and a third pin *C* engages the inside of the casting at the forward end to support the thrust of the milling cutters. Each

of the suspension arms of the crankcase must be supported in order to prevent distortion resulting from the pressure exerted by the milling cutters. For this purpose three spring plungers *D* are used, which come up into engagement with the work at the time that it is placed in the fixture. Each of these plungers is then clamped in the desired position by means of a screw *E*, the screw for bolting the pin at the front end of the fixture not being shown in the illustration. With the casting set up and located in this way, it is clamped back on the fixture by two straps *F* which are made semi-cylindrical in form to fit the crankshaft bearings. These straps are furnished with V-shaped slots and are dropped over the bolts, instead of having the bolts enter holes drilled through the straps, the purpose being to enable the straps to be lifted off the bolts after the nuts have been slightly loosened. This saves a large part of the time which would otherwise be required to screw the nuts all the way off the bolts in order to remove the straps and allow the castings to be lifted off the fixtures. The work is done at a cutting speed of 75.5 feet per minute, with a feed of 4 inches per minute, and the rate of production is seven and one-half completely milled crankcases per hour.

Work-holding Fixture for First Operation on Cylinder Blocks. — Cylinder blocks of the "Super-Six" and "Essex" motors are milled on Beaman & Smith multiple-spindle milling machines. Two machines are used for this work. The first step is to set up three pairs of cylinder block castings on a machine equipped with a single table and a string of fixtures. This machine has two side-heads mounted on the housings, each of which carries an inserted-tooth milling cutter of sufficient size to face off the exhaust manifold seats and the valve chamber cover. Figure 10 shows that each of the three fixtures will hold two cylinder blocks, so that this operation may be performed simultaneously on six castings by cutters carried on the opposed spindles of the side-heads. For this milling operation, each cylinder block casting is located against three fixed points *A*, *B*, and *C*, on the vertical face of the fixture. To assist in supporting the work, there are eight spring plungers

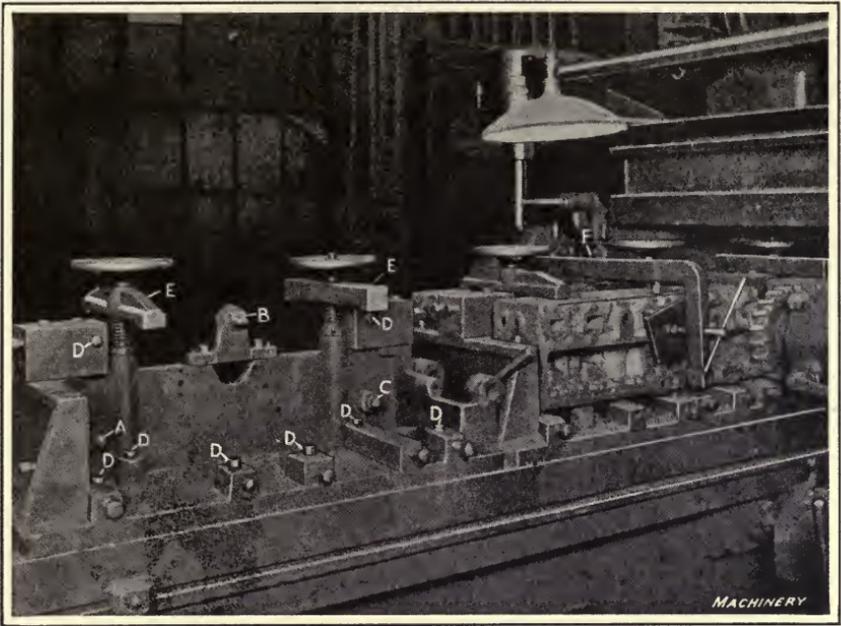


Fig. 10. Work-holding Fixture for First Operation on Hudson Cylinder Blocks

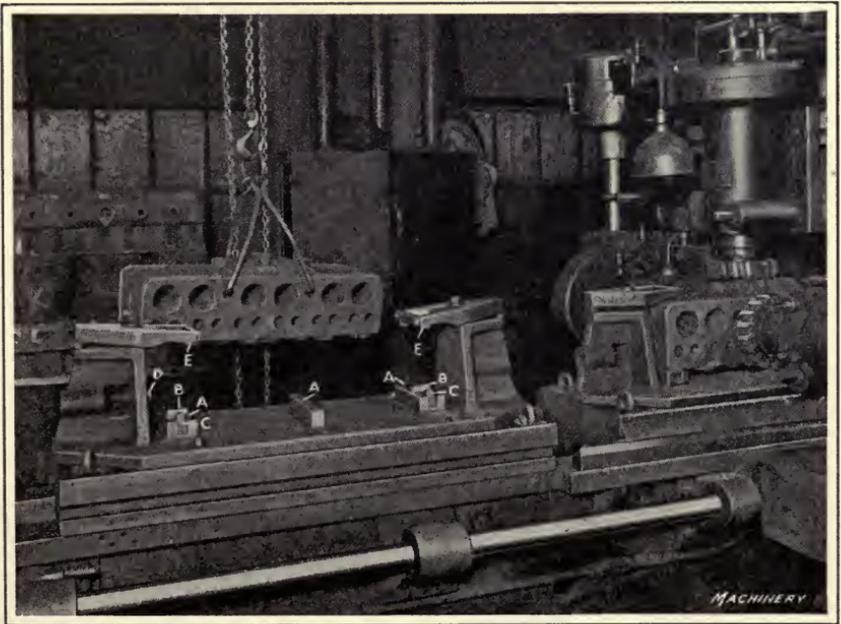


Fig. 11. Work-holding Fixture for Second Operation on Hudson Cylinder Blocks

D equipped with locking screws which hold them rigidly in place after engaging the casting; and the final clamping is accomplished by two straps *E* provided with handwheels as illustrated. These straps have compression springs beneath them, so that they are raised out of contact with the work when the handwheels are unscrewed.

Before straps *E* are tightened, a yoke *F* is placed over the two castings at opposite sides of the vertical plate of the fixture, and the screw of this yoke is tightened to draw both castings firmly back against their fixed locating points, *A*, *B*, and *C*. While the yoke is still over the castings, the screws which clamp spring plungers *D* are tightened and the handwheels that clamp straps *E* are also turned down, thus accurately locating the two castings at opposite sides of the fixture. After they have been tightened up, the yoke *F* may be removed without any danger of the work springing out of place. When milling cylinder blocks for the "Essex" motor, the surface to be milled is approximately 19 inches long by $9\frac{1}{4}$ inches wide. Owing to the hardness of the metal, the rate of feed employed is rather lower than that called for by average practice, namely, 6 inches per minute; and the cutting speed is 63 feet per minute. The production obtained for an eight-hour working day is 130 cylinder blocks. On the "Super-Six" blocks, the surface to be milled is $29\frac{3}{4}$ inches long by 9 inches wide, and on this job, 70 cylinder blocks are milled in an eight-hour working day.

Work-holding Fixture for Second Operation on Cylinder Blocks. — Following the usual practice in milling large-sized pieces of work, the surface machined during the first operation on the cylinder blocks is made the locating point for the second operation. A close view of one work-holding fixture and of the roughing cutters on the machine used for this second operation is shown in Fig. 11; and Fig. 12 illustrates a view of the complete machine in order to show how each section of the divided table is brought back to the starting end of the machine ready to be loaded for the next operation. On this machine, rough- and finish-milling operations are performed

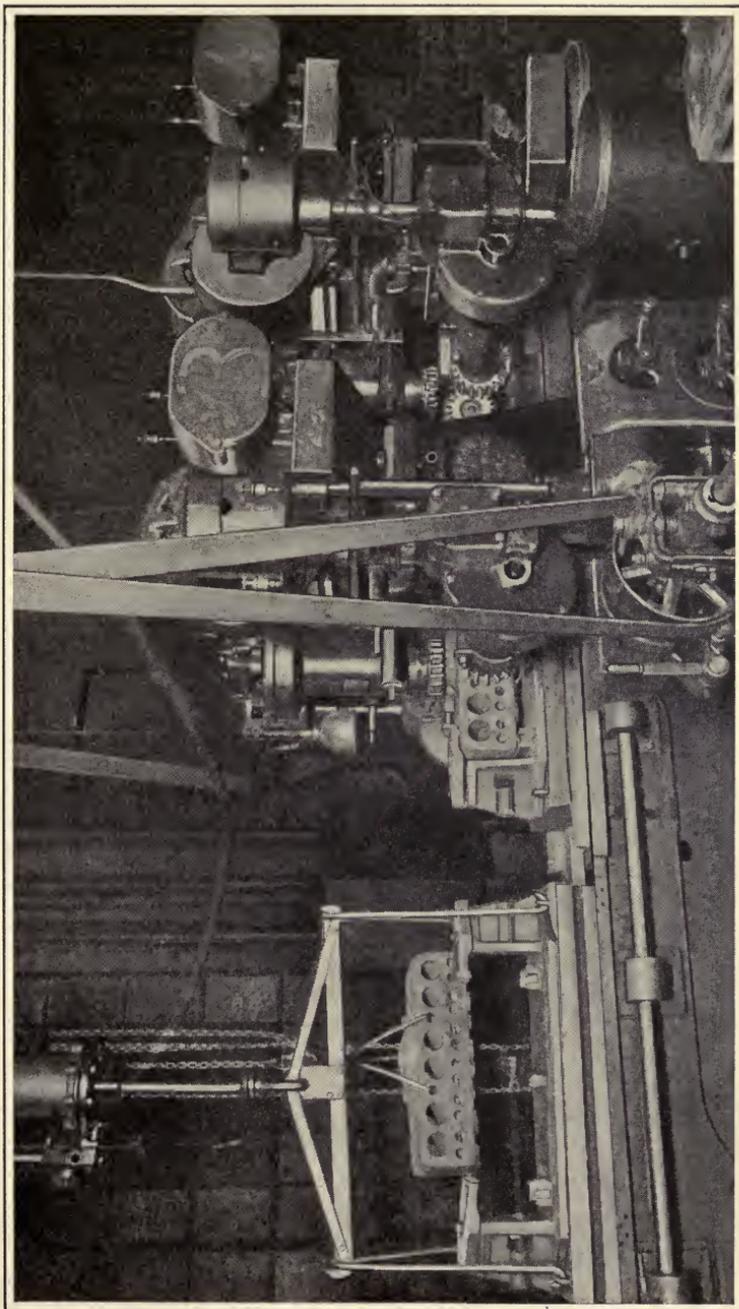


Fig. 12. Complete View of Machine partially illustrated in Fig. 11 showing the Method of returning a Table Section to the Starting Point on the Bed of the Machine

on the three faces of the cylinder block, to which the crank-case, intake manifold, and cylinder head will be bolted. The machine is provided with two sets of three cutters. One set of cutters rough-mills three faces of the work, and then the table and work-holding fixture mounted upon it carry the cylinder block between the second set of cutters that finish-mills the same faces.

Different Machines Used for First and Second Operations.

— It was previously mentioned that, in designing multiple-spindle or planer-type milling machines for a specified class of work, the number of parts to be milled per day is an important factor and that, where a high rate of production is not an important consideration, the use of less complicated and less expensive machines is desirable. It was for this reason that a relatively simple machine was designed for performing the first operation on Hudson cylinder blocks. This machine has a single set of roughing cutters and a plain table upon which a string of work-holding fixtures is mounted. The first operation of milling the seats for the exhaust manifold and for the valve chamber cover plate is shorter than that performed on the second machine and, owing to the higher rate of production, it is needless to take advantage of the continuous operation feature of the divided-table machine in order to increase production. As a matter of fact, the machine used for the first operation is able to accumulate work more rapidly than it can be taken care of by the second machine.

Setting up and Removing Work from Divided-table Machine. — In the second operation, as each section of the table carries its work between the second set of milling cutters, for finishing the work, the fixture is unloaded and picked up by a trolley hoist that carries it around to the starting point on the milling machine bed. The two machines for the first and second operations are set up with the beds end to end and with the tables running in the same direction. As the fixtures on the first machine are unloaded, the milled castings are picked up with a trolley hoist and carried off to a pile built up near the starting end of the second machine. Then

as each table is brought back to the starting point and lowered to the bed, a cylinder block casting is taken from the pile and lowered into the fixture. The best method would, of course, be to have the castings taken directly off the first-operation machine and carried over to the second machine, synchronizing the speed of the two machines so that their production would be equal. This has been found impracticable in the present case, however, because the first machine produces much more rapidly than the second one; hence the necessity of accumulating a reserve of castings around the machine for the second operation.

This machine is equipped with four work-holding fixtures and two sets of three milling heads, one head of each set being mounted on the cross-rail and one on each of the housings. Cutters carried by these heads rough-mill the faces to which the cylinder head, the crankcase, and the intake manifold are bolted. There is a similar set of cutters mounted on a second housing for the finish-milling operations on the same faces of the work. The design of the work-holding fixtures on this machine is explained by Fig. 11, where it will be seen that there are three finished faces *A* to support the work from the surface of the exhaust manifold seat and valve chamber seat, which were milled during the first operation. This holds the cylinder block in a horizontal position; but as the top and bottom surfaces of the block are to be milled, it is important to have the casting so located that these surfaces will be accurately aligned with other faces of the work. This location is accomplished by means of two blocks *B* which engage fixed points cast in the valve chamber of each cylinder block for that purpose. The casting is held back against these blocks *B* by hooks *C* which engage the casting, and it is drawn to the desired location by screws manipulated from the opposite side of the fixture. The casting also rests against the head of screw *D* which supports the end thrust. After being located in this way, the casting is clamped down in the fixture by two straps *E*. This operation is accomplished at a speed of 65 feet per minute with a feed of 11 inches per

minute, and the rate of production obtained is 150 cylinder blocks in an eight-hour working day.

Practice of Hinkley Motors Corporation in Milling Cylinder Blocks.—The Hinkley Motors Corporation manufactures motor truck engines with cylinder blocks that require the faces on which the cylinder head, crankcase, and the manifold and valve chamber cover are mounted to be machined so that the edges of the block are sharp. This would not present an unusual condition in machining were it not for the desirability of finishing all of these three faces at a single operation. In handling this job the use of a multiple-spindle type of milling machine was decided upon, but special means had to be provided to produce sharp edges at the intersection of the finished faces of the work and still avoid interference of the milling cutters. A multiple-spindle milling machine built by the Ingersoll Milling Machine Co. was selected and the sharp edges required on the work were obtained by using interlocking milling cutters arranged as shown in Figs. 13 and 14. Such a method of tooling up the machine provided for finishing the work to the desired form; but care had to be taken to design the milling cutters with their teeth so spaced in relation to the speed of each cutter that there would be freedom from interference of the teeth.

A study of both the illustrations will explain the method of setting up cylinder block castings in the work-holding fixtures used on this machine. The rough castings are dropped into place in the fixture and held on three suspension points *A*, two of which are fixed plugs, while the third is a wedge-shaped block that enters the space between the outer walls of adjacent cylinders. In addition, four spring plungers *B* engage the work, and these are locked by screws *C*. The wedge-shaped block *A* is carried on a cross-slide so that it may be drawn back by screw *D* to provide for pulling the entire cylinder block backward and thus bring the bosses cast under the flange into contact with two fixed stops which are best shown at *E* in Fig. 13. Jacks *F*, located in the side walls of the fixture, engage the ends of the casting to support

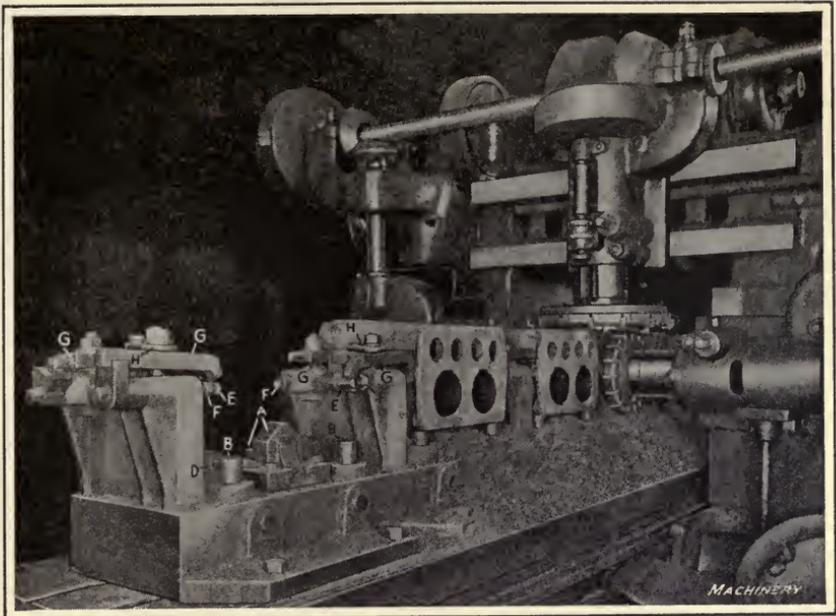


Fig. 13. Milling Machine with Interlocking Cutters to produce Sharp Edges

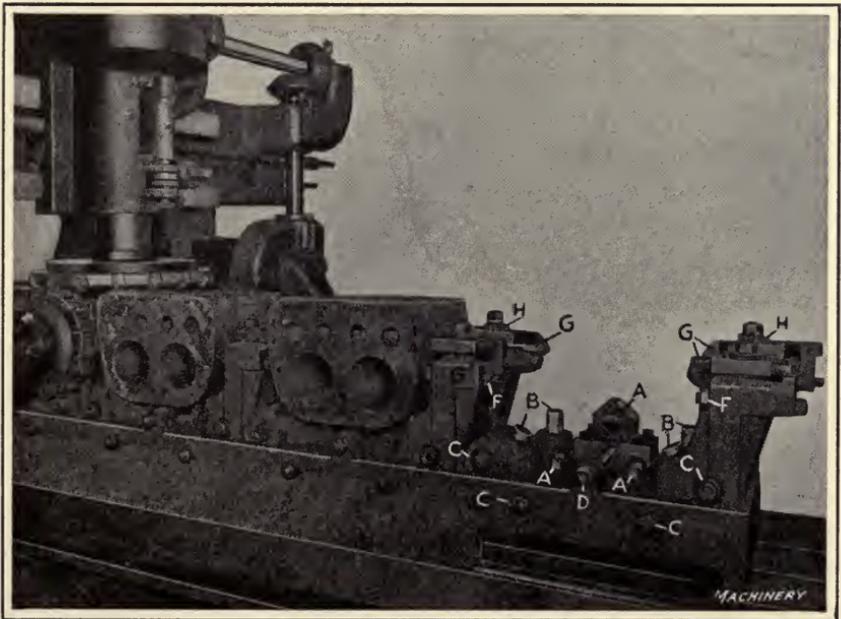


Fig. 14. Opposite Side of Multiple-spindle Milling Machine shown in Fig. 13

the thrust of the milling cutters and also to locate the work in the required endwise position.

Four straps *G* which engage each corner of the work hold it down in the fixture. It will be seen that two of these straps have cylindrical shaped ends which enter holes in the casting, while the straps at the opposite side are tightened down on the top of the same bosses which are engaged on their inner sides by pins *E*. The two straps which engage bosses under the flange of the cylinder block are fastened with a C-latch *H* which goes under the clamping nut. The hole in the strap is of sufficient size to pass the nut, so that it is merely necessary to loosen the nut slightly, swing the latch back and lift the strap over the nut. The other two straps have compression springs beneath them, and the work can be disengaged after these straps have been slightly loosened without requiring them to be removed from the fixture. These features save considerable time in loading and unloading the fixture. In milling these cylinder blocks, five castings are set up on the machine table, following the usual routine employed in operating such machines. It requires thirty minutes to feed five castings between the cutters which run at a speed of 75 feet per minute. The rate of feed is about 5 inches per minute, and 75 cylinder blocks are produced in a nine-hour working day.

Milling Packard Cylinder Blocks. — Cylinder blocks for motor cars built by the Packard Motor Car Co. are machined by a different method than those previously described. At this plant, rough cylinder blocks are first delivered to a combination milling and cylinder boring machine. Two castings are set up on this machine, which is designed to bore four cylinders in one of these castings and simultaneously mill the crankcase face of the other cylinder block casting. After both of these operations have been performed, the castings are transferred to a multiple-spindle drilling machine built by the Baush Machine Tool Co., which provides for drilling all of the holes required in the crankcase face. Then each casting is slid off the table of the drilling machine to a gravity carrier

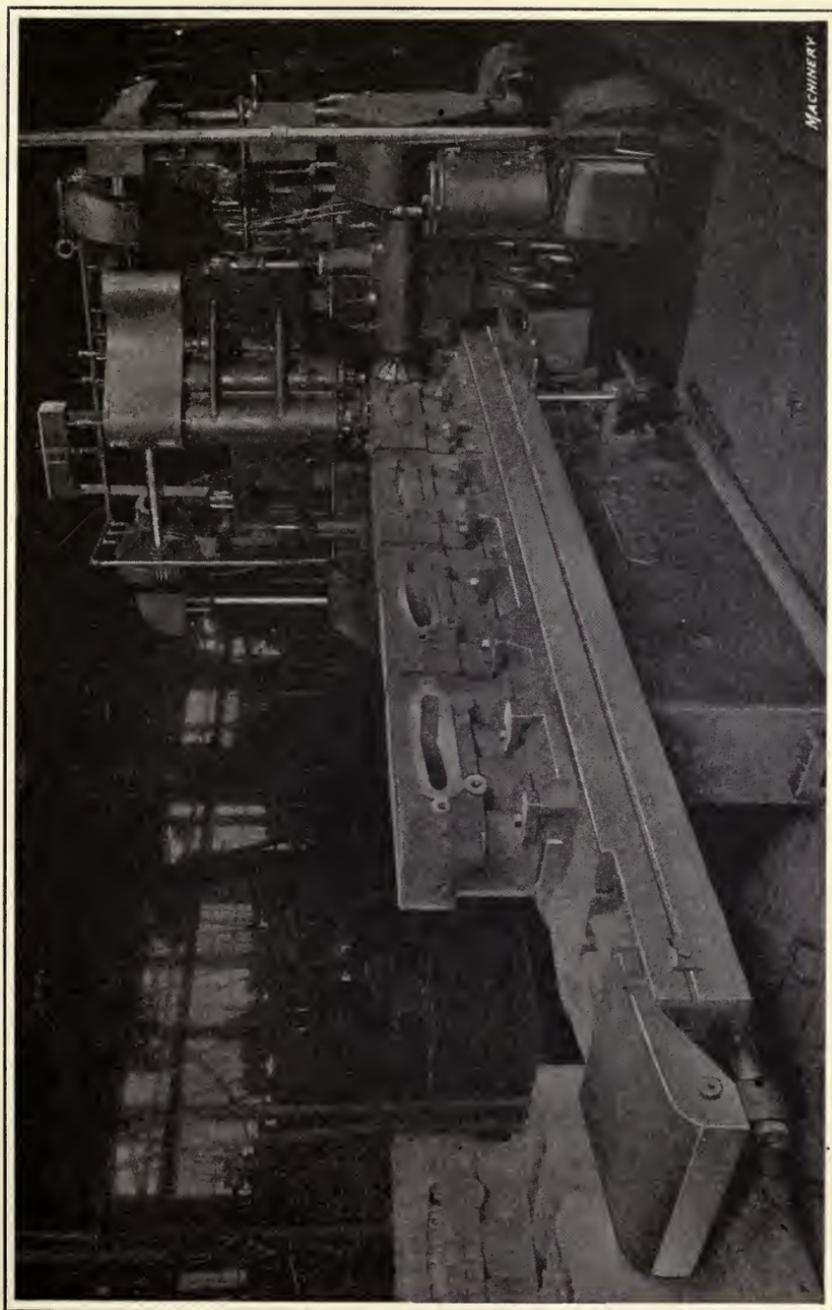


Fig. 15. Multiple-spindle Milling Machine equipped for machining Packard Cylinder Blocks

along which the castings run to a multiple-spindle milling machine, shown in Fig. 15, on which the remaining milling operations are performed. This machine is equipped with four milling cutters to mill the seats for the valve chamber cover, the intake manifold, the cylinder block cover, and the exhaust manifold simultaneously. The equipment of this machine is not unusual, with the possible exception of the fact that a two-spindle side-head is mounted on one of the housings for driving two cutters used for milling the valve cover seat and the intake manifold seat at different levels.

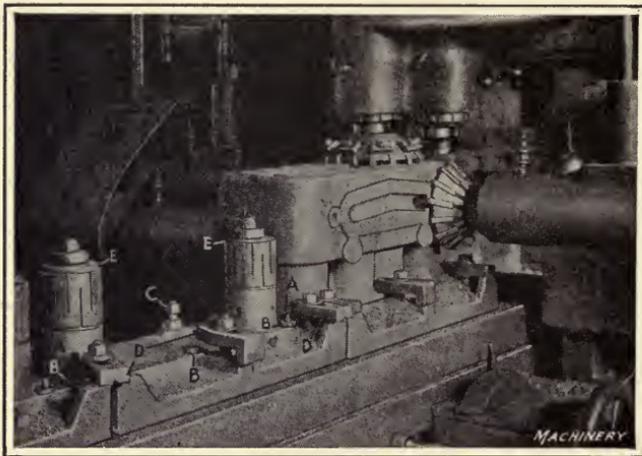


Fig. 16. Work-holding Fixture and Cutters used for machining Packard Cylinder Blocks on Multiple-spindle Milling Machine

A marked departure from the usual practice has been made in designing the work-holding fixtures used on this machine, but this would naturally be expected as the cylinder blocks delivered to the machine have been bored and milled on the crankcase face, and all of the holes have been drilled in this face of the work, while in the case of other cylinder block milling fixtures which have been described, the work is set up on the machine in the condition in which the castings are delivered from the foundry. At the time holes are being drilled in the crankcase face of these cylinder blocks, two dowel-pin holes are drilled, which will be utilized in the engine

assembling department for lining up bolt holes in the cylinder block and crankcase. Locating pins *A* on the fixture enter these dowel holes when setting up the work on the milling machine shown in Figs. 16 and 17. The previously milled surface on the work is used to support it for subsequent milling operations, and for this purpose nine finished pads *B* are provided.

The casting is held down at one side by two bolts *C*, which pass through holes drilled in the flange of the crankcase face; and at the opposite side there are three straps *D* which bear

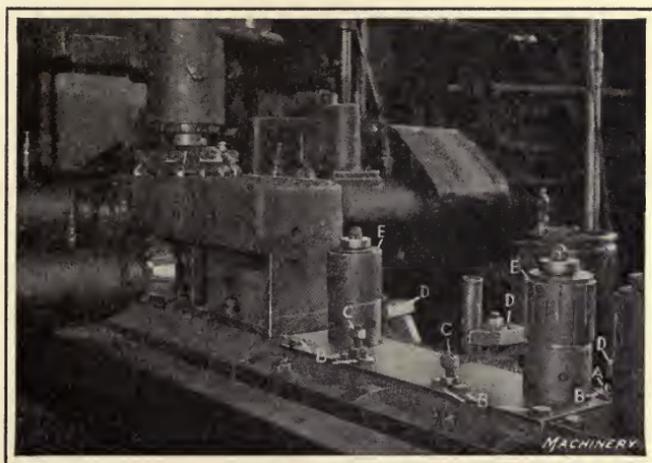


Fig. 17. View from Opposite Side of Multiple-spindle Milling Machine shown in Fig. 16 showing Further Details of Cutters and Fixtures

upon the upper surface of the same flange. All of these clamping members are located at the base of the work, and it is necessary also to steady the work to prevent pressure of the cutters applied near the top of the castings from setting up chatter and vibration. This is done by two split chucks *E* which fit into the bored cylinders at opposite ends of the block. By tightening the nuts located at the top of chucks *E*, tapered blocks inside of these chucks are drawn downward, thus expanding the chucks and causing them to obtain a firm grip on the work. The fixtures can be loaded with very little loss

of time. The work is fed to the milling cutters at a rate of 8 inches per minute and the cutters are geared to give a cutting speed of 60 feet per minute. The rate of production obtained is from 45 to 50 cylinder blocks in a nine-hour working day. Four cylinder blocks are set up on the machine for each traverse of the table.

Practice of Studebaker Corporation in Milling Cylinder Blocks. — Ingersoll multiple-spindle milling machines are

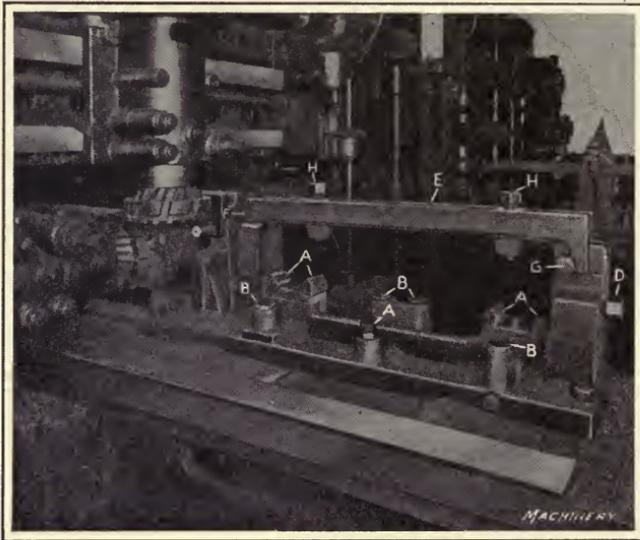


Fig. 18. Close View of Work-holding Fixture and Cutters on Multiple-spindle Milling Machine for milling Studebaker Cylinder Blocks

used by the Studebaker Corporation for milling the surfaces of cylinder blocks on which the manifold, crankcase and cylinder head are mounted. Figures 18 and 19 explain the design of the work-holding fixtures used on these machines. The fixtures are shown from opposite sides in order to illustrate fully the locating and clamping mechanisms, and the arrangement of cutters on each of the milling heads. The work is set up in these fixtures with the cylinders lying in a horizontal position. To supplement the way in which the casting is held by the three suspension points *A* on the fixture,

four spring plungers *B* come up into engagement with the work and are then locked in that position by the usual arrangement of binding screws. One of the buttons *A* engages the under side of the water jacket, and there are a pair of buttons *A* at each end of the fixture, which straddle the outside of the cylinder wall. Sidewise location of the castings is accomplished by having the flange of the casting come into engagement at each end of the work with fixed stops *C*. The end of screw *D* projects inward through the body of the fixture,



Fig. 19. Opposite Side of Machine illustrated in Fig. 18 showing Further Details of Work-holding Fixture Design and Arrangement of Cutters

engaging the work and supporting the end thrust of the cutters. Bar *E* clamps the castings down in the fixture. This bar is pivoted at *F* and formed in such a way that a narrow extension at the free end of the bar enters a slot milled in the upright of the fixture body so that it may be held down by a sliding pin *G*. When bar *E* has been lowered and locked in place, two screws *H* are tightened down on the cylinder block casting, thus holding it securely in the desired position in the fixture. The castings are fed to the milling cutters at the rate

of approximately 8 inches per minute, and the cutters are driven at a cutting speed of $61\frac{1}{2}$ feet per minute. Three castings are set up at a time and the rate of production obtained is six cylinder blocks per hour. One man can operate two machines as it takes only two minutes and fifteen seconds to load a fixture. The machine is started after loading the first one of the string of fixtures on the table.

Practice of Continental Motors Corporation in Milling Cylinder Blocks. — It is always interesting to compare the methods used by different tool designers in equipping machines for the performance of the same operation, and such an opportunity is now presented for contrasting the practice of the Continental Motors Corporation, of Detroit, Mich., in milling cylinder blocks as shown in Fig. 20, with that of the Hinkley Motors Corporation, shown in Figs. 13 and 14. In both cases, the machine is required to mill the faces to which the crankcase, valve chamber cover plate, manifold, and cylinder head are bolted. It will be recalled that the Hinkley tool designers adopted the use of interlocking milling cutters in order to produce square edges on the work; but for the same operation on Continental cylinder blocks, the tool designers decided upon a four-spindle milling machine, shown in Fig. 20. Two large inserted-tooth cutters, carried by the side-heads, mill the top and bottom faces of the cylinder block according to the usual practice. But for milling the seats on which the valve chamber cover plate and the manifold are mounted, two vertical spindles are employed, the spindle which carries the small cutter to mill the manifold face being offset sufficiently so that its teeth do not interfere with the teeth on either of the cutters carried by the vertical or the horizontal spindle. The cutters carried by the two vertical spindles are also set to mill the manifold face and valve chamber cover plate face at different levels, instead of having two cutters mounted on the vertical spindle, as shown in Figs. 13 and 14. With this arrangement, the cutters that mill the cylinder head face and manifold face can each overhang the work sufficiently to mill a square edge at the intersection of

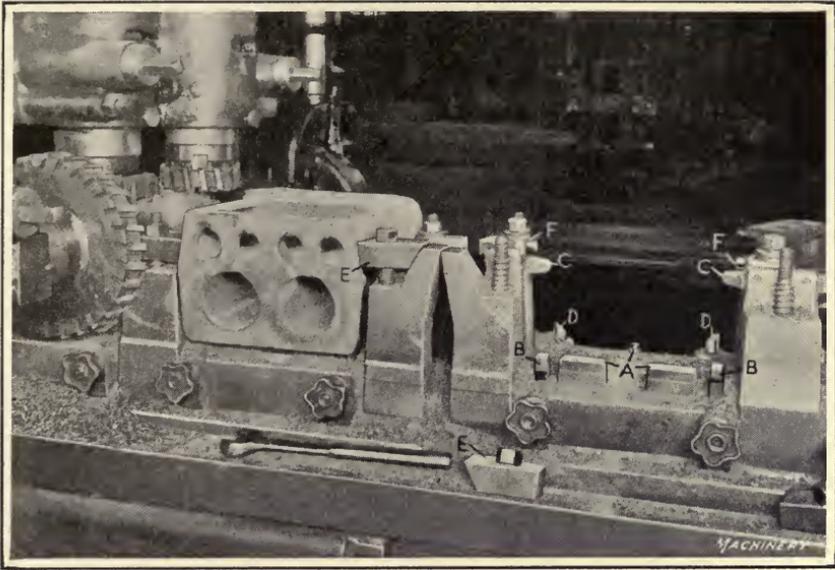


Fig. 20. Design of Fixture and Arrangement of Cutters used on Multiple-spindle Milling Machine for milling Continental Cylinder Blocks

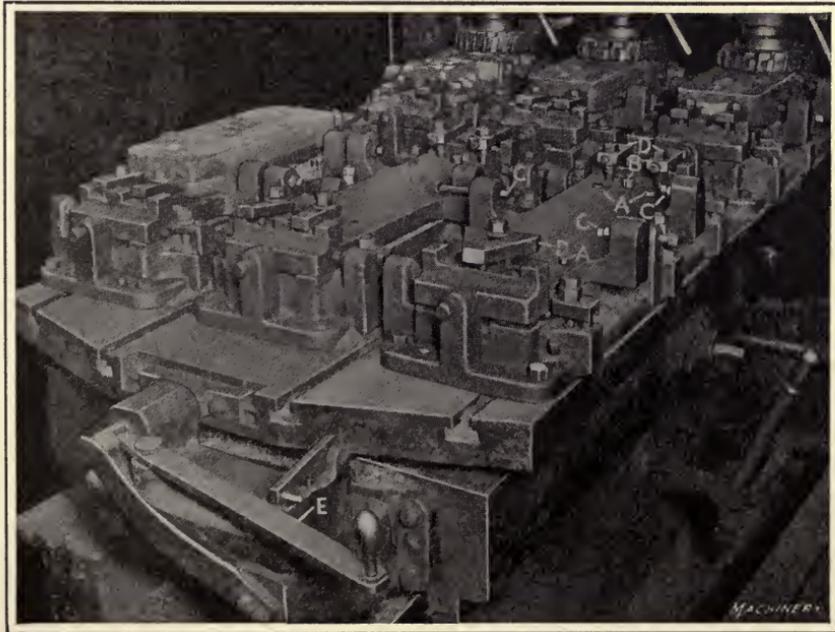


Fig. 21. Multiple-spindle Milling Machine equipped with an Indexing Table for milling Hudson Cylinder Heads

these surfaces. The inserted-tooth cutter which mills the crankcase face is made of considerably larger diameter than the width of the face to be milled. With this arrangement, the cutter that mills the valve chamber cover plate face projects beyond the edge of the work into the space created by having the edges of the blades of the cutter, which is carried by the horizontal spindle, project out from the body of the cutter in the usual way.

The work is placed in the fixture with the cylinders in a horizontal position and with the valve chamber at the top. The casting is supported by three fixed pads *A*. Two capstan-head screws operate hooks *B* which engage the flange on the work and provide for pulling the casting forward against two sidewise locating stops *C*. At the opposite side of the fixture there are two screws that operate tapered plugs located beneath the adjustable pads *D*, to afford additional support for the work. The screws draw these pads *D* up into contact with the work, locating them in the required positions. Each casting is held down in the fixture by means of two bevel-ended straps *E* at one side of the fixture and by two straps *F* at the opposite side, which are provided with cylindrical shaped ends that enter the core support holes in the casting. Seven castings are set up on the machine at a time, and the cutters are driven at a speed of 76 feet per minute, with a rate of feed of 8 inches per minute. The rate of production is 11 cylinder blocks per hour. Two men load and unload the fixtures on this machine.

Milling Continental Cylinder Heads. — In machining Continental cylinder heads for automobile engines, it is necessary to mill the bottom face which is bolted to the cylinder block and also face off the bosses at the top surface of the head. For these two operations a four-spindle milling machine is used, equipped with fixtures of the type shown in Fig. 22. Two castings are set up on the top of this fixture for facing off the bosses; then the two pieces of work are turned over and bolted to the sides of the same fixture ready for a second operation that mills the lower surface of the head which engages the milled

top face of the cylinder block. To provide the required amount of clearance in the combustion chambers of these cylinder heads, the work is located by means of two hardened plugs *A* which project up into the combustion chambers. These two plugs are supported at their lower ends by a rocker arm, so that they can adjust themselves for slight variations in the

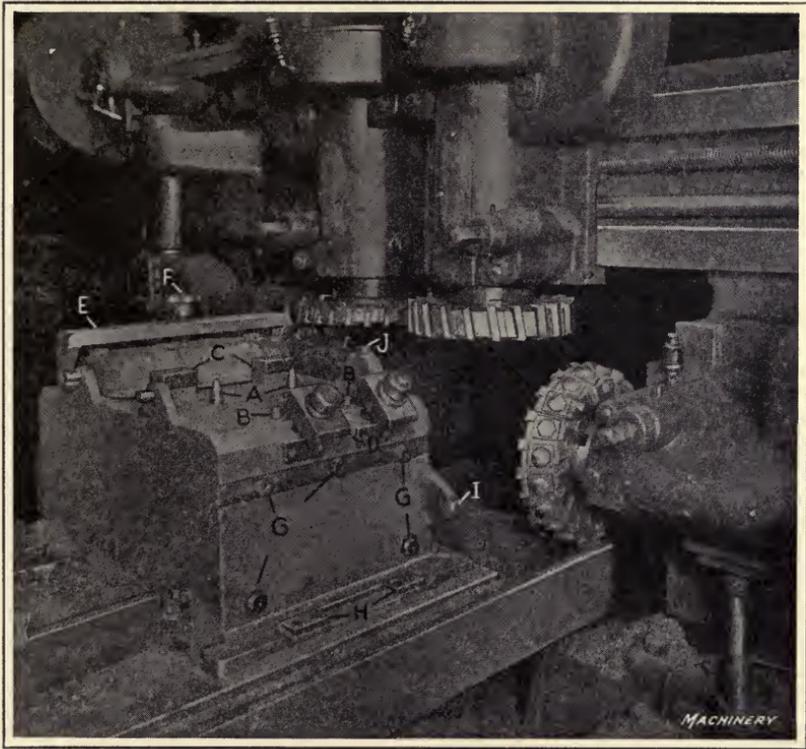


Fig. 22. Arrangement of Cutters and Design of Work-holding Fixture used on Multiple-spindle Machine for milling Continental Cylinder Heads

castings. Two other supporting pads *B* rest against the under side of the flange on the work. The castings are held in the fixture between two knurled stops *C* and two knurled straps *D*, the latter also being used to hold the castings on the side of the fixture for the second operation. In setting up two castings on the top of this fixture for the first milling operation it is important to have the work held down tight against the

locating points of the fixture. This is done by yokes *E* which have a hook at each end; these hooks grip pins provided in the fixture for that purpose. Then capstan screw *F* is tightened on the work to force it firmly against the locating points of the fixture. When the casting has been located in this way, straps *D* are tightened; yokes *E* may then be removed without springing the work out of place.

After the first operation has been performed on castings mounted in the two stations at the top of the fixture, they are set up at the sides of the fixture, being located from the milled faces of the bosses on the castings, which come into engagement with five fixed stops *G*. Straps *D* secure the work at the side of the fixture, these straps forcing the casting down against knurled stops *H*. Each fixture, as it passes under the milling cutters, is loaded with four cylinder head castings, two of which have the first operation performed on them while the second operation is being performed on the other two castings. Consequently, two cylinder heads are finished as each fixture passes under the cutter. There are two setting points *I* and *J* that are used with a "feeling gage" $\frac{1}{16}$ inch in thickness for locating the cutters at the time the machine is being set up. The cutting speed is 102.6 feet per minute, with a feed of 4 inches per minute. The rate of production for both operations on the cylinder heads is 12 per hour. Two men are employed to load and unload the fixtures.

Milling Hudson "Super-Six" Cylinder Heads. — For milling the water-jacketed head of the "Super-Six" motor, it is necessary to take one facing cut over the top of the head, and a roughing and finishing cut over the surface which comes into engagement with the milled top of the cylinder block. For these operations, a special three-spindle milling machine is used which is equipped with an indexing table fitted with six work-holding fixtures. This equipment, which is shown in Fig. 21, has the advantage of allowing milling operations to be performed on three castings carried in the fixtures at one end of the table while the operator is removing milled cylinder heads and substituting other castings in the fixtures at the

opposite end of the table. Then it is merely necessary to withdraw the locking pin and rotate the table through 180 degrees to bring the next castings into the operating position. With an equipment of this kind, there is little idle time of either the machine or its operator.

Lever *E* provides for withdrawing the locking bolt when it is required to index the table to bring the next set of castings into the operating position. The first operation consists of milling the top face of one cylinder head, and there are two castings set up on the table for this operation, one of which is shown under the left-hand spindle of the machine, while the other casting will be set up diagonally opposite, that is, at the right-hand end of the front row of fixtures. After this operation has been performed on the top of the casting, it is removed from the first fixture, turned over and set up in the middle fixture of the same row, so that at the next traverse under the cutters it is ready to have the roughing cut taken on its under surface that comes into contact with the top of the cylinder block. When the table is again indexed to reset the work, this casting is moved over to the position shown at the extreme left in the front row of fixtures, and thus is in place for taking the finishing cut. The cutters which perform the roughing and finishing operations on the under side of the cylinder heads are set at levels which differ by approximately 0.020 inch, so that a finishing cut of average depth can be taken. All three fixtures are loaded before the table is traversed under the cutters, so that the milling of one head is completed for each traverse movement of the table.

The design of the fixtures used for milling opposite sides of these castings is essentially the same. The casting is dropped into place in the fixture, where it is supported by three pads *A*, and a pin *B* carries the end thrust. Sidewise location of the casting is accomplished by means of three screws *C*, two fixed screws being provided at one side of the fixture and an adjustable screw at the opposite side. Straps *D* hold the work down in the fixture. These straps are provided with round-pointed ends to enter the core-support holes in the castings.

At one end of the fixture there are two straps *D*, while at the opposite end there is a strap provided with two points to enter the core-support holes in the work. At one end of the fixture there are compression springs beneath these straps, while at the opposite end the strap is slotted so that the round points may be withdrawn from the core-support holes in the work after slightly loosening the bolts. The milling cutters used for this operation run at 52 feet per minute, and a rate of feed of 9 inches per minute is employed. On the "Essex" head, the surface milled is 19 by $8\frac{3}{4}$ inches in size, and on the "Super-Six" the surface to be milled measures $7\frac{3}{4}$ by 29 inches. The rate of production obtained is 85 cylinder heads in an eight-hour working day.

CHAPTER V

MILLING PRACTICE IN LOCOMOTIVE SHOPS

ENGINEERING works engaged in building locomotive engines have a number of heavy-duty milling operations to perform on parts of their products. Among the more severe of these are operations required on forgings for connecting-rods and side-rods. Figures 1 to 7, inclusive, show some of the typical milling operations for which the multiple-spindle or so-called "slabbing" type of milling machines, built by the Bement-Miles Works of the Niles-Bement-Pond Co., are used in several large locomotive shops in this country. Some of these operations are among the most severe classes of service required of milling machines, both as to the rate at which metal is removed by the cutters, and the toughness of the forgings to be milled.

Slabbing Operations on Locomotive Side Frames. — Figures 1 and 2 show two of the operations required for milling locomotive side frames from the forgings. The finished piece is illustrated in Fig. 3. When four forgings have been set up on the machine, the first step is to mill faces *A*, *B*, and *C* in the order named, and after this has been done, surfaces *D* and *E* are milled. In handling work of this general character on a slabbing type of milling machine, it is possible to use the machine for sinking the cutters to the required depth in the work, in addition to feeding the work under the cutters. The power mechanism provided for traversing the cross-rail on the housings is used to sink the cutter into the work. This method was also used for forming the curved shoulder, or "radius," between surfaces *A* and *C*, and also between surfaces *B* and *D*, and *B* and *E*.

As faces *A*, *B*, and *C* are parallel to the under side of the forging, the four pieces of work can be set flat on the machine

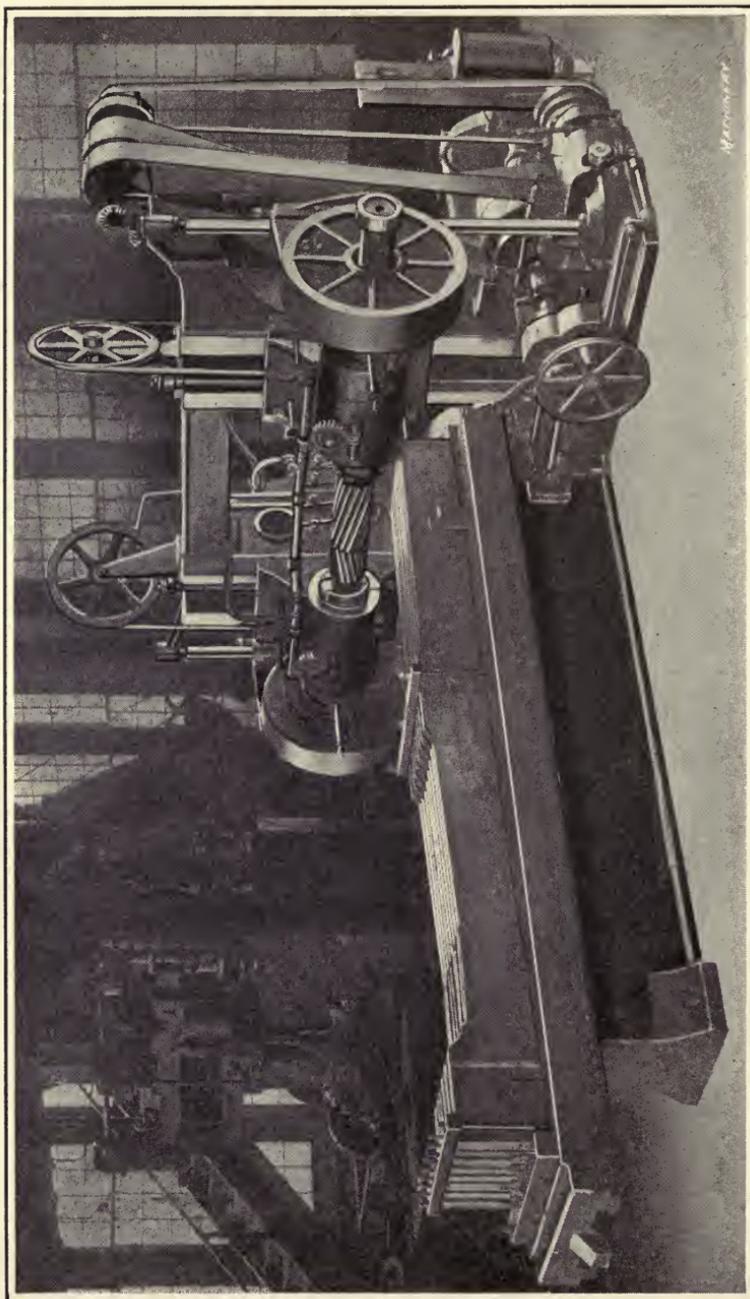


Fig. 1. Slabbing Type of Milling Machine equipped for milling Edges of Locomotive Engine Side Frames

table for the milling of these surfaces. Surface *D* on each of the four side frames is machined next. Figure 3 shows that this surface is inclined to face *C* and so special means must be provided for obtaining the required angle. This is easily done by blocking up the work at one end in order that traversing the forgings under the cutters may result in milling surface *D* on each forging in the desired relationship to other finished faces. As in the preceding case, it is necessary to sink the cutter into the work to produce the required radius between faces *B* and *D*. After finishing this operation, the blocks are removed in order to drop the forgings back to a position flat on the table, and the cross-rail must next be raised to allow sufficient clearance to pass the central work-holding clamps beneath the cutters. The cutters are then sunk into the work to the required depth, after which the feed is engaged for milling surface *E*. This completes the operations performed with the forgings held in the position shown in Fig. 1.

Slabbing Operations on Reverse Edges of Locomotive Side Frames.— On the opposite edge of the forgings, when set up on the machine as shown in Fig. 2, there are three parallel faces *F*, *G*, and *H*, and two inclined faces *I* and *J*, to be milled. For finishing the parallel faces, the work is located from the two parallel faces *A* and *B*, which were finished during the preliminary slabbing cut that was taken across the opposite edge of the forgings when they were set up on the machine as shown in Fig. 1. A similar slabbing cut is taken across the work after it is set up, as shown in Fig. 2, and this results in finishing face *F*. The work is next blocked up to the required position for milling inclined face *I*, after which the blocks are removed to relocate the forgings from faces *A* and *B*. Then the cutter is sunk to the required depth and surface *G* is milled, care being taken to trip the power feed at exactly the desired point to produce the required "radius" at the opposite end of this face. The cross-rail is next reset in position for milling face *H*, after which the forgings are blocked up to the position shown in Fig. 2 ready for milling

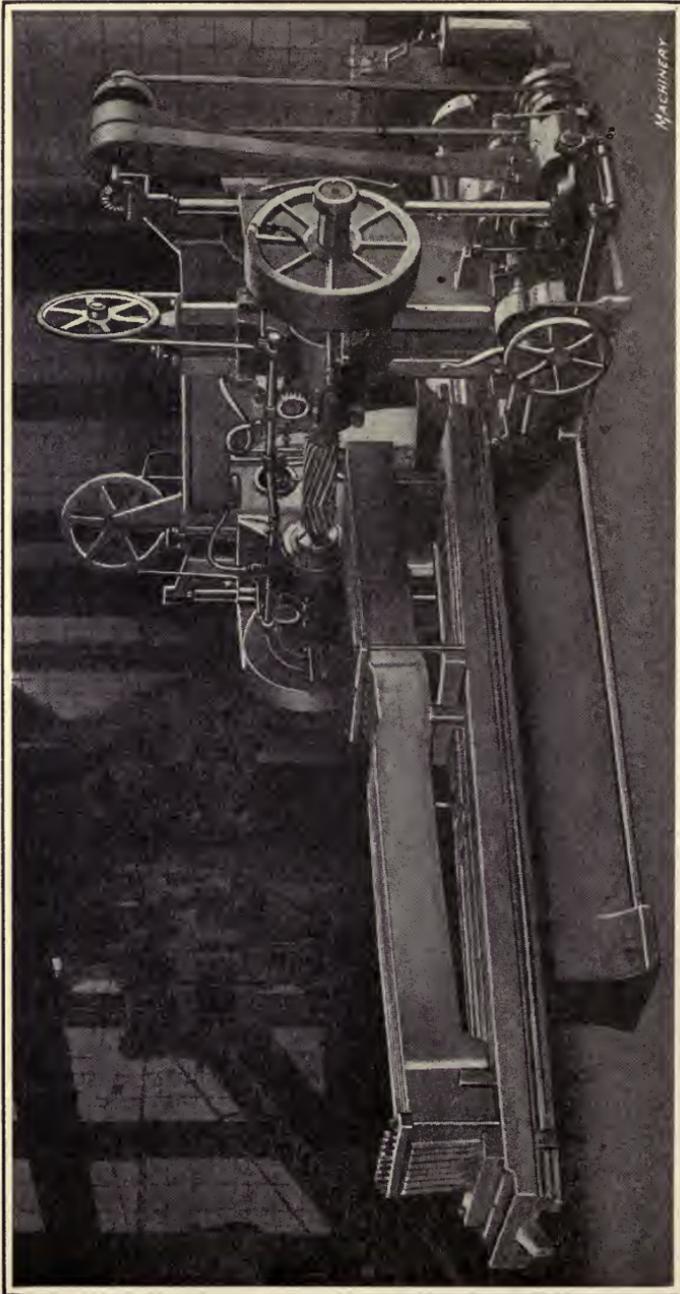


Fig. 2. Slabbing Operation on Same Locomotive Side Frames that are shown in Fig. 1 but with the Work turned over for milling Opposite Edges

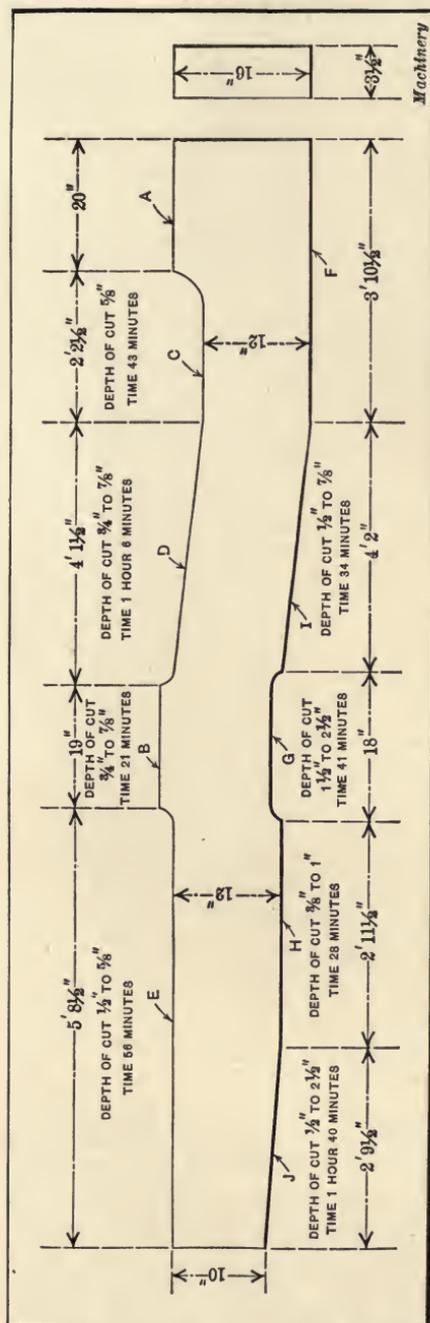


Fig. 3. Design of Locomotive Side Frames which are shown being milled in Figs. 1 and 2

inclined surface *J*, which completes the operations required on the edges of the work. There are other milling operations to be performed on the sides of the work and subsequent machining operations, but these will not be described here. A good idea of the amount of service obtained from the milling machines used on this work will be gathered from the fact that approximately 1356 pounds of

steel are removed from the edges, and the length of time required for the work is six hours twenty-nine minutes. The depth of cut taken on each face of the work and the time occupied in milling each face are shown in Fig. 3.

Fluting or Channel-milling Operations on Connecting-rods. — Forgings from which locomotive engine connecting-rods are to be machined are

formed by the same general method as described for milling side frames. Consequently a detailed description of the preliminary operations is unnecessary. Figures 4 and 5 show the performance of what is variously known as the channeling or fluting operation. Three cutters mill the channel in three forgings which are set up on the machine at a time. For these channeling operations, the machine cannot be

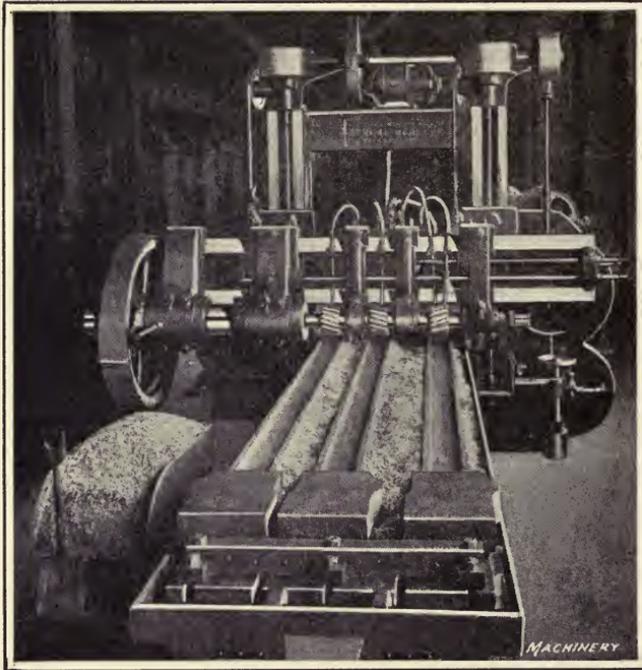


Fig. 4. Slabbing Type of Milling Machine equipped for the Performance of Channeling Operation on Locomotive Connecting-rods

operated under as severe conditions of speed and feed as in the case of plain slabbing operations, because it is more difficult to dissipate the heat generated by the cutters, owing to the fact that they are more closely surrounded by the metal.

The method of setting up these forgings for milling the channels is apparent from the illustration. The conditions of speed and feed, and the time allowed by one well-known

locomotive plant for this operation are as follows: On the connecting-rods shown in process of milling, the channels are $4\frac{1}{2}$ inches wide by $1\frac{2}{3}\frac{5}{8}$ inches deep by 10 feet long; and the forgings are made of 45- to 50-point carbon steel. For the channel-milling, the rate of feed is from $2\frac{1}{2}$ to 3 inches per minute, this being all that the milling cutters will stand without excessive wear. In this plant, a feed of $5\frac{1}{2}$ inches per

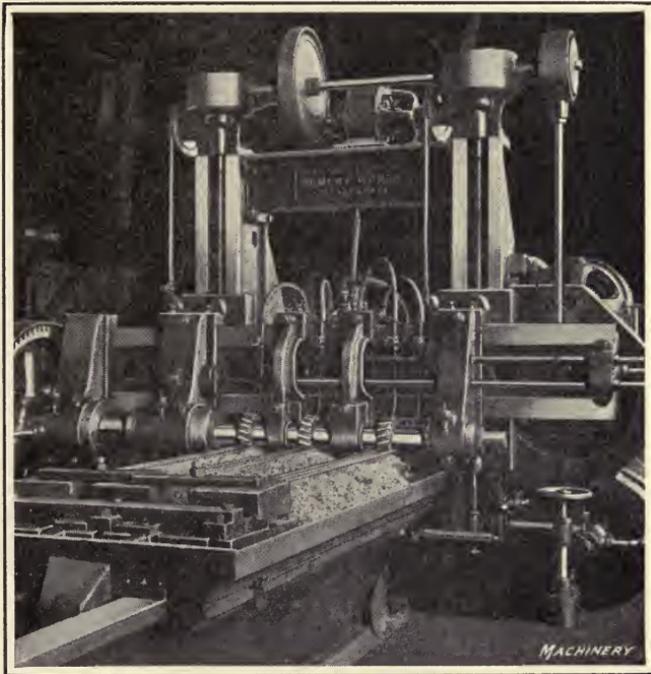


Fig. 5. Close View of the Work and Cutters on the Slabbing Type of Milling Machine shown completely in Fig. 4

minute has been employed with a cutting speed of 80 feet per minute, but operating under such severe conditions, it was found that the rapid wear of the milling cutters more than offsets the improved rate of production. Operating with a feed not exceeding 3 inches per minute, the milling cutters are good for three settings, that is to say, for milling the flutes on both sides of nine connecting-rods, before they require

grinding. On this operation, the time required to complete three rods is twelve hours, this figure representing the time from floor to floor. It is found economical to take two cuts in each channel, the first being $1\frac{1}{8}$ inches in depth and the second $\frac{2}{3}\frac{1}{2}$ inch in depth, giving the required total of $1\frac{2}{3}\frac{5}{8}$ inches.

Slabbing Operations in Milling Locomotive Side-rods.—Bement-Miles planer-type milling machines are used in a number of plants for milling the side-rods that connect driving

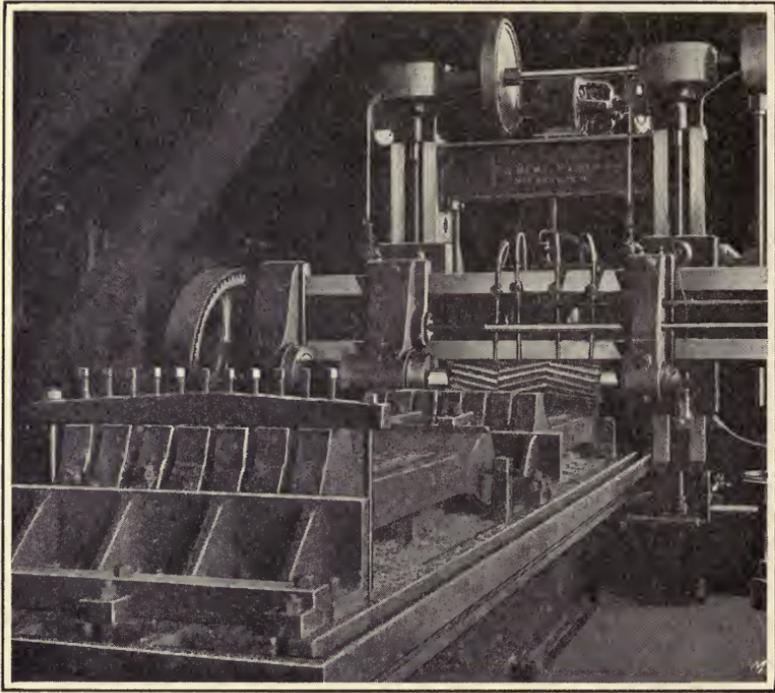


Fig. 6. Slabbing Type of Milling Machine equipped for simultaneously milling Edges of Seven Locomotive Engine Side-rods

wheels of locomotive engines. Figures 6 and 7 show two of these machines set up for slabbing operations on the edges and flats of side-rod forgings. For milling the edges of the work, fixtures are employed which have sufficient capacity for setting up fourteen forgings at a time; and by utilizing the power feed mechanism for the cross-rail, the rods can be

milled to the desired form. The fixtures used for holding these parts on the milling machine table consist merely of end blocks for supporting the thrust of the cutters, and straps at each end for holding the forgings down on the fixture. After one side of the forgings has been milled and the work turned over ready for the second operation, it is necessary to place a

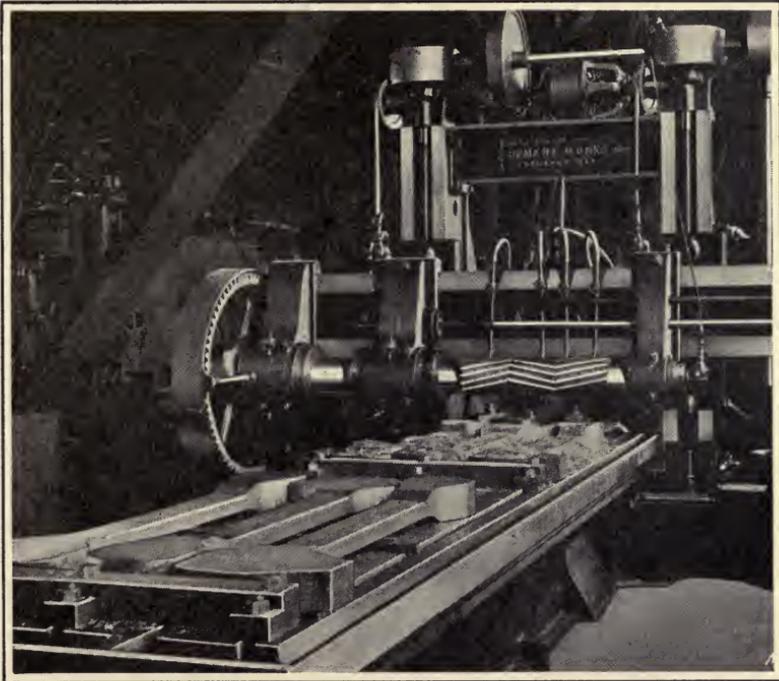


Fig. 7. Locomotive Engine Side-rods shown in Fig. 6 set up for the Simultaneous Performance of Slabbing Operation on the Flat Sides of Three Pieces of Work

supporting block under the work at the center (Fig. 7) to avoid danger of having the pressure of the cut spring the forgings.

Increasing Production in Slabbing Operations. — The method used for setting up forgings on the machines shown in Figs. 6 and 7 greatly reduces the idle time of both the machines and their operators, thus increasing production. On the machine set up for milling the edges of the forgings, two rows of seven pieces each are mounted on the table; and

when the pieces are set up for milling the side faces, two rows of three forgings each are set up ready for this operation. This is not in any sense an application of "string" fixtures, however. A brief inspection of the illustrations will make it apparent that it is impracticable to continue the feed movement of the table in order to bring the second row of forgings under the milling cutters. The method actually followed in loading and unloading the fixture shown on these machines is as follows: One row of forgings is set up in either the front or rear fixture, as the case may be, and these forgings are brought into the proper relation to the milling cutters, after which the power feed is engaged. Then, while forgings held in the first fixture are being milled, the machine operator unloads the milled pieces from the second fixture and sets up fresh forgings ready for the next operation. After the cut has been taken on the parts held in the first fixture, the cross-rail is raised to traverse the table over to bring the pieces set up in the second fixture into the milling position. Setting up two sets of fixtures and using them alternately in this way shows an improvement in production time as compared with the use of only one set of fixtures.

Capacity of Planer-type Milling Machines for Removing Metal. — Properly designed planer-type milling machines are the most rapid to use where heavy forgings and castings require a considerable amount of metal to be removed in order to bring them to the required form. This fact is demonstrated by tests made by the Niles-Bement-Pond Co. on machines of this type. The following data gives the results of such a test made on a 45-inch connecting-rod milling machine of the three-motor type. The driving motor used for making the test developed 90 horsepower, and 50 cubic inches of 30-point carbon steel per minute, or 110 cubic inches of cast iron per minute were removed. An inserted-tooth cutter used for this test was 18 inches long and provided with high-speed steel blades. Operating with such a motor, it was found that the power supplied to the machine was the limiting factor, rather than any structural limitations of the machine. The size of

connecting-rod milling machine used for the test is not ordinarily equipped with so powerful a driving motor. For normal conditions of operation, a 40-horsepower motor is used, and the machine is then capable of removing from 20 to 25 cubic inches of 30-point carbon steel per minute, and from 45 to 55 cubic inches of cast iron per minute. In slabbing operations, that is to say, in taking broad, shallow cuts, the milling cutters are in contact with a much broader area than in connecting-rod channeling operations, as a result of which the slabbing cutters work under more favorable conditions for the dissipation of heat. For this reason, more metal can be removed in a given length of time than is true in milling channels in connecting-rods.

With the exception of friction losses, the full power of the driving motor is delivered to the spindle of this machine, as the feed mechanism is driven from a separate motor wired to the driving motor in such a way that when the spindle is stopped the table feed is also automatically disengaged. With such an arrangement, it is impossible to have the table continue feeding when the spindle comes to rest. One important advantage secured by providing a separate feed motor is that the rate of feed is made independent of the spindle speed, thus adapting the machine for milling materials requiring the use of high speed and low feed, or vice versa. This separate feed motor is found useful when milling rough forgings that are likely to have inequalities in the amount of metal to be removed, thus making it desirable to reduce or increase the rate of feed at different points. The feed motor is of the variable speed type, provides a wide range of feeds with very small changes, will adapt itself to a reasonable overload, and is also used for operating the fast traverse of the table, a switch being provided for that purpose. An important feature in the design of planer milling machines is to provide an elastic medium in the feed mechanism in order to protect the cutters and machine in case an unusual strain is caused by a hard spot in the work.

CHAPTER VI

STRING MILLING FIXTURES

FOR milling large numbers of duplicate parts it will frequently be found desirable to use the familiar string type of work-holding fixture which may be employed on practically any kind of milling machine. One advantage in using this fixture is that a number of parts can be set up at a time, so that the milling machine is kept running for a considerable period before it becomes necessary to stop the spindle, unload the fixture, and return the table to the starting point. The ratio of idle time to operating time is thus substantially reduced.

Method of Loading String Fixtures. — Variations in the conditions under which milling machines are operated make it necessary to modify the method of loading and unloading string fixtures. Where either the size of the pieces to be milled or the rate of feed that must be employed allows sufficient time while a piece of work is passing between the cutters to enable the operator to set up a blank in an adjacent station of the fixture, the best method is to unload the milled parts as soon as they have passed out of engagement with the cutters. After the last station on the fixture has been unloaded and the table has been returned to the starting point, the milling-machine operator sets up a piece of work in the station nearest to the cutters and starts the feed mechanism. He then sets up pieces of work in the remaining stations, working from the position nearest to the cutters toward the opposite end of the fixture. In this way, the machine and the operator are idle for a minimum length of time. It frequently happens, however, that the pieces to be milled are so small or that the rate of feed is so high, that insufficient time is allowed, while one piece of work is fed between the cutters, to allow the opera-

tor to set up a piece in the next station. Under such conditions, either several of the stations or the entire fixture should be loaded, before the feed is engaged; but even when such conditions are encountered, a substantial reduction on production time will be effected through the use of string fixtures, as compared with many other types of fixtures in which only one piece can be set up at a time, and where it is necessary to

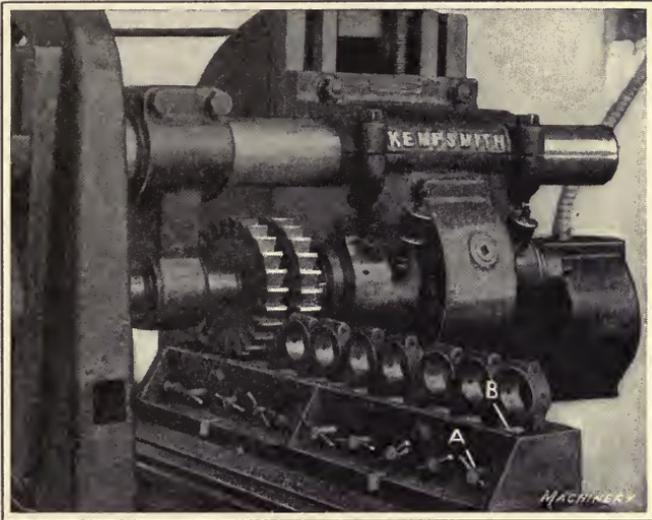


Fig. 1. Kempsmith No. 33 Lincoln-type Milling Machine equipped with Stellite Cutters for straddle-milling Gear-box Levers

stop the machine and return the table after each separate piece has been milled.

Milling Gear-box Levers. — The milling operation shown in Fig. 1 is interesting not only as a good example of string fixture design, but because the cutters are made of stellite. The parts being milled are levers for use in the gear-box on either the No. 2 or No. 3 plain or universal milling machines built by the Kempsmith Mfg. Co. As this firm manufactures large numbers of these levers, a very satisfactory method of milling on a quantity production basis has been developed. The machine illustrated is of the Kempsmith No. 33 Lincoln type; and the string fixture holds ten castings which are straddle-milled

on their opposite faces. The fixture has been so designed that the work of setting up can be very readily accomplished. There is a projection on each piece of work, which extends down into a channel in the fixture. Each casting to be milled has a transverse hole drilled through it, which is utilized as the locating point by sliding a T-head pin *A* through holes in the walls of the fixture and through this hole drilled in the work. At the opposite side of the fixture there is a set-screw at each of the ten stations, and when a casting has been located by means of pin *A*, this set-screw is tightened to force the casting up against the finished face of a hardened steel stop *B*. Thus castings can be set up and removed with very little loss of time. The material being milled is cast iron and the stellite milling cutters are driven at 60 revolutions per minute, which corresponds to a cutting speed of 125 feet per minute. The work is fed to the cutters at a rate of 8 inches per minute, and the rate of production obtained is seventy-six pieces per hour.

Milling Clutch Shifter Forks for Kemp Smith Milling Machines. — Figure 2 shows one method of milling clutch shifter forks for the Kemp Smith No. 33 Lincoln-type milling machine. For this operation a No. 3 plain milling machine is used, which is provided with a string fixture that enables two pieces of work to be operated upon at each traverse of the table. Owing to the offset form of the forgings to be milled, the work-holding fixture was so designed that one piece of work could be supported as shown at *A* and the other in the position illustrated at *B*. In the case of each piece of work, the end to be milled is supported on one of the blocks *C*, these two blocks being arranged to hold the ends of the two pieces of work at the same height from the table. To compensate for the offset form of the forgings, and also to afford means of clamping them in the fixture, use is made of the holes drilled in the opposite ends of the forgings. A sliding pin is passed through these holes and also through holes in blocks *D*, to hold the end of fork *A* at such a level that its opposite end will be supported by the top of block *C*. Similarly, the piece of

work shown at *B* is held by a pin *E* that slides through holes in the work and through two other holes drilled so as to be in accurate alignment in the bottom of block *D* and in block *F*.

By holding one forging with its offset end extending downward and the other forging with its offset end extending upward, the opposite ends of these two forgings are so located on blocks *C* that they may be milled by a single passage under a formed milling cutter, which produces a convex surface on the work of the required radius of curvature. Posts are pro-

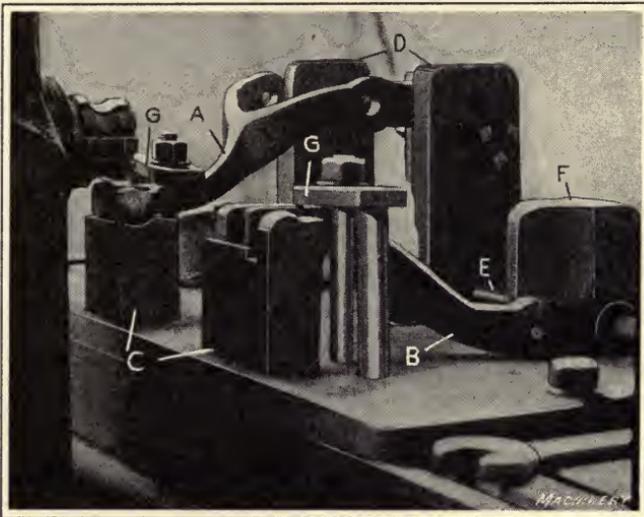


Fig. 2. Kempsmith No. 3 Plain Milling Machine equipped for milling a Convex Surface on Clutch Shifter Yoke Forgings

vided on the bed of the fixture to support two straps *G* which hold the pieces of work down on the tops of blocks *C*. To facilitate loading and unloading the fixture, these straps *G* are slotted, so that by merely giving the clamping nuts a half turn, it is possible to draw the straps back from their position over the work, instead of having to remove the nuts from their bolts in order to lift the straps off. In this way, a great saving is effected in the setting-up time.

After the two forgings have been milled while held in the position shown in Fig. 2, they are removed from the fixture

and reset in the opposite position to provide for milling the other side of the work. In these operations, the 3-inch formed milling cutter is driven at a speed of 92 revolutions per minute, which corresponds to a cutting speed of 72 feet per minute. The work is fed to the cutter at a rate of $1\frac{1}{8}$ inches per minute; the rate of production is seventeen completely milled pieces per hour, which represents the time taken from floor to floor.

Milling Hudson Connecting-rods. — After the crankpin and wrist-pin bearings have been bored in Hudson connecting-rod

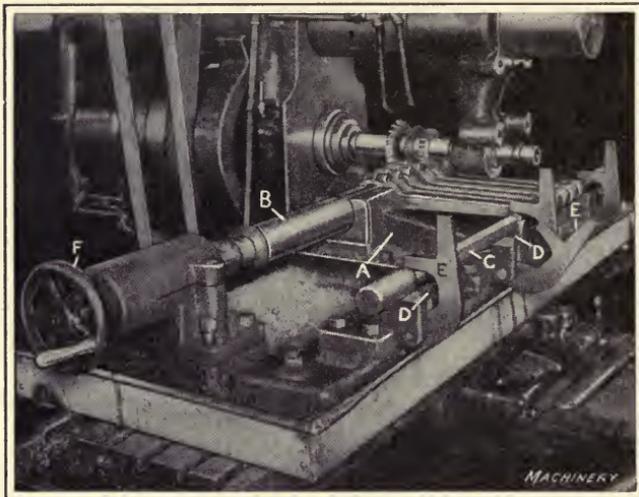


Fig. 3. R. K. LeBlond No. 3 Plain Milling Machine equipped for simultaneously milling Top and Bottom of Bolt Bosses of Connecting-rods, and cutting off Crankpin Bearing Caps

forgings, it is necessary to straddle-mill the top and bottom faces of the bosses in which holes are drilled for the bolts that hold the crankpin bearing cap in place, and to cut this cap off from the forging. These operations are simultaneously performed on an R. K. Le Blond No. 3 heavy-duty plain milling machine which is equipped with a fixture of the form shown in Fig. 3. This fixture combines features of both the string and indexing types. It is primarily a string fixture, but provision has been made for milling and cutting-off operations

on six forgings held in one station while the six milled forgings held in the other station of the fixture are being unloaded and fresh blanks substituted in their places.

When the connecting-rod forgings come to this machine, they have already had the crankpin and wrist-pin bearings bored. These two holes in the work are utilized as locating points in setting up the pieces in the fixture. At a point near the center of the milling machine table, there is a bracket *A* supporting two mandrels *B* that project out from bracket *A* toward the opposite ends of the table. These mandrels are of such size that the crankpin bearing in the connecting-rods can just be slipped over them. Six pieces of work are located on each mandrel *B*, and after these six forgings have been set up, a sliding pin or bar *C* is pushed through the wrist-pin bearing holes. This small bar rests on two hardened steel pads *D* and is held down by pivoted latches *E* which are swung up over bar *C* to hold it down on the pads *D* after the bar has been pushed through the wrist-pin holes in the connecting-rods. Outboard support for mandrels *B*, which support the entire pressure of the cut, is provided by a tail-center manipulated by handwheel *F*, which enters the outboard end of mandrel *B*, the same method of support being used at each end of the fixture.

Arrangement of Mechanism at Opposite Side of Fixture. —

At the opposite side of bracket *A*, there is exactly the same arrangement of mechanism, so that a complete set of forgings can be set up at each side of the central bracket, these two sides of the fixture being independent of each other. The method of operation is as follows: The operator sets up six forgings on that section of the fixture located at the left-hand side of the central bracket *A*, brings the table up to the proper level, and engages the feed mechanism. While the forgings carried in this section of the fixture are being fed under the cutters for straddle-milling the bolt bosses and cutting off the bearing caps, the operator sets up a similar set of six forgings in the station of the fixture located at the right-hand side of central bracket *A*. After the first set of forgings has been

milled, the table feeds across to bring the milling cutters into engagement with the second group of forgings. Then the operator moves over to the other side of the table to remove the milled forgings and be ready to set up fresh blanks in their places. After the second group of forgings has been milled, the table is lowered sufficiently to allow it to be traversed back to the starting point without interference from the milling cutters. The table is then raised to bring the work into proper relationship with the milling cutters, as determined

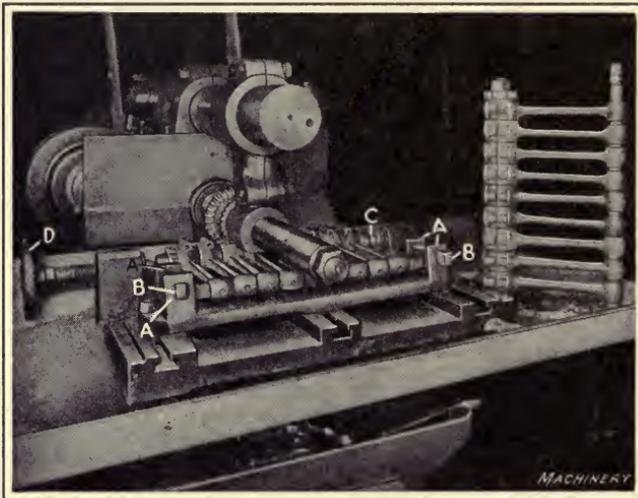


Fig. 4. Cincinnati No. 2 Plain Milling Machine equipped for Straddle-milling Top and Bottom of Bolt Bosses on Connecting-rods, and cutting off Crankpin Bearing Caps

by a stop, after which the left-hand side of the fixture is loaded and the feed mechanism is again engaged. This cycle of operations may be repeated indefinitely with very little loss of time for either the machine or its operator.

After the bolt bosses have been milled and the bearing cap cut off at one side, however, the six forgings must be removed from the fixture, turned over, and again set up in the same fixture ready for a similar operation on the opposite side of each piece. An improvement of this condition could be made in either of two ways. If it were required to use the same milling machine which is now employed, this could be done by

so constructing the fixture that the entire string of forgings could be taken out, turned over, and reset, without requiring the individual forgings to be removed from their supporting mandrel. This idea is illustrated in Fig. 4. An even better arrangement is accomplished at a certain plant where this operation is performed on a semi-automatic milling machine equipped with two spindles. With a tool of this type, the straddle-milling operations and the sawing off of the bearing cap may be simultaneously accomplished at both sides of the connecting-rod forgings, thus greatly reducing production time through eliminating the necessity of resetting the work and performing a second operation. In performing this operation on the machine equipped as shown in Fig. 3, the cutters run at 60 revolutions per minute, and owing to variations in their diameters they have speeds of 79, 63, and 55 feet per minute, respectively. The work is fed to the cutters at the rate of 3 inches per minute, and the rate of production is 300 connecting-rods in an eight-hour working day.

Milling Continental Connecting-rods. — In Fig. 4 there is shown the method used for performing the same milling operation on Continental connecting-rods which is illustrated in Fig. 3. This job is done on a Cincinnati No. 2 miller. Although the methods used by these two companies are similar in their essential principles, the plan of setting up the work differs in several details. Figure 4 shows that instead of having a central bracket, with mandrels projecting out in opposite directions for holding six connecting-rod forgings at each side of the fixture, it is possible on this machine to set up a string of nine forgings on two mandrels through the crankpin and wrist-pin bearing holes. These mandrels are entirely separate from the body of the fixture, so that the work and mandrels may be removed as a unit and turned over for straddle-milling and cutting-off operations on the opposite side of the work. Such a unit can, of course, be much more quickly removed and set back in the fixture than is possible where individual forgings must be taken off the mandrels and put back separately after being turned over. The mandrel which passes through

the wrist-pin bearings in the rods is squared, so that it may be dropped into place between yokes *A* at opposite ends of the fixture, and held down on finished seats machined in these yokes by means of tapered pins *B*. The mandrel which passes through the crankpin bearings is centered at its ends, so that it may be supported by a fixed center *C* and an adjustable center manipulated by handwheel *D*. The form of the milling cutters and method of mounting them on the arbor are the

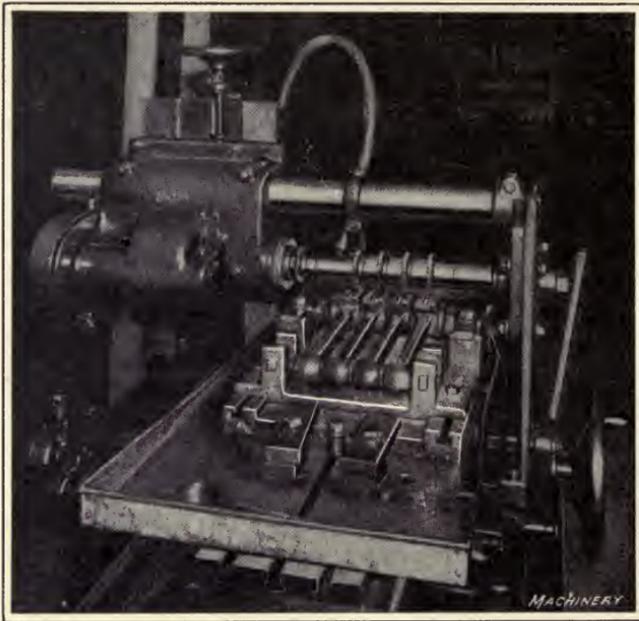


Fig. 5. Brown & Sharpe No. 13 B Lincoln-type Milling Machine equipped for roughing out the Clearance Spaces between Bolt Bosses on Connecting-rods

same as in the equipment described in connection with the preceding illustration. This operation is performed at a cutting speed of 94.2 feet per minute, with a feed of 2.30 inches per minute. The rate of production is forty completely milled connecting-rods per hour, or 320 in an eight-hour day.

Milling Clearance between Bolt Bosses on Connecting-rods.

— On some types of connecting-rods for motors, a practice is made of milling out the clearance between bosses provided for

bolts that secure the caps in place on the connecting-rods, instead of forging these bosses on the work. For this clearance milling operation, two machines are used which perform a roughing and a finishing operation, respectively. These machines are illustrated in Figs. 5 and 6. Figure 5 shows a Browne & Sharpe No. 13B Lincoln type of machine, on which the first operation is performed. After this miller has done its work, the two mandrels on which four connecting-rod forg-

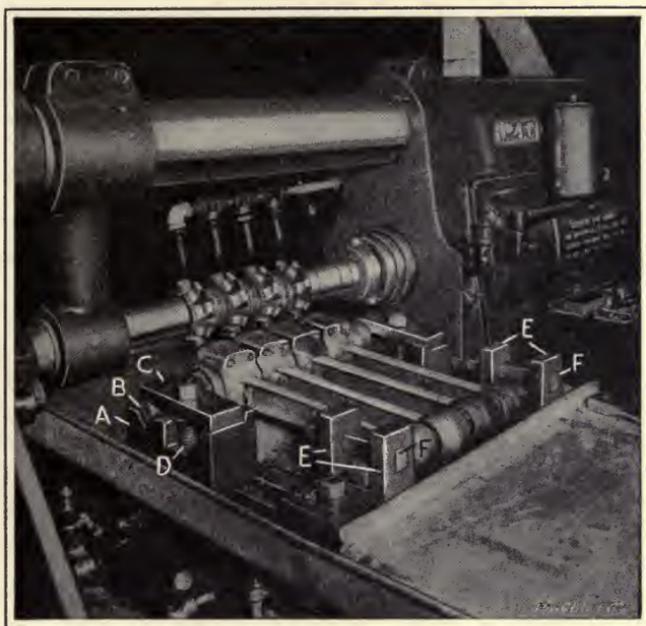


Fig. 6. No. 4 Cincinnati Milling Machine equipped with Formed Cutters for finish-milling Clearance Spaces between Bolt Bosses on Connecting-rods

ings are carried, are removed from the machine with their work as a single unit, and transferred to the No. 4 Cincinnati milling machine, illustrated in Fig. 6, on which the four forgings are set up ready for the finish-milling operation in the clearance grooves. As the mandrels on which the work is carried are transferred from one machine to the other, the work-holding fixtures used on both machines must be of the same design. The only difference in the equipment of these

two machines is that plain milling cutters are used for the roughing operation, while formed cutters are employed for finishing the grooves. The work-holding fixture is best illustrated in Fig. 6, to which attention is called in connection with the following description.

Forgings to be milled by the machines shown in Figs. 5 and 6 are clamped to the mandrel which passes through the crankpin bearings. This mandrel has a collar at one end, and it is threaded at the opposite end; but in order to facilitate assembling forgings on the mandrel, the clamping nut is made small enough to pass through the crankpin bearing. A C-shaped washer slips under this nut, the washer being of sufficient size to afford a bearing surface on which the pressure of the nut is applied to the work, in order to clamp it firmly against the collar at the opposite end of the mandrel. At the wrist-pin end, the connecting-rod forgings are held on a small mandrel which is merely a sliding fit through these bearings without being clamped in place, the function of this mandrel being simply to support the end of the forgings and hold them in the desired alignment. It has already been noted that four connecting-rods are assembled on these two mandrels to constitute a unit which may be removed from the machine on which the first operation is performed and transferred to the second machine, and that on both machines, the design of the work-holding fixture is the same.

Reference to Fig. 6 will show that at the front end of the fixture there are V-blocks *A* to hold the round ends of mandrel *B* on which the work is clamped. A strap *C* at each end of the mandrel holds it down in the V-block, and a compression spring *D* is placed under each of these straps so that when the nut is loosened, the strap is automatically raised. The mandrel which passes through the wrist-pin bearings in the connecting-rods is squared at each end to rest on hardened steel pads placed between blocks *E*. When the mandrel is dropped into place, two wedges *F* are driven into openings in the blocks *E* to hold the squared ends of this mandrel down on their seats in the fixture. On the roughing operation, the

cutters are driven at a speed of 60 feet per minute, and the rate of feed employed is $1\frac{1}{4}$ inches per minute. On the finishing operation, the cutters are driven at 42.8 feet per minute, and the rate of feed is $2\frac{1}{4}$ inches per minute. On each operation, twenty-two connecting-rod forgings are milled every hour.

Cutting Racks on a Milling Machine. — At the plant of the Walker Mfg. Co., in Racine, Wis., a No. 33 Kemp-smith Lincoln-type milling machine is used to cut eighteen spur teeth in racks made of steel stock measuring 1 by 1

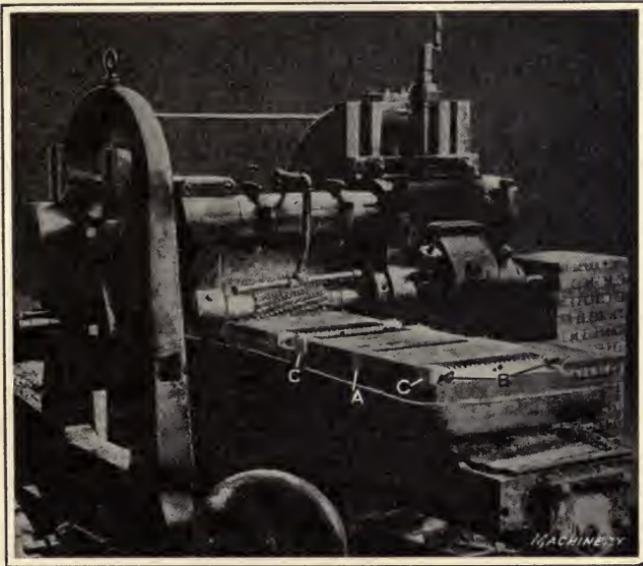


Fig. 7. Kemp-smith No. 33 Lincoln-type Milling Machine equipped for milling Teeth of Racks

inch. It will be evident from Figs. 7 and 8 that a gang of rotary gear-cutters is mounted on the milling machine arbor to cut all these teeth simultaneously; and these cutters are set up with their teeth staggered relative to each other, the purpose being to so distribute the teeth that there will be no tendency for all of them to come into engagement simultaneously, thus setting up a "hammer blow" action.

To facilitate loading and unloading this fixture, and to reduce idle time of the operator, the fixture in which these

blanks are held is made in four sections which may be loaded and unloaded independently of each other. As a result, the operator can load the first section of the fixture and then engage the feed mechanism. Six blanks are mounted in each section of the fixture, and as the rate of feed is one inch per minute, this allows the operator six minutes in which to load the second section of the fixture, which is really more time than he requires. After the last section of the fixture has been loaded, the operator goes around to the back of the ma-

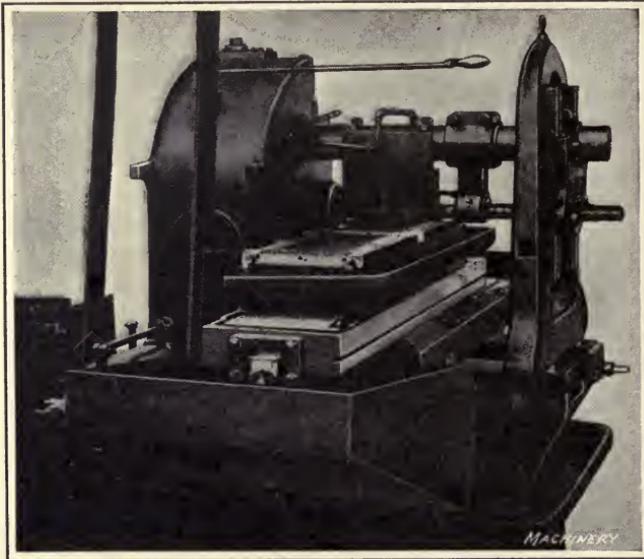


Fig. 8. Opposite End of Milling Machine working on the Rack-cutting Operation illustrated in Fig. 7

chine and starts removing milled racks from the fixture, so that after the last rack comes out from under the cutters it is merely necessary to unload the last section of the fixture before the table is returned. This method reduces the idle time of both the operator and the machines. The fixture is of simple design. Each of its four sections holds six blanks, and two sections are divided by a stop-bar *A*, against which the six pieces in each section are clamped. Set-screws *B* are carried in end bars *C*; and by tightening these set-screws, the rack

blanks are clamped against opposite sides of the stop-bar *A*. The cutters are driven at a speed of 71 feet per minute, and the rate of feed is 1 inch per minute. The rate of production obtained is 60 racks per hour, which includes the time of loading and unloading the fixture.

Use of Milling Machine Vise as a String Fixture. — At a certain automobile plant, it is necessary to perform a slot-milling operation in the brake-lever for a passenger car. The

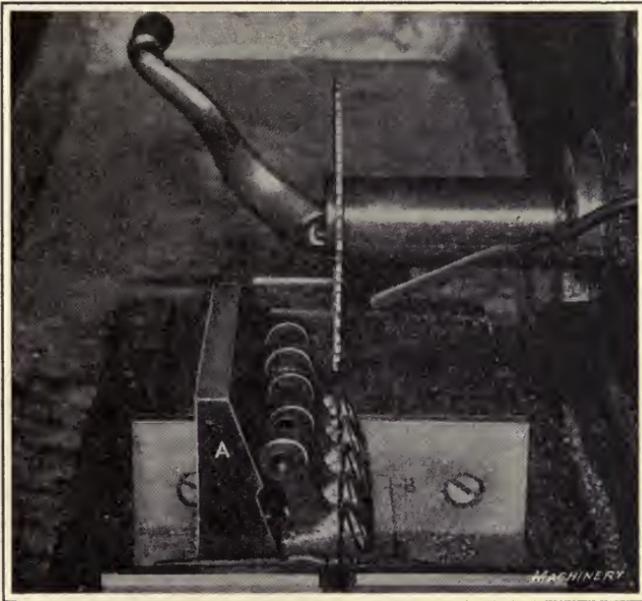


Fig. 9. R. K. LeBlond No. 3 Plain Milling Machine used for Slotting Operation on Brake-levers

slot milled in these small levers must be located at an angle to the axis of the lever arm, and it was found possible to utilize an ordinary milling machine vise for this simple operation. The work is done on a No. 3 LeBlond plain milling machine, and Fig. 9 shows a close view of the vise set on the table of this machine for holding a string of five brake-levers. As far as clamping the work is concerned, the milling machine vise answers every requirement, but it is also necessary to locate the pieces of work at exactly the proper angle. For

this purpose, a block is bolted to the bed of the vise. This block *A* has one face inclined at such an angle to block *B*, upon which the ends of the pieces of work rest, that each piece is held at the proper angle to enable a slitting saw carried by the horizontal arbor in the machine spindle to cut the slot in exactly the proper position. Blocks *A* and *B* must be made short enough to allow the five pieces of work which are set up in the vise at a time to have a total length just exceeding the

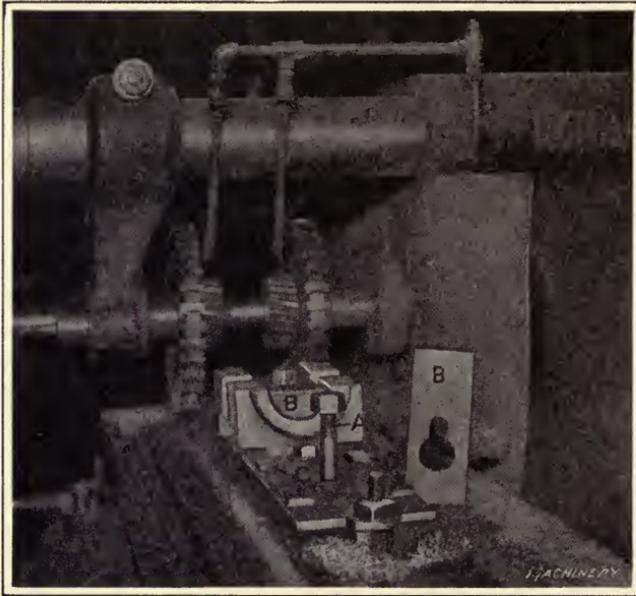


Fig. 10. Kearney & Trecker Milling Machine equipped for simultaneously milling Four Faces of Crankshaft-bearing Caps

length of these five levers. Consequently, when the movable jaw is tightened, the work is secured between the vise jaws, ready for milling. An advantageous feature of this method of holding the work is that five pieces may be set up and removed from the fixture in half a minute. The rate of production obtained is 75 milled brake-levers per hour.

Milling Hudson Crankshaft Bearing Caps. — On Hudson passenger cars heavy aluminum caps are used for the crankshaft bearings. In machining these caps, it is necessary to

mill four faces of the work, and in order to mill these surfaces simultaneously, a Kearney & Trecker milling machine is equipped as illustrated in Fig. 10. Four cutters are mounted on the arbor — two inserted-tooth mills for facing the large side surfaces of the work, and two plain cutters for milling the small surfaces at each side of the bearing groove. Four pieces of work are mounted in a string fixture on the table, and this fixture is equipped with a quick-acting clamping mechanism to facilitate loading pieces in the fixture, or removing them after the milling operation has been completed. Between each pair of bearing caps there is a bolt *A*, which holds down a semi-cylindrical shaped strap *B* fitted into the bearing groove in the two caps at each side of this clamping bolt.

The hole in strap *B* is made large enough to clear the nut on bolt *A*, so that the strap may be dropped over this bolt and then pushed sidewise in order that the groove cut in the side of the hole may allow the strap to slide under the nut ready for clamping it down on the work. Figure 10 shows that the work must be so located that the sides of the bearing caps will be milled square with the ends. This result is accomplished by having small blocks *C* on the bed of the fixture come into contact with ribs extending across the sides of the work. The way in which these blocks *C* locate the work will be readily understood by referring to the piece which is shown clamped in place on the fixture. Owing to the different sizes of the cutters used for this operation, the speeds vary considerably, the rates employed being 280 and 220 feet per minute, respectively, with a feed of 18 inches per minute. If the material were not aluminum, such rates of speed and feed could not be successfully employed. In an eight-hour working day, the output of each machine is 700 bearing caps.

Milling Retainer Rings in Roller Bearing Raceways. — In making roller bearings of the type manufactured by the Hyatt Roller Bearing Co., grooves must be milled in the outer raceways to form an anchorage for the roller retainers. For this operation, satisfactory results are obtained by the use of a Kearney & Trecker vertical-spindle milling machine equipped

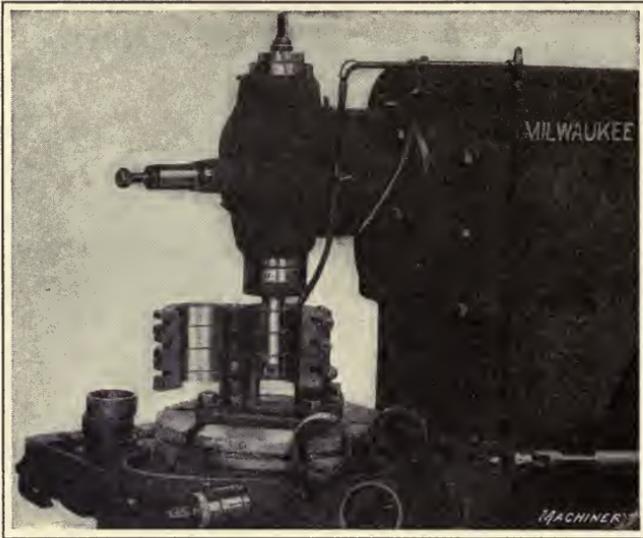


Fig. 11. Unusual Form of Fixture provided on a Kearney & Trecker Machine used for milling Grooves in Outer Raceways of Roller Bearings

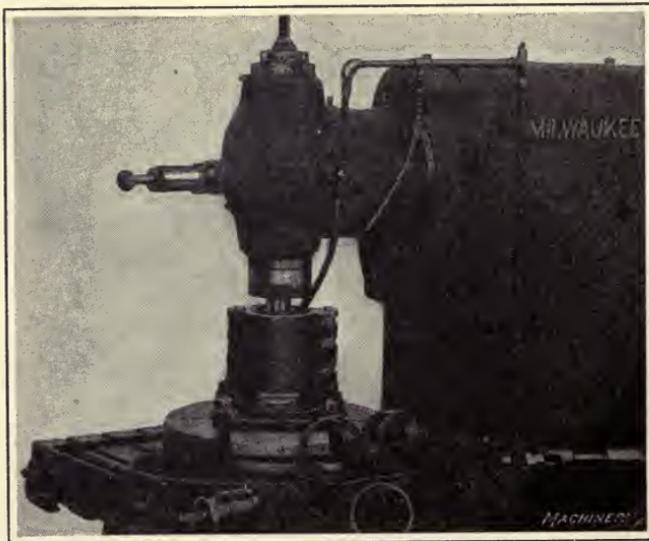


Fig. 12. Same Milling Machine and Work-holding Fixture illustrated in Fig. 11, but with the Fixture closed, ready for milling the Three Retainer Anchorage Grooves

with a rotary table and work-holding fixture of the type shown in Figs. 11 and 12. In Fig. 11 it will be seen that three slitting saws are mounted on the arbor. These saws are $\frac{1}{8}$ inch in width, which is the proper width for cutting the retainer grooves in the roller bearing raceways. The fixture mounted on the rotary table holds three raceways, in each of which the retainer groove is cut by one of the saws. As each raceway is located in this fixture, the two half rings which hold it in place are bolted together. After all three pieces have been set up, the rotary table is started, and also the transverse feed movement. As the rotary table revolves the work, the saws cut continuous slots all the way around the three pieces held by the fixture. A limit stop for the transverse movement of the table stops this feed when the slots have been milled in the work to the required depth. The parts being milled are pieces of seamless steel tubing, and the rate of production obtained is three pieces per minute.

Milling Footstocks for Spiral Heads. — Figure 13 shows a Brown & Sharpe No. 3B heavy-duty type of plain milling machine equipped for facing off the sides and milling the center space of footstocks for spiral heads. This operation is of interest owing to the height of the side surfaces which have to be milled, making it necessary to employ a gang of cutters of unusually large diameter. Three castings are set up in a string fixture, so that they can all be milled at a single traverse of the table. The outsides of the uprights on these castings are faced, and the space between the two uprights is cut to the required width. Side-milling cutters with inserted teeth are employed for this job, these cutters being 12 inches in diameter. The two outside cutters have their teeth set parallel with the axis of the arbor on which they are carried, because the face width is not great enough to cause an objectionable amount of shock when the teeth engage the work, or other undesirable conditions of operation, obviated through the use of milling cutters with spiral teeth. The middle cutter, which is of greater face width, has the teeth set at an angle with the axis of the arbor, in order to produce a shearing action, and

these teeth are nicked to break up the chips. The fixtures used for holding the work for this milling operation are of simple design, consisting merely of bolts fitted into the T-slots on the table to hold straps down on the flange which extends around the base of each footstock casting.

Multiple Work-holding Fixtures Placed Side by Side.— The term "string milling fixture" is generally applied to that class of fixture in which the castings are placed in a row on

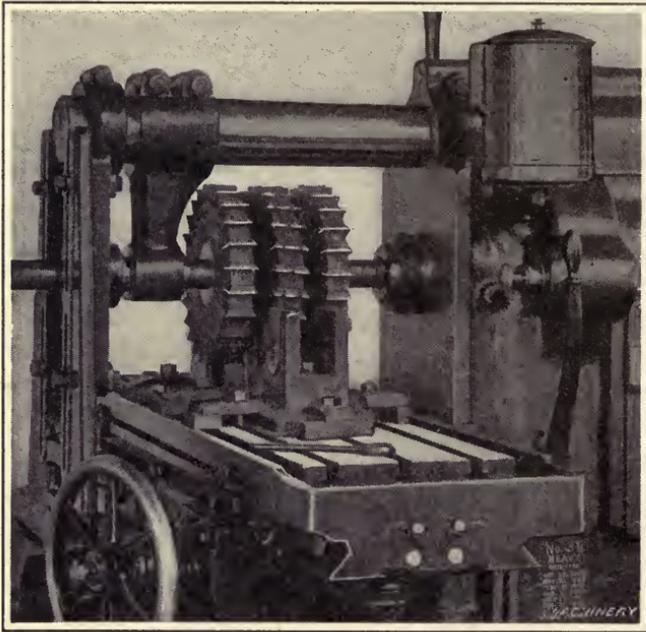


Fig. 13. Milling Footstocks for Spiral Heads on a Brown & Sharpe No. 3 B Heavy-duty Plain Milling Machine

the milling machine table, running in a direction parallel to the line of travel of the table, so that all of the castings can be milled with a single cutter, or gang of cutters, mounted on the arbor. In some cases, however, it may be found more desirable to set up the work in fixtures that hold the castings or forgings side by side, instead of end to end. A case in point is illustrated in Fig. 14, which shows a Brown & Sharpe No. 5B plain milling machine engaged in simultaneously rough-

milling the angular sides of the slides on four milling machine tables. This kind of job could be performed on a planer or slabbing type of milling machine equipped with a table of sufficient length to set the four castings up end to end; and if such a practice were followed it would be necessary to use only one milling cutter. However, by performing the operation as shown in Fig. 14, a less expensive machine is utilized;

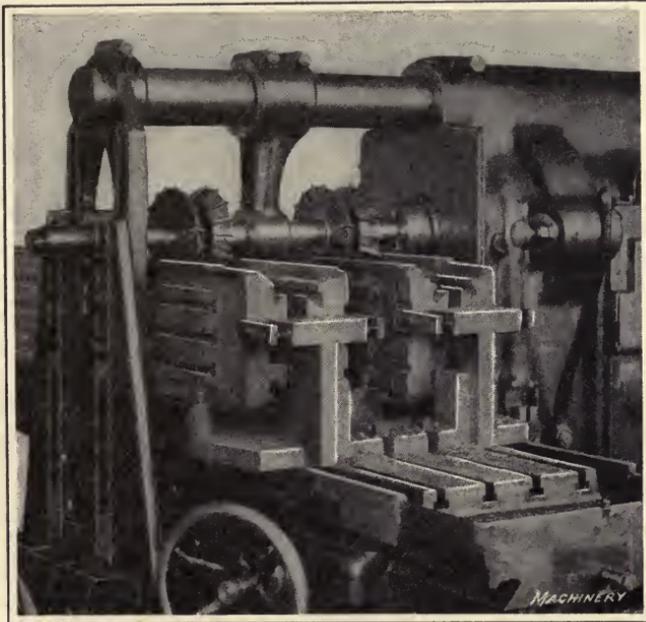


Fig. 14. Rough-milling Angular Sides of Slides on Milling Machine Tables, using a Brown & Sharpe No. 5 B Milling Machine

but in order to do so it is necessary to set the castings up side by side, because the length of the table is insufficient to mount them in a single row. The castings are set up on two knee-type fixtures, each of which holds two castings, one on each side of the fixture. The same fixture is used to mill the opposite angular sides of the slide, the four pieces of work being merely turned over and reset for taking the second cut.

Milling Two Grinding Machine Tables Simultaneously. — The No. 5B plain milling machines are used for simultane-

ously milling two tables for Brown & Sharpe grinding machines, as shown in Fig. 15. The reason for setting up the castings side by side on this machine is the same as explained in connection with the job illustrated in Fig. 14. The two grinding machine table castings are held at opposite sides of a knee fixture, and two gangs of cutters, with six in each gang, are employed for simultaneously milling the various surfaces which have to be finished. To hold these castings

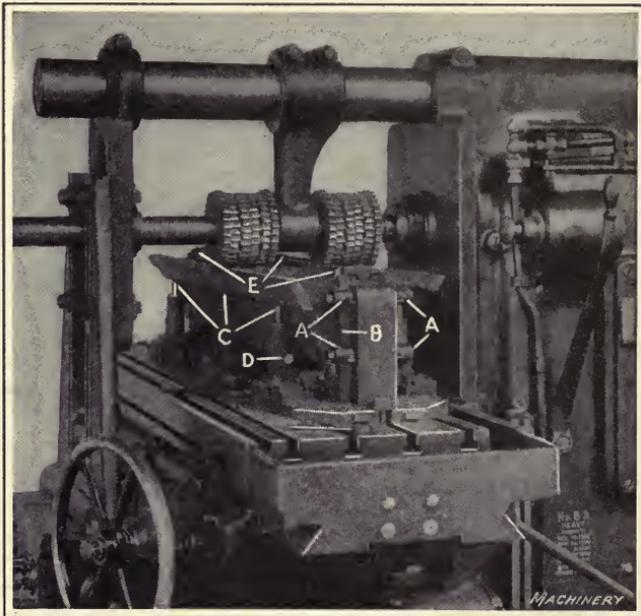


Fig. 15. Milling Operation simultaneously performed on Two Grinding Machine Tables, using a No. 5 B Heavy-duty Brown & Sharpe Milling Machine

back against the locating points, there are four straps *A* at each end of the fixture, these straps being provided with lugs which project inward to engage the flange *B* on each end of the castings that have to be milled. By tightening the nuts over straps *A*, the lugs on these straps pull the work securely back against the locating points. Owing to the form of the castings, the work must be supported to avoid danger of its being distorted through pressure of the milling cutters. This

support is furnished by three spring plungers *C*, which engage the inside of the work, after which nuts *D* are tightened to lock these plungers in place. Additional support is furnished by three straps *E*, which straddle the two castings and hold them firmly against the locating points on the fixture, in addition to keeping them down in place.



Fig. 16. Milling Grooves in Carriage Roll Guides



Fig. 17. Milling Grooves in Tabular Typewriter Rods

Milling Typewriter Carriage Roll Guides to Reduce their Weight. — A large number of parts known as carriage roll guide rods are required on Royal typewriters, these pieces being of the form shown in Fig. 16. It is important to reduce the weight of all typewriter parts as far as possible, without impairing their strength. To cut down the weight of the rods shown in Fig. 16, a longitudinal slot is milled along the

back side of each rod, in order to remove as much surplus metal as possible. This job is done on one of the Briggs milling machines built by Gooley & Edlund, Inc. Four of the carriage roll guides are set up at a time, the fixture consisting of a special form of vise provided with two openings, in each of which two of the carriage roll guide rods can be mounted. The jaws are slightly under-cut so that when they are tightened on the work, they serve the double purpose of gripping it and forcing it downward, thus obtaining an accurate location and secure hold simultaneously. The two outer jaws move inward from opposite directions and grip the work against the central jaw, which constitutes the fixed jaw for each of the two vise openings.

A rather unusual type of fixture feeds the work up against the milling cutters, in order to cut grooves of the required depth in the carriage roll guide rods. This fixture is merely a sub-table on which the special milling vise is mounted, and by simply throwing over a lever, the work is raised against the milling cutters so that the groove will be cut to exactly the proper depth. The reason for this procedure will be made clear by referring to the form of the work shown in Fig. 16, where it will be seen that at each end of the carriage roll guide there is a threaded section, while the groove milled in the work projects beneath the level of the threads. Consequently it is not possible to mill the groove by a single horizontal feed movement of the table; the work must be raised into engagement with the milling cutters at the point where the groove starts, and then lowered away from the cutters at the opposite end of the groove. By this method, the groove is cut to the proper depth and the threads at either end of the work are not damaged.

Figure 18 shows how this fixture operates. The vise which holds the work is shown at *A*. To raise this vise and to bring the pieces carried by it into engagement with the milling cutters, lever *B* is thrown over from the position indicated by broken lines to the one shown by full lines. Attached to lever *B* there is a link *C*, which has two pivoted levers *D* and *E*

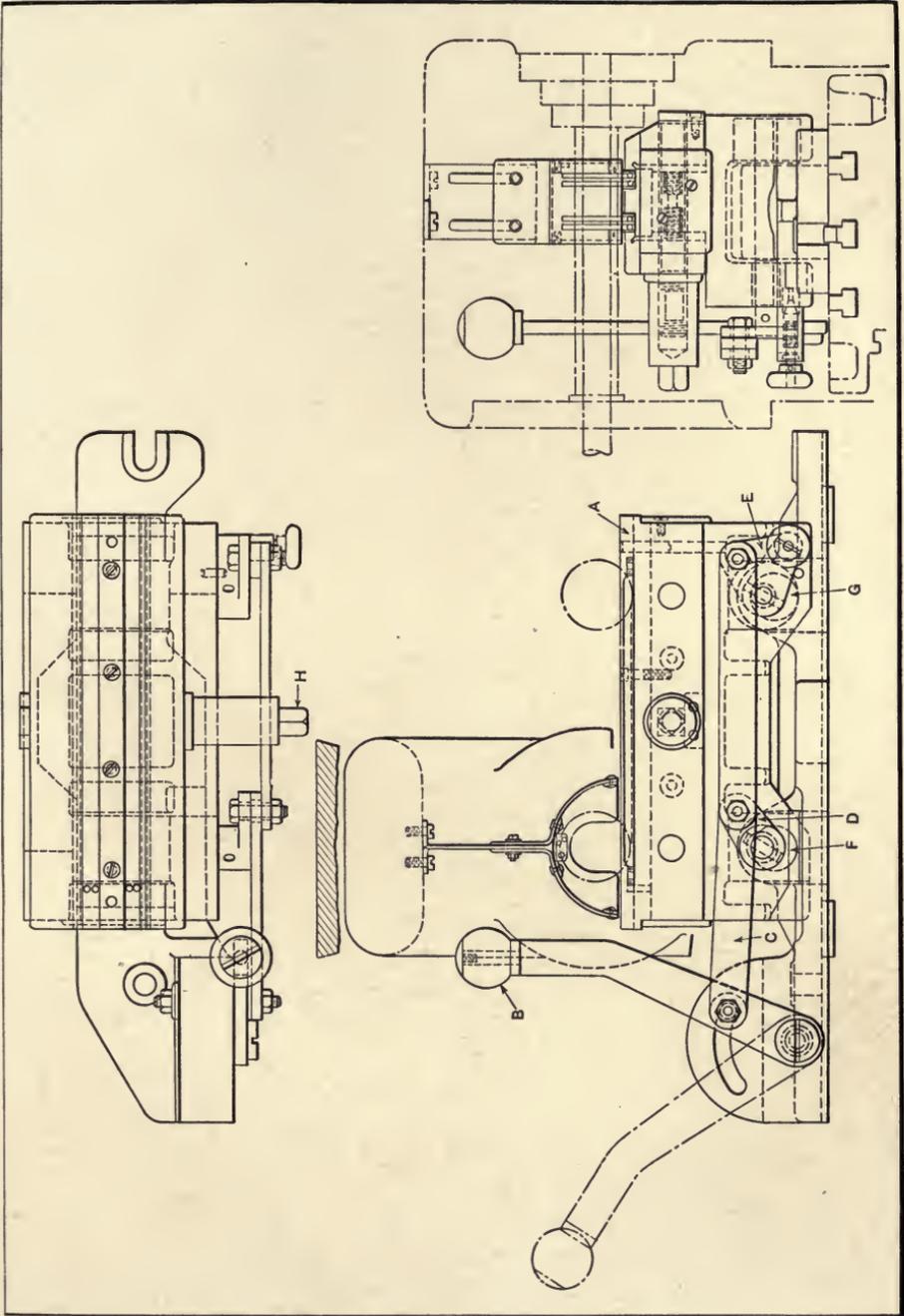


Fig. 18. Design of Elevating Device for Work-holding Fixture used on Milling Machine shown in Fig. 16

secured to it. These pivoted levers are keyed to the ends of two eccentric shafts *F* and *G*, which are free to rotate in close-fitting bearings. When lever *B* is pushed forward to the position shown by the full lines, the motion is transmitted through links *C*, *D*, and *E*, to the eccentric shafts *F* and *G*. The rotation of these eccentrics, which are held in a fixed position, imparts a vertical movement to the bed of the fixture and the work carried by the vise mounted on it. After the horizontal feed movement has advanced the cut to the far end of the groove required in the work, lever *B* is simply pulled back to lower the work out of engagement with the cutter, so that the threaded ends of the carriage roll guide rods will not be damaged. Stops are furnished to locate the starting and stopping points of the cut. The vise jaws holding the work are tightened by turning the square end of screw *H*, which is threaded right-hand at one end and left-hand at the opposite end to provide for moving the two outer jaws in opposite directions. A special form of ratchet handle, which goes on the square end of the operating screw, tightens or loosens the vise jaws by a reciprocating action of this lever, instead of complete rotations of a crank handle having to be made. The work to be milled is made of cold-rolled steel and the slots are 10 inches long; the rate of production obtained is 325 pieces in a nine-hour working day.

Milling Slots in Tabular Typewriter Rods.— Figure 17 shows a Becker-Brainard No. 2 plain milling machine equipped for milling grooves in two tabular rods for these typewriters. This operation is quite similar to the one just described, but as the work-holding fixture provides for setting up only two pieces of work at a time, the machine is idle during a greater percentage of a full working day. The result is that on this job the rate of production obtained is only 200 pieces per nine-hour day, instead of 325 pieces secured on the equipment shown in Fig. 16, although the length and cross-sectional area of the groove to be milled is the same for both jobs, and the parts are both made of cold-rolled steel. The special form of fixture for raising the work into contact with the milling

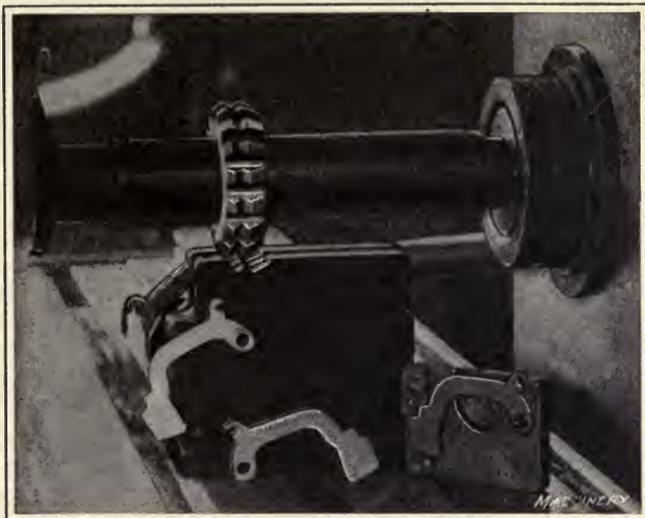


Fig. 19. Machine for milling Shift Locks for Typewriters

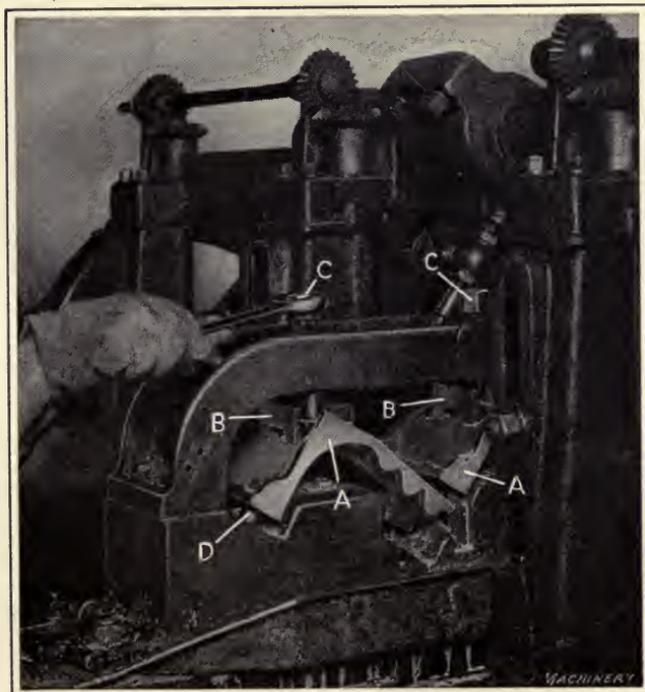


Fig. 20. Machine for milling Self-starter Generator Frames

cutters is not required in this case, because, although the work is threaded at each end, the diameter of the threaded sections is sufficiently reduced from the height of the body of the work, so that the milling cutters may be fed straight across the work without damaging the threads. On both of these jobs the work is kept flooded with lard oil.

Form-milling Typewriter Shift Locks. — At the front of the work-holding fixture illustrated in Fig. 19, there are shown two of the finished shift locks which are form-milled on their upper surface by means of the equipment shown in this illustration. After being milled, these parts are gaged, as shown at the right-hand side of the illustration, to make sure that they fulfill the specified requirements. On this job, the milling vise is utilized in a somewhat different way from any which has previously been mentioned. The illustration clearly shows how the form-milling cutter on the arbor mills the required contour on the top surface of the work. As this could not be performed with accuracy if the edges of these thin stampings were allowed to project the required distance above the jaws of the vise, the tops of the jaws are milled to the same contour as required on the work. Thus, the pieces clamped between the jaws are well supported without in any way hampering the work of milling them. Five stampings are set up in the vise at a time, the pierced hole in one end of the stampings being utilized as a locating point by slipping the hole in the work over a locating pin provided in one of the vise jaws. This job is done on a plain milling machine, and the rate of production is 350 shift locks from one machine in a nine-hour working day.

Milling Generator Frames for Automobile Self-starters. — Figure 20 illustrates a method employed by the Dayton Engineering Laboratories Co., of Dayton, Ohio, for tooling up and operating a No. 8 double-head Lincoln milling machine built by the Hendey Machine Co., for simultaneously milling both sides of the frames of electric generators for the self-starting and ignition system on Buick motor cars. The fixture is designed to hold two pieces of work which are shown at *A*. After

the piece that is located nearest the cutters has been set up, the feed is started and the operator then sets up the second piece. As the length of cut is ten inches, ample time is afforded to set up the second piece before the cut has been completed on the first casting. This method also keeps the machine operator employed during the greater part of the day. These generator frames are made of malleable iron, and the rate of production is 300 pieces in a working day of nine and three-quarter hours.

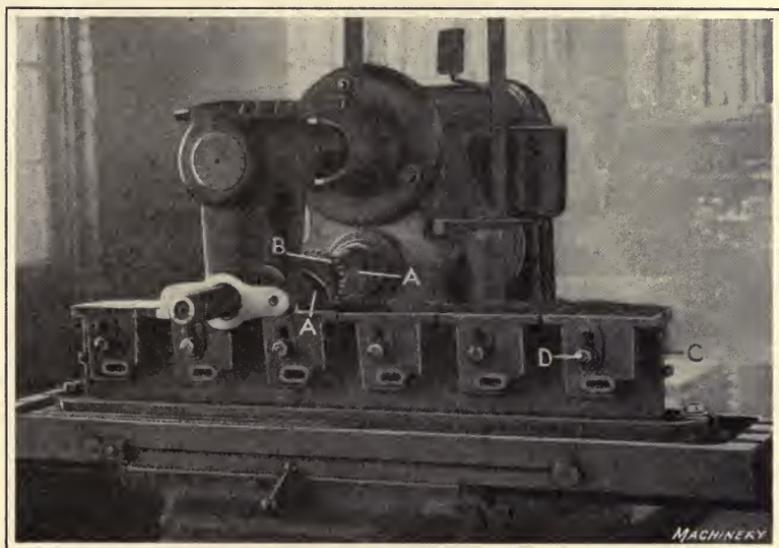


Fig. 21. Milling Parts of Dividing Heads on a Rockford No. 2½ Double Back-gear Miller

The two pieces of work *A* are set up in the string fixture on this machine, which is of relatively simple design. The two opposed spindles of the duplex machine provide for milling opposite faces of the work, each piece being clamped down in the fixture by means of a V-block *B*, which is forced down by tightening the bolt *C*. At the time the work comes to this machine, none of the surfaces have been finished, so three suspension points are provided on each station of the fixture, one of which can be seen in contact with the casting at *D*.

After the operator has set the second casting up in the fixture, he moves around to the back of the machine; and as soon as the first casting has passed out of engagement with the cutters, he releases the clamping bolt and removes this casting from the fixture. He is idle during only a short time while the cut is being completed on the second casting. As soon as this piece

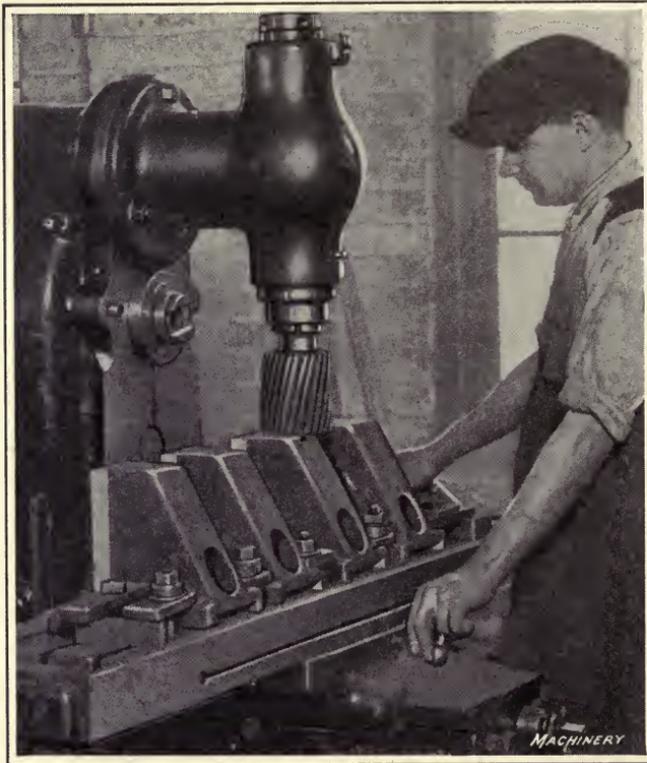


Fig. 22. Milling Surface of Knees for Hand Millers on a Rockford No. 2 Double Back-geared Miller

comes out from between the cutters, the operator removes it and goes back to the front of the machine to set up fresh castings for the next operation.

String Fixture for Milling Dividing Head Parts.— At the plant of the Rockford Milling Machine Co., No. 2½ double back-geared millers are equipped with string fixtures of the

type shown in Fig. 21, to provide for a combination face-milling and grooving operation on parts of dividing heads. Six pieces of work can be set upon the string fixture employed for this job. Two spiral cutters *A* are mounted on the arbor, with a narrow face cutter *B* between them, so that at a single traverse of the table the entire top surface of the work may be faced by cutters *A*, while the narrow cutter *B* mills a groove at the center. Conforming with the usual practice where spiral-toothed cutters are used, it will be evident that

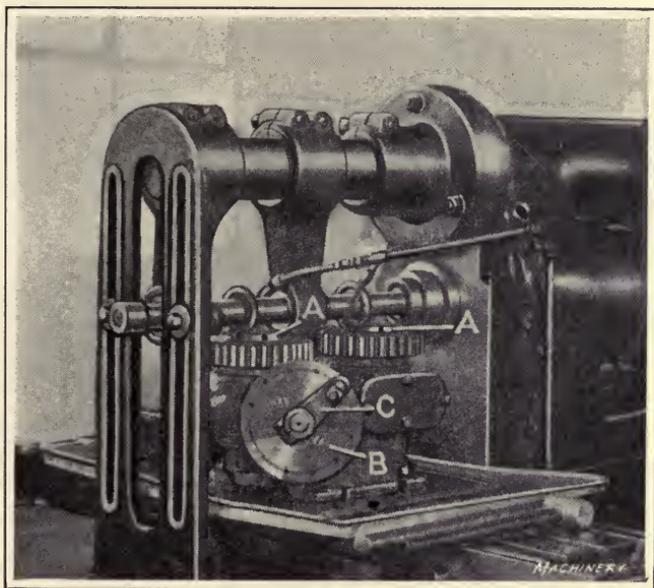


Fig. 23. Milling Clutch Teeth on a Rockford No. 2 Double Back-gear Miller

the machine is set up with the spiral running left-hand at one side and right-hand at the opposite side, thus avoiding any tendency for the cutters to develop an end thrust. The work-holding fixture is of simple design, consisting of a vertical plate *C* over which the castings are dropped so that they may be clamped by means of bolts *D*. The spindle is driven at a speed of 64 revolutions per minute and the rate of feed is 0.076 inch per revolution, which corresponds to a feed of

approximately $4\frac{7}{8}$ inches per minute. The cut is $\frac{3}{16}$ inch deep by 4 inches wide and in milling these gray iron castings the rate of production is one piece in one minute forty-three seconds.

Milling Top of Hand Miller Knees. — At the plant of the Redin & Ekstrom Co., a No. 2 double back-gearred Rockford milling machine, shown in Fig. 22, is employed for milling the top surface of the knee for hand milling machines. This illustration shows the application of a vertical milling attachment on production work, an end-mill of sufficient size to cover the entire surface of the work being utilized with successful results. Four castings are set up at a time. The string fixture is of simple design, consisting of bolts in the T-slots of the milling machine table and straps to engage the flanges on the work. The end-milling cutter is 4 inches in diameter by 6 inches long, and is driven at 106 revolutions per minute with a feed of 0.070 inch per revolution, which corresponds to a cutting speed of 111 feet per minute with a feed of 7.42 inches per minute. The depth of cut is $\frac{1}{8}$ inch, and the face to be milled is $3\frac{1}{2}$ inches in width. On this job the total time for milling four pieces of work is six minutes.

Duplex Fixture for Clutch Cutting. — In the plant of the Cotta Transmission Co., a Rockford No. 2 double back-gearred miller is used for a clutch cutting operation. This machine is equipped with a duplex indexing fixture as illustrated in Fig. 23, which provides for simultaneously cutting two clutches with cutters 3 inches in diameter by $\frac{3}{8}$ -inch face width. The clutch teeth are cut in slightly raised bosses *A* on the gears. Each gear is mounted on a vertical spindle, these two spindles being connected by an indexing mechanism *B* so that turning crank *C* simultaneously rotates the two clutch gear blanks through the necessary angle to locate the work for cutting the next groove. On this job the cutters are driven at a speed of 80 revolutions per minute, with a feed of 0.110 inch per revolution, which corresponds to a cutting speed of 62.8 feet per minute with a feed of 8.80 inches per minute. The time required to finish cutting a clutch is approximately four minutes.

CHAPTER VII

INDEXING MILLING FIXTURES

IN setting up milling machines for quantity production there are a number of fundamental principles which must be observed in order to obtain maximum production and quality workmanship. Although these points, briefly outlined in the following paragraphs, are simple and obvious, too much emphasis cannot be laid on the importance of observing all of them.

When making arbors for use on milling machines, do not attempt to use soft machine steel. To give satisfactory service, arbors should be made of machine steel and first carburized to increase the carbon content at the surface of the metal. Then the arbors are hardened, with the result that their entire surface is covered by a skin of hard steel, which protects them from becoming bruised or nicked; at the same time, the inner metal is left soft and tough so that it has ample strength to resist severe shocks. It may be that an arbor is required for immediate use, making it impracticable to take the time for carburizing. In such a case, a fairly satisfactory arbor can be produced from 60-point carbon or chrome-nickel steel. An arbor made of this material is not so good as one made of machine steel and casehardened, because when it is heat-treated the hardness extends all the way through the steel, and without the tough inner core there is more danger of the arbor breaking.

When a milling machine is set up, the arbor should be put in place in the spindle and carefully tested with a sensitive indicator to make sure that it runs true. If the arbor does not run accurately, a uniform action of the milling cutters cannot be obtained. For the same reason, it is necessary to take great care of the taper hole in the machine spindle. When

the arbor is set up, there should be no chips in the spindle socket or adhering to the shank of the arbor. Chips will not only throw the arbor off center, but will also prevent close engagement between the arbor shank and the spindle socket, thus making it impossible to secure the required frictional resistance between the arbor and the milling machine spindle in which it is mounted.

There is some difference of opinion as to the best form of outboard support for a milling machine arbor. It is quite general practice to use a split cylindrical bearing for this purpose, the claim being made by advocates of the straight bearing that if a tapered bearing is used to provide means of adjustment to compensate for wear, the mechanic will in many cases set the bearing too tight, and thus produce a condition that is worse than would result from the slight amount of lost motion in a cylindrical bearing. Advocates of the tapered bearing, however, maintain that a set-up man who has charge of a milling machine department should have the necessary skill and experience to adjust a tapered bearing properly. Dependence cannot be placed upon cold-rolled steel for making keys for securing milling cutters on their arbors. A good grade of key stock should be used for this purpose and the finished keys should be drawn to a spring temper. When the cutters have been set up on an arbor, care should be taken to see that they run true and that all of the teeth do their proper share of the work. Where these conditions are not obtained, accurate work will not be produced and the life of the cutters will be greatly reduced. Methods of designing work-holding fixtures, which is a point of equal importance to those just given in regard to cutters and arbors, will be fully described later. The information presented on these topics may be summarized by saying that it is absolutely essential for both the cutters and the work to be properly "housed" in order to get the best possible results.

The milling machines should be inspected at specified intervals. If bearings or slides fit badly, or if there is lost motion between feed-screws and their nuts, accurate results

cannot be obtained; also, such conditions will affect production adversely, because when a machine in poor condition is run at a high speed and heavy feed, there will be a tendency for the cutters and work to chatter. When this kind of trouble is experienced, the natural thing is to slow down the speed and feed in order to eliminate the chattering of the cutters and work; but this also reduces the rate of production. In many cases such a loss could be avoided by making the necessary adjustment of bearings, slides, gibs, etc., on the milling machine.

General Types of Indexing Fixtures. — On small or medium-sized machines it will frequently be found advantageous to use indexing fixtures for holding the work. Such fixtures may be designed to carry two or more pieces according to conditions; but the general arrangement is to have two stations, so that the piece or pieces mounted in one station may be milled while the operator is removing finished parts from another station and setting up fresh blanks in their places. Then, after milling the parts held in the operating position, the fixture is indexed to bring the blanks which have just been set up into position for milling. The operator then removes the freshly milled pieces from the fixture. This sequence of movements can be constantly repeated, with little idle time of either the machine or its operator.

Many successful modifications of design have been worked out for indexing fixtures to be used for holding pieces of work on milling machines. The simplest of these is represented by a case in which provision is made for merely holding two pieces of work, so that a piece held in one station of the fixture can be milled while the other station is unloaded and a fresh blank set up. It is a common practice, however, to arrange indexing fixtures so that two or more parts are mounted at each station, examples of such fixture designs being shown in Figs. 1 to 6, inclusive. Another commonly used type of indexing fixture is that employed for turning pieces of work for successive operations on the different sides, in order to bring the work to a square, hexagon, or some other desired form. Examples of this method of designing indexing fixtures are

shown in Figs. 7, 8, and 9. Fixtures of this kind may be made with a number of collets or other means for holding the work; and a gang of cutters may be mounted on the milling machine arbor, one or more of these cutters engaging each piece of work. The work-holding devices and the indexing mechanism of the fixture should preferably be geared together so that turning one handle simultaneously indexes all pieces of work.

Another method of indexing fixture design is that of combining with the indexing principle the features of a string fixture, which tends to increase rates of production. An example of such a design will be shown further on in this chapter. Such fixtures consist essentially of a plate, carrying two strings of work-holding clamps, which is mounted on a pivot midway between the two ends of the fixture. Not only does such a method make it possible to take advantage of the string-fixture principle, but it also avoids practically all the idle time involved in unloading and resetting fresh pieces of work before the next operation can be started. After the pieces in one station of the fixture have been milled, the operator simply releases the lock-pin and swings the baseplate around, end for end, so that the string of parts held in the second station of the fixture are brought into the milling position. Then he unloads the milled parts and sets up fresh pieces of work, while those pieces held in the other station are being milled.

Still another application of the indexing type of fixture, for milling parts of small or medium size, consists of making two duplicate indexing fixtures which are mounted at opposite ends of the table. This method is used where both ends of the work have to be milled. One end of the work, held in the fixture at the left-hand end of the table, is milled first; then the table is moved over to allow the cutters to start milling the work held by the right-hand fixture. While this cut is being taken, the left-hand fixture is indexed into position for taking a cut at the opposite end of the work held by this fixture. The table is then moved back to take this cut and the right-hand fixture is indexed. While the second cut is being taken on the work held in the right-hand fixture, the

finished work is removed from the left-hand fixture and a new piece is set up in its place.

Standard Design of Indexing Fixture. — Substantial savings may often be made in the cost of special tool equipment required for a variety of machining operations by adopting standard tool parts which may be adapted to the requirements of a specified job. A case in point is seen in the indexing milling fixture illustrated in Figs. 1 and 2. The body of this

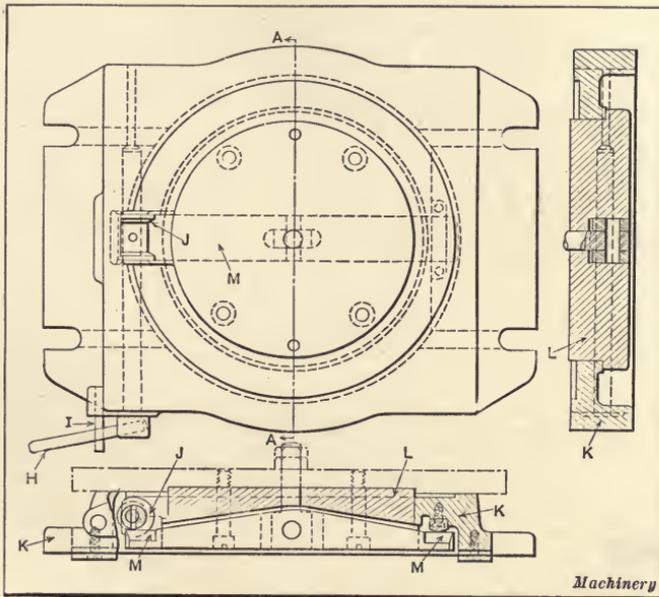


Fig. 1. Plan and Cross-sectional Views of the Standard Type of Indexing Milling Fixture shown in Fig. 2

fixture is now used in most cases where an indexing type of work-holding fixture is required for a milling operation in the Detroit plant of the Studebaker Corporation. Such fixtures are made in quantities, and when a specific job is to be handled, it is only necessary for the tool-room to provide, on the body of the fixture, suitable clamps and locating devices for the work in question, which are simply discarded when a fixture of this type becomes obsolete. The body of the fixture can be utilized for another job.

Figure 2 illustrates how one of these standard fixtures is adapted for a specified milling operation. The fixture shown has been arranged for milling off the end of the shank of transmission pinion forgings in order to reduce them to the required length. Two forgings are set up in the V-blocks on each station of the fixture and held in position by straps *A*, which are drawn up by a bolt *B*. The two bolts *C* extend through the body of the fixture and are secured to straps *A*. Bolt *B* is threaded through bar *D* and abuts against the wall of the fixture, so that when bolt *B* is tightened it pulls back bar *D*

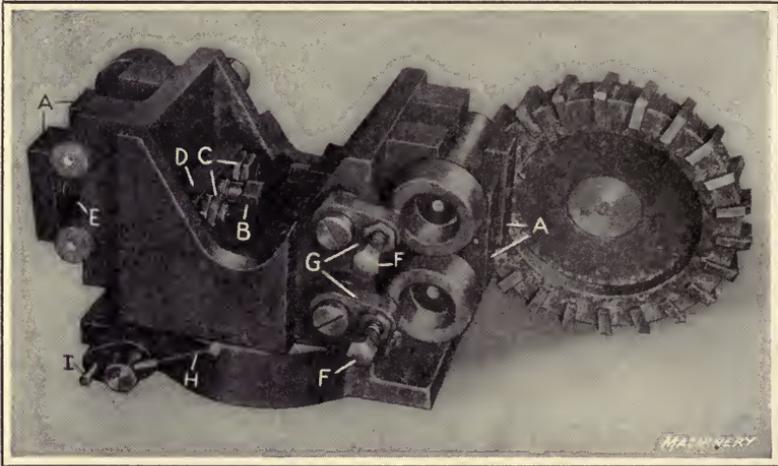


Fig. 2. Indexing Fixture of Standard Design, equipped for holding Transmission Pinion Forgings for milling them to the Specified Length

and, through the action of bolts *C*, causes straps *A* to clamp the work in the V-blocks. Compression springs *E* are placed under straps *A* so that, when bolt *B* is loosened, these straps are automatically lifted out of engagement with the work.

As the purpose of this operation is to reduce transmission pinion forgings to the required length, accurate endwise location of the work is important. Such location is secured by two stop-screws *F* carried by swinging brackets *G*. In setting up the work, each forging is pushed up into contact with screw *F*, after which bolt *B* is tightened to clamp the two forgings in place ready for milling. The end-stops are mounted

on swinging straps *G* because a practice is made of loosening bolt *B* just sufficiently to allow the forgings to be drawn through the V-blocks to remove them from the fixture. As the size of the heads on the work makes it necessary to push these pieces through from the end at which stops *F* are located, provision must be made for getting these stops out of the way while the milled pieces are being withdrawn from the V-blocks and fresh forgings set up in their places. On this operation, the milling cutters rotate at a speed of $57\frac{1}{2}$ feet

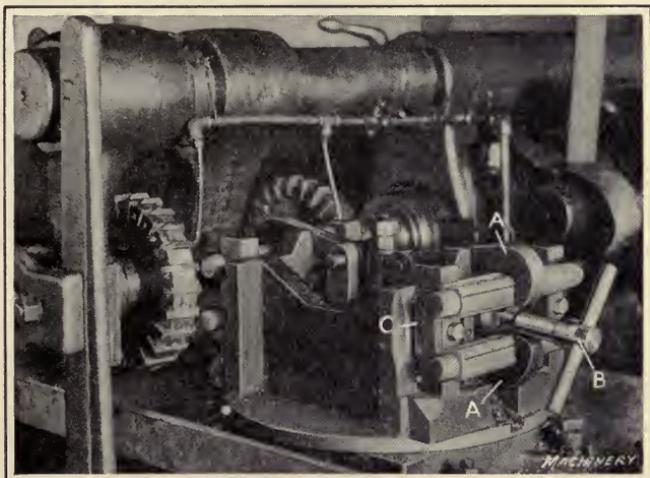


Fig. 3. Milling Machine equipped with Indexing Fixture for straddle-milling Transmission Shafts

per minute and the work is fed to the cutters at a rate of 1 inch per minute. The production obtained is 200 pinions per hour.

The important feature of design of this standard fixture is that it is only necessary to manipulate a single handle in order to locate the fixture in either of its two working positions and to lock it in place. This locating and locking of the fixture is accomplished by lever *H* (Figs. 1 and 2). In the position in which the lever is shown in Fig. 2, the fixture is locked; and when it becomes necessary to release the fixture in order to bring the opposite station around into the working position,

lever *H* is swung over against pin *I*, after which the fixture may be revolved by hand. When brought to approximately the required position, lever *H* is pushed back, thus obtaining an accurate location of the fixture and locking it in the position so obtained.

A better idea of the way in which this fixture is designed will be obtained by referring to Fig. 1. Lever *H* is carried by a cross-shaft on which is mounted a cam *J* that has eccentric beveled flanges around its ends. The fixture consists of a stationary base *K* and a table *L* which may be indexed to bring the work carried on it into either the milling or the unloading position, as desired. This table *L* has a slot cut in its under side, in which is mounted a bar *M*, projecting outward at each side to engage the tapered flanges on cam *J*. Consequently, when an approximate location of the table has been secured through rotating it by hand, the turning of lever *H* causes cam *J* to be rotated so that the eccentric beveled flanges on this cam engage bar *M* and turn table *L* slightly, in either direction, to locate it accurately, after which further turning of cam *J* clamps the table firmly in place. The cross-sectional view shows that the flanges on cam *J* are cut away at one side, so that when lever *H* is swung over into contact with pin *I*, the cut away section of the cam allows the table to be rotated for indexing. When lever *H* is swung in the opposite direction, the flanges on the cam engage bar *M*, locating and locking it in the manner just described.

Straddle-milling Transmission Main Shafts to Length. — Figure 3 shows a Becker-Brainard No. 4 milling machine equipped with a standard indexing fixture which has been adapted for straddle-milling transmission main shafts to length. Two forgings are mounted on each station of the fixture. These forgings are held by V-blocks, in which they are secured by hooks *A*, that are tightened on the work by turning a socket wrench *B*. This socket wrench turns a screw which pushes back a rocker link located inside of the fixture; this link, in turn, is connected to the rear ends of the two hooks *A*. When manipulated, this rocker link pulls hooks *A*

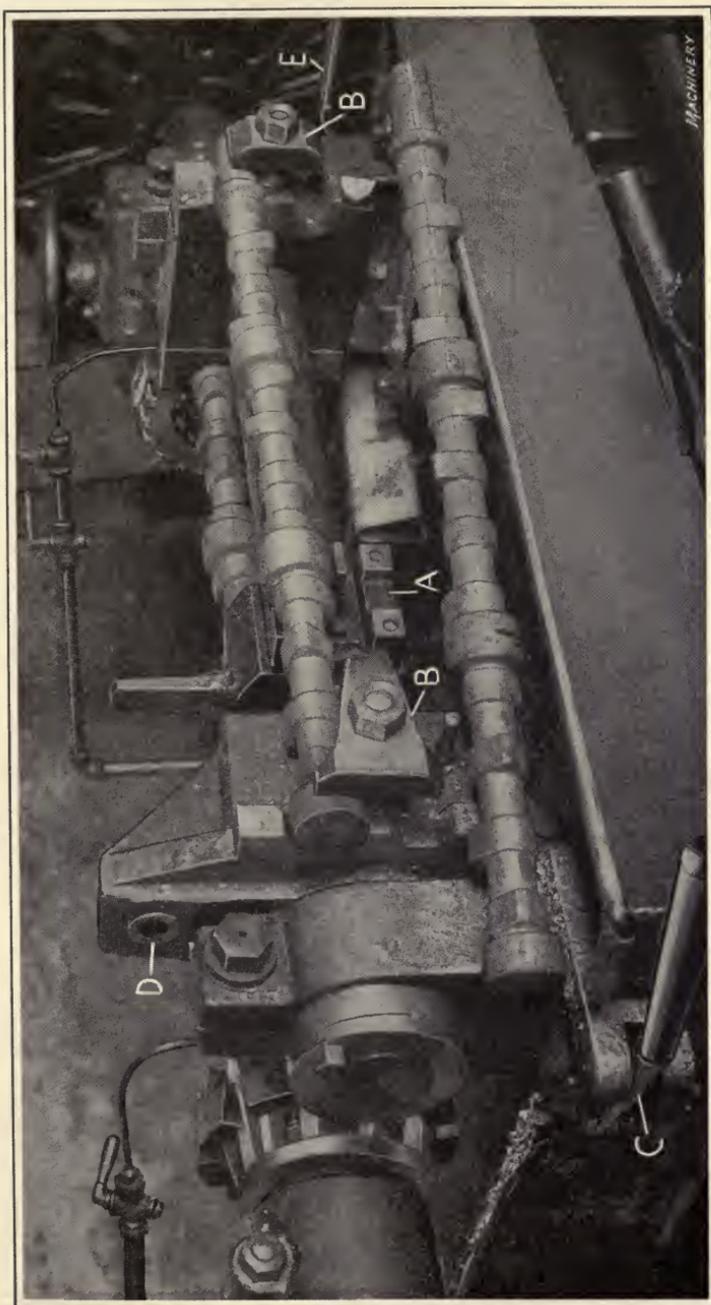


Fig. 4. Indexing Work-holding Fixture for straddle-milling Camshafts

back on the forgings and draws them into their seats in the V-blocks. A sufficiently accurate location of the work may be obtained from the end of one of the splines on each forging, which is brought into engagement with a locating plate C. The remainder of the fixture is of standard design. On this operation, the rate of production obtained is 135 transmission shafts per hour.

Straddle-milling Camshafts to Length.—The first operation on camshaft forgings in the Studebaker machine shop is to

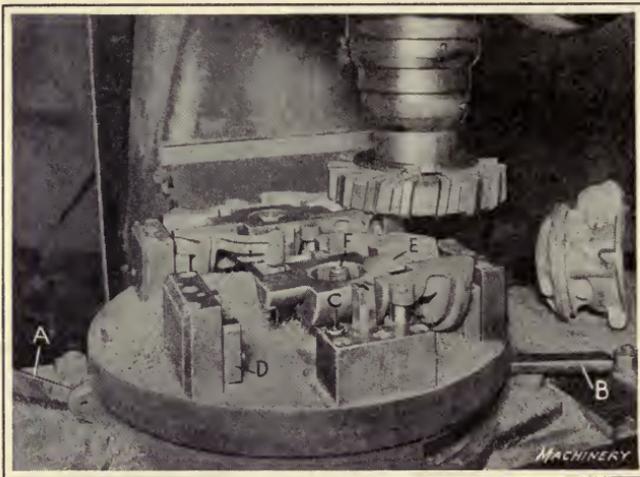


Fig. 5. Vertical Milling Machine equipped with Indexing Fixture for facing Joints of Bearing Caps

straddle-mill them to the specified length on a Becker duplex milling machine, which is shown in Fig. 4. This machine is equipped with an indexing fixture of different design from the standard type used by this company. In this case, two forgings are held in each station of the fixture, one of the forgings having been removed from the V-blocks at the front and laid on the bed of the machine, in order to show the fixture more clearly. Endwise location of the work is accomplished by gages A which fit over one of the bearings on the camshaft. At both ends of the fixture there are straps B which hold the two forgings back into their V-blocks. At each end of the

fixture there is a lever. Lever *C* at the left-hand end pulls a locking pin which slides through holes located at 180 degrees from each other, one of these holes being shown at *D*. Lever *E* at the opposite end of the fixture is used to manipulate a tapered index-pin, that is depended upon to locate hole *D* in accurate line with the locking pin, so that this pin may always find its way "home." It was necessary to build an extension

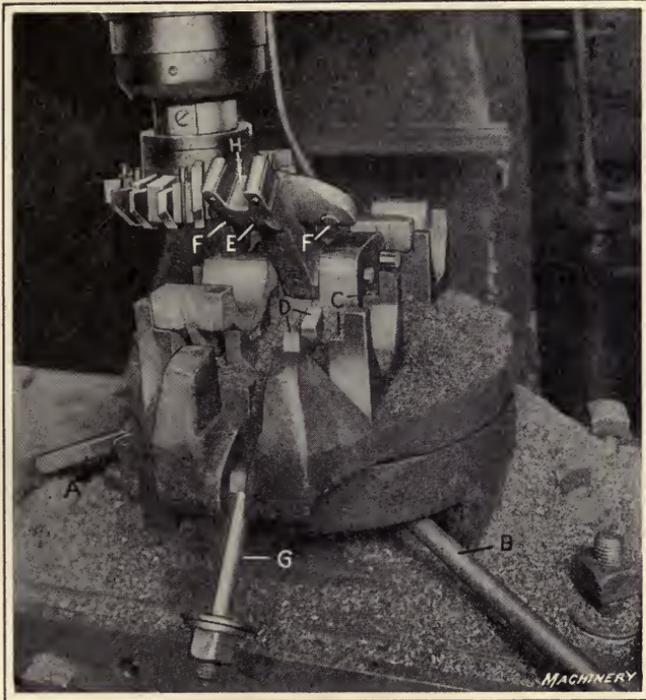


Fig. 6. Vertical Milling Machine equipped with a Special Indexing Fixture for a Similar Job to the One shown in Fig. 5

at the right-hand end of the milling machine bed to enable the required spacing to be secured between the cutters. A copious flow of coolant is delivered to the cutters. The rate of production obtained is 50 camshafts per hour.

Special Indexing Fixtures. — Figures 5 and 6 illustrate the use of two indexing fixtures which are of different design from the standard form used by this company. Both of the fixtures

illustrated are employed for face-milling cast-iron crankshaft bearing caps. Both of these operations are performed on Model C vertical milling machines built by the Becker Milling Machine Co. Instead of having a single lever for locating and locking the milling fixture in either of the two available positions, it is necessary to manipulate two levers. On both of these fixtures, lever *A* manipulates a tapered pin which locates the fixture in exactly the desired position; then lever *B* is swung over to bring an eccentric binder into action, which locks the fixture in place ready for the milling operation.

The device for locating and clamping the bearing cap castings in place is shown on the fixture in Fig. 5. In setting up the work in both of these fixtures, supporting points are provided, which constitute the equivalent of the three-point suspension used for holding large-sized castings on planer-type milling machines. On the fixture shown in Fig. 5, each casting is supported by two fixed points, one of which is shown at *C*, and by two points on a pivoted block *D*. Owing to the way in which block *D* floats, it adjusts itself for slight variations in the size and shape of the castings so that both of the supporting points at the top of block *D* will come into engagement with the work. If this block were not pivoted, the work would probably be supported by the two points *C* and one of the points at the top of block *D*.

After two castings have been set up on the supporting points on one station of the fixture, a half round strap *E* is dropped into place in the bearing grooves in the two pieces of work, and the clamping nut is tightened down on screw *F* to secure these two castings in place. While the castings are being set up on one station of the fixture, the other two castings in the second station are being milled; and when the milling operation has been completed, the fixture is indexed to bring the two fresh castings into the operating position. The material is cast iron, so no cutting oil or coolant is necessary. The rate of production is 40 bearing caps per hour.

Figure 6 shows a fixture of somewhat different design from the one in the preceding illustration. This fixture is used for

milling a smaller size of crankshaft bearing caps. As previously mentioned, the method of indexing and clamping these two fixtures is the same. In the fixture shown in Fig. 6, each of the castings set up in one of the stations on the fixture is carried by two knurled shoulders *C* and a V-block *D*, the arrangement constituting the equivalent of the three-point suspension used for supporting pieces of work for a first operation. After the castings have been dropped into place, strap

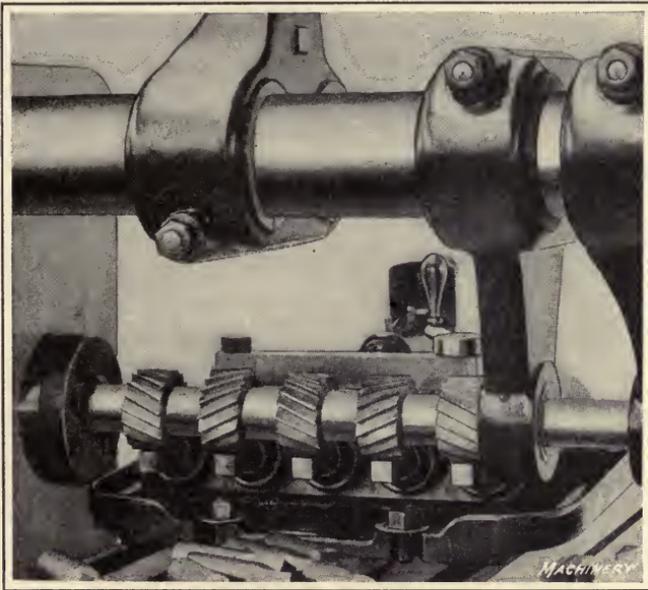


Fig. 7. Milling Machine equipped with Indexing Fixture for simultaneously milling the Sides of Five Square Piercing Punches. Details of this Fixture are shown in Fig. 9

E is tightened down so that the two knurled points *F*, on this strap, come into contact with the top of the work and hold it down on the suspension points. To secure strap *E* on the work, a pivoted bolt *G* is swung up into place in the slot *H*, after which the nut is tightened on bolt *G* to hold the strap down. The slot provided to receive bolt *G* makes it unnecessary to do more than loosen the nut to remove the work from this fixture. In this operation, the pieces of work are smaller

than those shown in the preceding illustration, as a result of which the rate of production obtained is twice as high, or 80 bearing caps per hour.

Indexing Fixture for Producing Required Form of Work. — The term “indexing” is generally understood to imply the rotation of the work through part of a turn, to provide for taking the next cut, as, for instance, cutting the next tooth of a gear blank or for milling the next side of a square or other

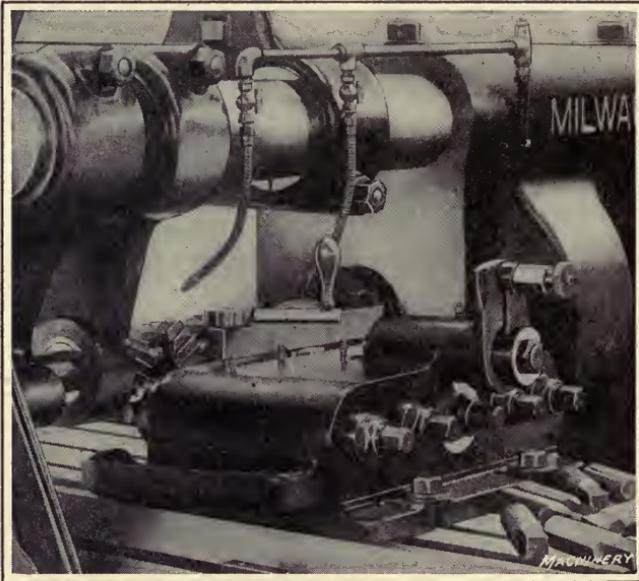


Fig. 8. Opposite Side of Work-holding Fixture shown in Fig. 7 showing the Single Crank for indexing the Work and Individual Bolts for operating the Collet Chucks

shaped piece of work. In any case, the indexing principle of fixture design is so applied as to produce the final form to which the piece is to be milled. In Figs. 7, 8, and 9 there is shown an indexing fixture of this kind. The pieces to be milled are piercing punches which are to be square in shape, with a 5-degree clearance extending back from the cutting edges. Four milling operations are performed with the work indexed through an angle of 90 degrees between successive operations, in order to obtain the square end for these punches; and by

having the milling fixture tilted at an angle of 5 degrees, the necessary clearance behind the cutting edges is obtained. On this operation, the material is tool steel, and a liberal amount of coolant is delivered to the milling cutters and work, to prevent overheating. The double-arm Milwaukee milling machine on which this operation is performed is used at the plant of the Portsmouth Steel Co., Portsmouth, Ohio, for mak-

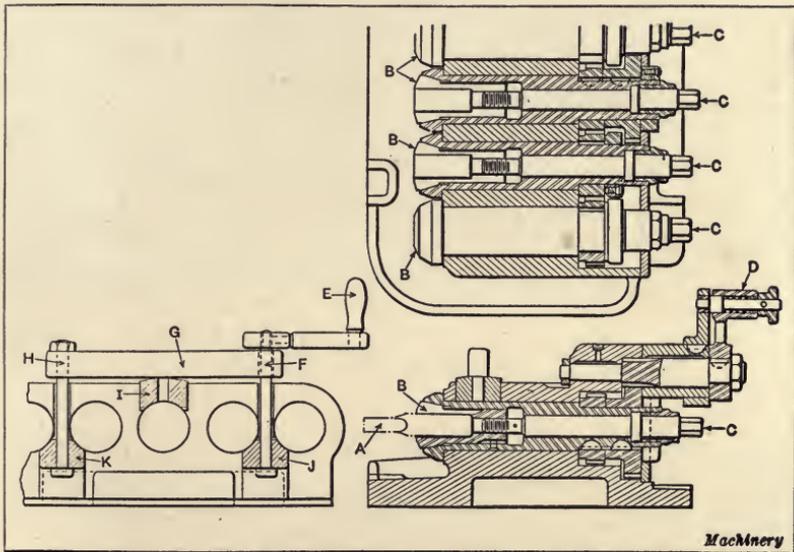


Fig. 9. Sectional Views of Indexing Work-holding Fixture shown on the Machine in Figs. 7 and 8

ing punches to pierce the spike holes in railroad tie-plates. The punches are $\frac{3}{4}$ inch square, and are made from $1\frac{1}{2}$ -inch round bar stock.

A better idea of the design of the work-holding fixture will be gathered from Fig. 9, which illustrates the mechanism for tightening the four collets in which the work is held, and for indexing the work to take four successive cuts required to complete the milling of these punches. Each of the four piercing punches *A*, to be milled, are carried by split collets *B* which are closed on the work by screws *C* at the back of the fixture. Each of these collets is manipulated independently by a wrench

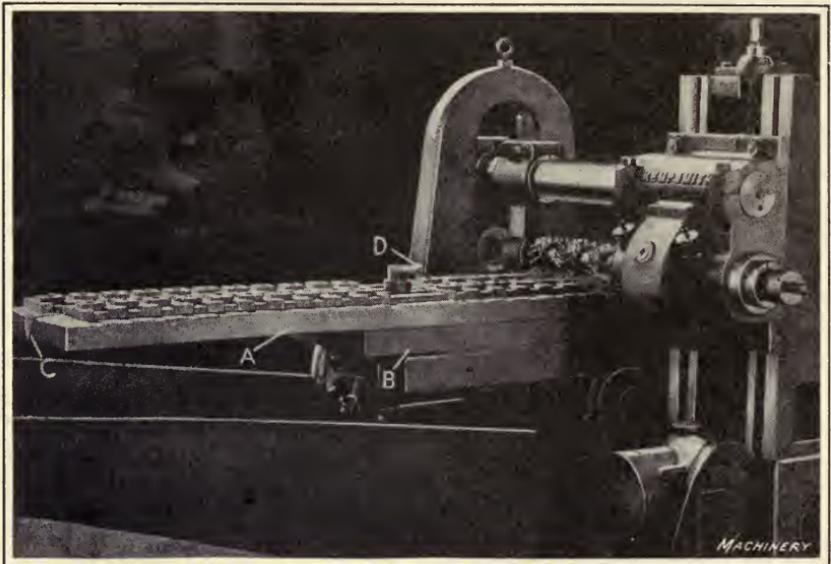


Fig. 10. Milling Threading Die-blocks, using a Fixture which combines Features of the Indexing and String Types of Equipment

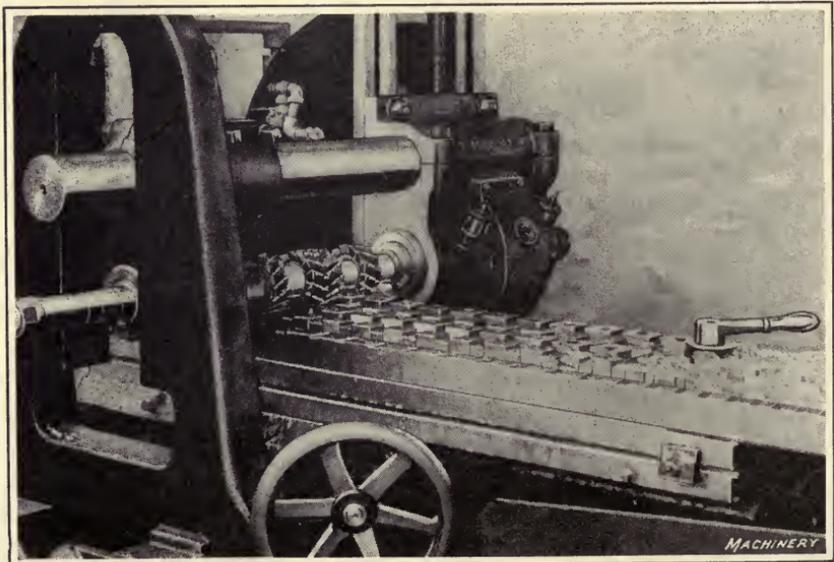


Fig. 11. Opposite Side of Machine illustrated in Fig. 10

that fits over the square end of the screw. After the work has been secured in the collets, the first of the square sides is milled. Then the milling machine table is backed away, and index lever *D* is turned through one revolution. This motion is carried to the collets by spur gears having a ratio of 1 to 4, so that one complete turn of handle *D* rotates the work through 90 degrees. The collets are then locked in this position and the second of the square sides is milled. By repeating this indexing and milling operation four times, the square ends of the punches are completely formed.

Crank handle *E* clamps the collets for each successive operation. This handle is secured at the top of the screw *F*, which passes through a hole in one end of bar *G*. At the opposite end, this bar is held by a bolt *H*. Bar *G* is supported by a fulcrum *I* formed by the top of a sliding block, the under side of which bears against the top of the central one of the five collets. At the lower end of bolt *F* there is a shoe *J* which engages the under sides of two other collets, and a similar shoe *K* at the opposite end of the fixture engages the under side of the two remaining collets. Turning crank handle *E* results in screwing the threaded hub of this handle down on bolt *F*, causing bar *G* to swing on its fulcrum, and, as pressure is exerted, shoe *J* is pulled up between two of the collets, thus locking them in place. Similarly, downward pressure is provided on shoe *I* for locking the third collet, and the tendency for bar *G* to swing over this fulcrum causes shoe *K* to be drawn upward, thus locking the two remaining collets.

Indexing Type of String Fixture. — At the plant of the Armstrong Mfg. Co., Bridgeport, Conn., Kempsmith No. 33 Lincoln-type milling machines are used for face-milling blanks for pipe-threading dies. One of these machines is shown in Figs. 10 and 11, which illustrate opposite sides. These illustrations show that the miller is provided with a rather unusual type of work-holding fixture, which combines features of the so-called "string" and "indexing" types. In other words, this tool consists of two stations, on each of which there are mounted clamps for holding four strings of pieces to be milled.

The fixture is mounted on a pivot, and while pieces set up in one station are being milled, the operator has ample time to unload the milled parts from the other station and substitute fresh blanks. The four plain milling cutters used for this operation are set up on the arbor with the spiral angles of the teeth opposed to each other, the purpose being to have these four cutters arranged in opposed pairs to neutralize the end thrust.

In designing a fixture of this type, the main table *A*, on which the work is mounted, is carried by a pivot mounted in an intermediate plate *B*, which is secured to the table of the milling machine. At the left-hand end of the table, there will be seen a notch *C*, and there is a similar notch at the right-hand end. This is the locating point for the tapered index-pin which locates the fixture in either of the two positions in which it is used. After indexing, the table must be clamped by a binder manipulated by lever *D*. In this operation, the cutters are driven at a speed of 56 feet per minute, and the work is fed to the cutters at a rate of $3\frac{9}{32}$ inches per minute. The material being milled is carbon tool steel.

Indexing Fixture for Face-milling Connecting-rods. — The No. 3 plain Kempsmith milling machine illustrated in Fig. 12 is used by the Holt Mfg. Co., of Peoria, Ill., for straddle-milling both ends of connecting-rod forgings. As the bearings to be faced are of different widths at opposite ends of the work, a choice had to be made between resetting the work for the second milling operation, or indexing the fixture in order to reach the opposite ends of the forgings. The latter plan was adopted, and in order to secure constant operation of all of the four pairs of milling cutters, the fixture was designed to hold two forgings, with their small ends facing the cutters, and two other forgings with their large ends facing the cutters. With this arrangement, the ends of four forgings are straddle-milled simultaneously, after which the fixture is indexed for milling the opposite ends of the same forgings.

This machine is set up with a fixture at each end of the table to avoid idle time of the machine while the operator is remov-

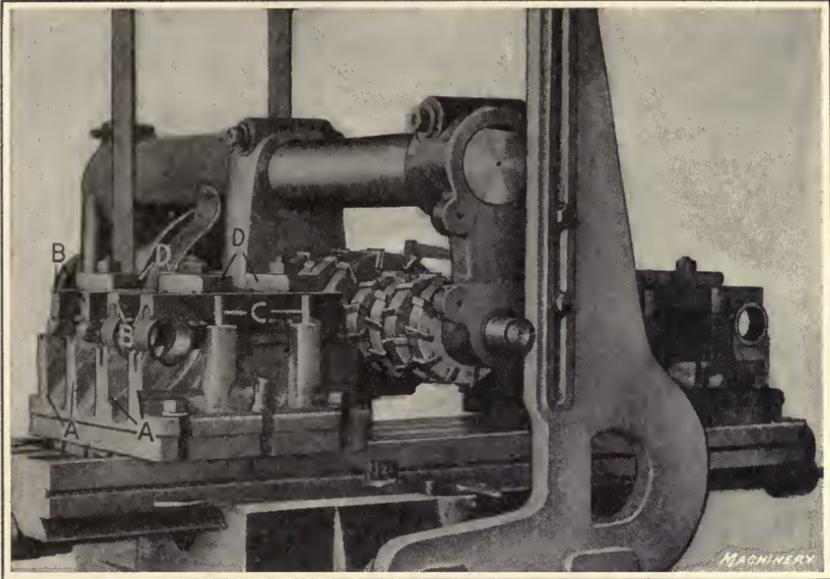


Fig. 12. Straddle-milling Both Ends of Connecting-rod Forgings

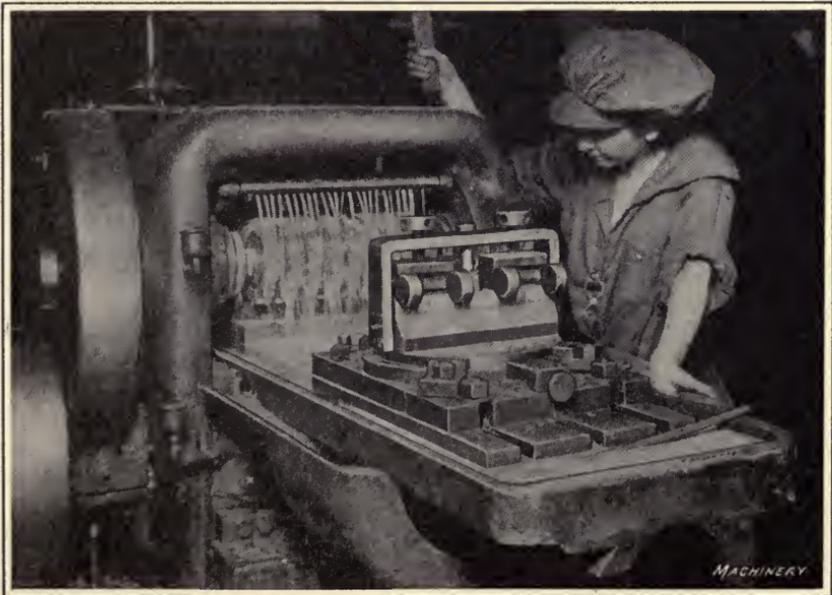


Fig. 13. Straddle-milling Spring Shackle Forgings; the Two Fixtures on the Table are used alternately

ing milled forgings and reloading the fixture. The sequence of operations is as follows: First, mill one end of the forgings held in the left-hand fixture; second, traverse the table over to mill one end of the forgings held in the right-hand fixture; third, index the left-hand fixture while pieces held in the right-hand fixture are being milled, and then traverse the table over to complete milling the forgings held in the left-hand fixture; fourth, index the right-hand fixture while the other milling operation is proceeding, and then traverse table over to complete milling the forgings held in the right-hand fixture. During the final operation on the forgings held in this fixture, the completely milled connecting-rods are removed from the other fixture and fresh forgings are set up. In this way, excellent rates of production may be obtained, as there is practically no idle time for either the machine or its operator. On the machine shown in Fig. 12, 400 connecting-rods are milled in a ten-hour working day.

The forgings are held in this fixture as follows: Each fixture is provided with four walls *A* in which transverse V-notches are cut to receive the bearings at each end of the connecting-rod, and longitudinal grooves to receive the bolt bosses. After four rods have been dropped into place, four bars *B* are placed on top of them. These bars also have been provided with longitudinal grooves and transverse V-notches to conform with the contour of work. The necessary sidewise adjustment of the work (longitudinal adjustment is effected by the V-blocks in which the work is carried) is accomplished by having pins *C* engage the finished sides of bars *B*. When the rods have been properly located, four straps *D* are tightened, to hold down the bars *B* and the connecting-rods secured by them. The machine operator has ample time to remove the milled forgings and substitute fresh parts while the remaining operation is being performed on parts held in the opposite station of the fixture.

Milling Spring Shackle Forgings.—At the plant of the National Motor Car & Vehicle Corporation, Indianapolis, Ind., use is made of Gooley & Edlund horizontal milling machines, which are equipped as shown in Fig. 13 for use in mill-

ing spring shackle forgings. The line illustration of the work, Fig. 14, shows that there are eight surfaces to be milled. The milling is done by a gang of eight milling cutters which simultaneously machine four surfaces on each of the two shackles mounted in the fixture. To conserve the operator's time, a duplex fixture allows the workman to set up new forgings in one fixture while pieces held in the other fixture are being machined. The method of procedure is as follows: When

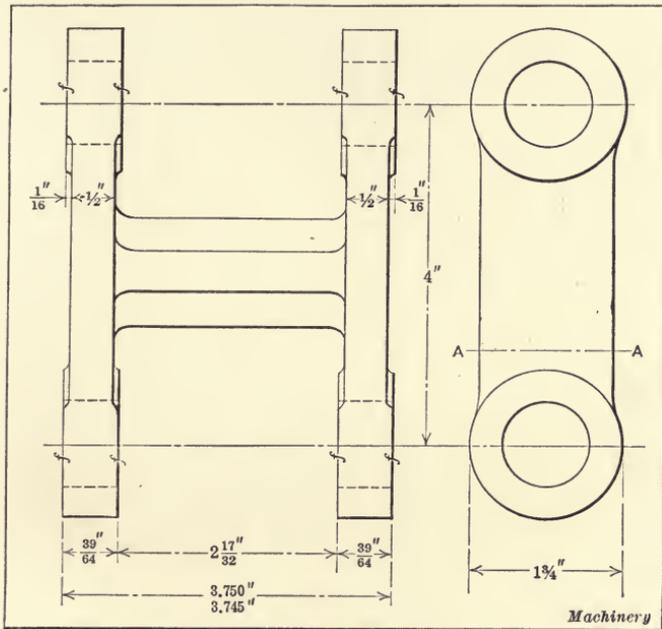


Fig. 14. Design and Dimensions of Spring Shackles milled on Machine shown in Fig. 13

the two shackles held in the first fixture have been milled, the table is traversed over to bring the forgings held in the second fixture at the opposite end of the table into place for milling them with the opposite sides of the cutters carried on the milling machine arbor.

During this operation, the operator removes the milled pieces from the first fixture and sets up forgings in their places. By this time the ends of the shackles which were being milled

will have been machined and the table may be traversed over to perform the first step of the milling operation on pieces held in the first fixture. During this operation, the operator indexes the second fixture through an angle of 180 degrees to bring the opposite ends of the forgings into position for milling. The next step will be to traverse the table to bring these pieces into position for the final operation, and while this machining is in progress the first fixture will be indexed ready to complete milling the pieces carried in it. The cycle of operations will

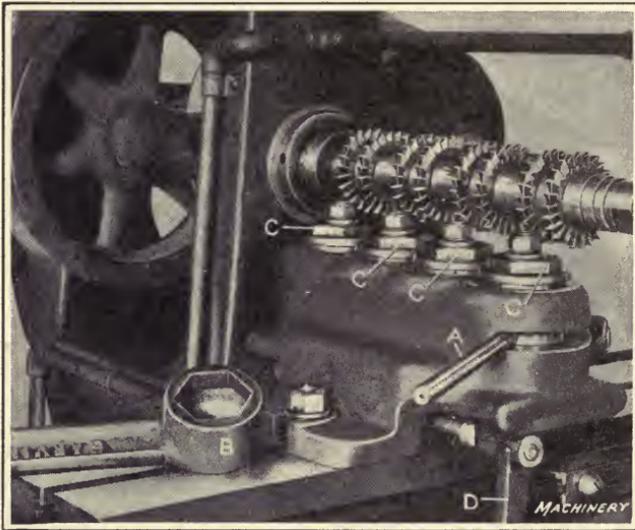


Fig. 15. Milling Machine equipped for straddle-milling the Flats on Hexagon Heads of Spark Plugs

be finished by feeding these forgings up to the milling cutters, after which the finished spring shackles will be removed from the second fixture.

This operation is performed with cutters 6 inches in diameter, which run at a speed of 40 revolutions per minute. Quick traverse brings the work into position for milling, after which a feed of 1 inch per minute is employed for the actual machining. Each milling cutter is required to face off a round surface on the spring shackles which is $1\frac{3}{4}$ inches in diameter, and approximately $\frac{3}{32}$ inch of stock is removed from each face.

The rate of production on this job is 22 completely milled spring shackles per hour. The work-holding fixture consists merely of a bridge carrying two screw-operated clamps which hold the pieces down on a pad at the base of the fixture. A simple form of locating bolt secures each fixture in either of the two stations in which it is required to operate.

Straddle-milling Flats on Hexagon Heads. — As previously mentioned, machines equipped with the indexing type of fixtures may be employed for two general classes of milling operations: First, to increase the rate of production through reducing the non-productive time of the machine and its operator, and second, to locate the work in two or more successive positions for milling the pieces to a square, hexagonal, or some other similar form. An example of the latter type of indexing milling fixture is shown in Fig. 15, which illustrates a Garvin No. 21 back-gear'd plain milling machine engaged in milling the hexagonal heads of spark plugs for the ignition system on motor car engines.

Four pieces of work are set up in a multiple fixture. By manipulating a single lever *A*, all four pieces may be indexed to the three successive positions in which they are held for straddle-milling opposite sides of the hexagon heads. To obtain these settings of the work, lever *A* is moved into three successive positions, which imparts motion to gearing that connects all four of the collet chucks of the fixture. In this way, time is saved that would otherwise be lost in indexing each chuck individually. The chucks are of the double-tapered contraction collet type, and they are tightened or loosened by turning a wrench *B* that fits over a hexagonal collar *C* at the top of each collet.

In operating these millers, the table is fed forward by power until a stop is engaged, which automatically trips the table feed-worm out of mesh with the worm-wheel. The operator then returns the table to the starting point with a handwheel; and after the collets have been loosened by using wrench *B*, lever *D* is lifted to manipulate the ejecting mechanism, which discharges the finished pieces from the fixture. When fresh

blanks have been set up and secured in the collets, the machine operator lifts a lever, which re-engages the feed-worm ready to start the next operation. It is necessary to make three cuts for each setting of the work. The table carries the work between the cutters, and continues its forward movement until the feed is automatically tripped. Then the operator returns the table to the starting point, and changes the position of lever *A* to index the work ready for the second cut, after which the power feed is re-engaged. This cycle of movements is repeated a third time to finish the work, after which the milled parts are removed and fresh pieces set up as previously described.

Vertical Feed Milling Attachment. — Where a milling cut is quite short, it is often more advantageous to feed the work vertically to the cutter, instead of employing a horizontal feed movement of the table. For handling such classes of work, the Garvin Machine Co. has developed what is known as a "vertical feed milling attachment," and Fig. 16 shows one of these attachments applied to a No. 3 hand milling machine. The attachment is shown at *A*, and is furnished with an indexing fixture *B* that holds four hex-nuts to perform a castellating operation on them. Four slitting saws are mounted on the milling machine arbor and the work-holding fixture is furnished with four sockets *C*, into which the nuts are dropped. As the work is fed vertically up against the saws, no means for clamping the nuts was considered necessary. The illustration shows that there is a nut in the left-hand socket while the other three are ready to receive fresh blanks.

In castellating these nuts, three cuts are taken at right angles to the flats. A hand-lever *D* indexes all four pieces into the three successive positions for taking the castellating cuts. The movement of this lever is limited in both directions. When it is in one extreme position, the first cut is taken; then the lever is moved to an intermediate position to index the work for the second cut; and finally, the lever is swung over to the opposite extreme, to index the work for taking the final cut.

It will be seen that lever *D* is secured to the first work-holding socket; and all of the sockets are so mounted in the fixture that they may be turned by gearing which connects the four sockets. Hand-lever *E* governs the vertical feed movement of the attachment, this lever being pushed down in order to raise the work to the cutters. After the final cut has been taken, the fixture is allowed to drop until stops *F* come into engagement and operate an ejecting mechanism which lifts

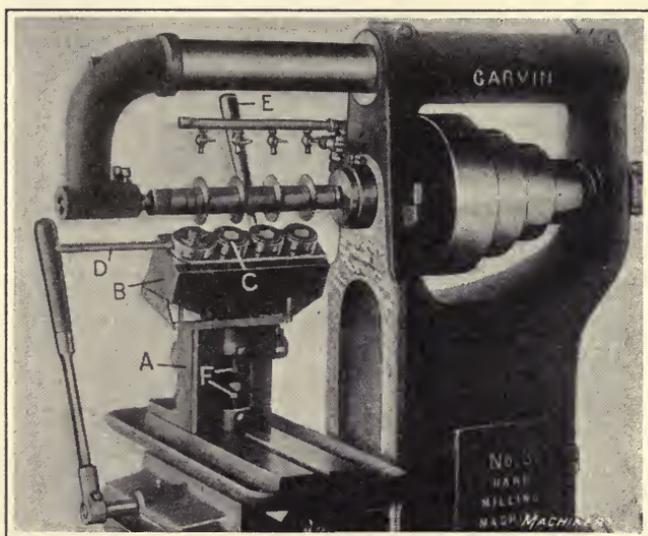


Fig. 16. Milling Machine equipped with Vertical Feed Attachment and Indexing Fixture for castellating Nuts

the four castellated nuts out of their sockets. The position of stops *F* is adjustable in order to adapt them to the requirements of various jobs.

Hobbing Worm-wheels on a Milling Machine. — During recent years, the trend of machine tool design has been toward the development of special tools for the performance of repetition operations on large quantities of duplicate parts. The installation of these special machines is advisable where the volume of work is great enough to enable a satisfactory return to be earned upon the investment in plant equipment. But many shops handling a general line of work do not have to

machine a sufficient quantity of any one part to justify the installation of special machine tools. Consequently, it is necessary for them to adapt standard types of machinery for handling these jobs and, by clever designing, satisfactory results can often be obtained. The No. 13 $\frac{1}{2}$ Garvin plain milling machine, shown in Fig. 17, equipped for generating the teeth of worm-wheels, is a case in point. The company agrees to produce a number of these wheels, although the quantity to be cut was not great enough to justify investment in a special hobbing machine. It was found that a satisfactory equipment for handling the work could be produced by designing a special fixture for the milling machine. At the angle from which this fixture is shown in Fig. 17, the illustration is a little misleading, as it might be inferred that the teeth of four worm-wheels are cut simultaneously. As a matter of fact, this is not the case. A generating operation is being performed on two wheels while the two other finished wheels are being removed from the fixtures and fresh blanks set up ready to have the teeth cut.

A clamping plate *A* is held down on each gear blank by two nuts. To avoid screwing these nuts all of the way off the clamping bolts, holes have been drilled in plates *A*, with slots running out from the holes. After a gear blank has been put in position, the plate is dropped over the nuts on the two clamping bolts, the holes in the plate being of sufficient size to clear these nuts. Then the plate is twisted so that the bolts slide into the slots, which are just wide enough to receive the bolts and allow the nuts to find a bearing surface on the top of the plate. Thus, it is only necessary to loosen the nuts about one-half turn to unload the fixture. For a hobbing operation, the work must be rotated while in contact with the hob. This is accomplished on the fixture shown in Fig. 17 by making connection between the milling machine spindle and the arbors on which the worm-wheel blanks are mounted. A spiral gear is mounted on the spindle nose and engages a second gear mounted at the middle of a shaft, one end of which can just be seen at *B*. This shaft is held by a bracket

secured to the bed of the milling machine, and the fixture is free to slide lengthwise on the shaft, which rotates but does not have any longitudinal movement.

An explanation has already been given of the way in which two wheels are being hobbled while the other two are in the idle position, so that the finished wheels may be removed and fresh blanks set up in the fixture. To stop rotation of the finished work two clutches on shaft *B* transmit power to the cross-shafts that drive the two pairs of work-holding arbors. When the table is moved over to bring two new blanks into contact with the hobs, one clutch moves out of engagement with the cross-shaft through which power is transmitted to the arbors on which the two finished worm-wheels are mounted.

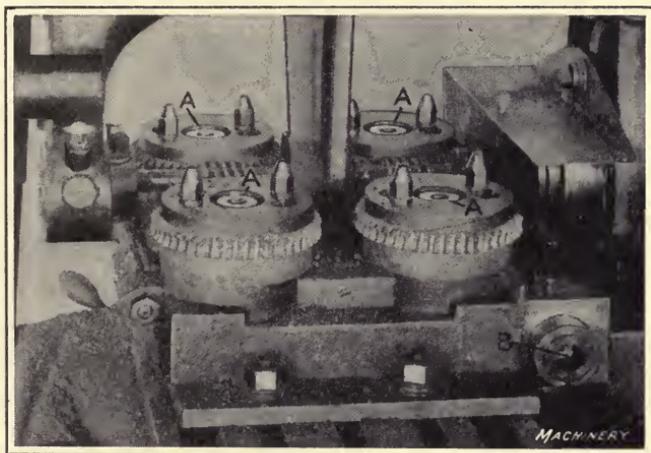


Fig. 17. Milling Machine equipped with Hobbing Fixtures

At the same time, the other clutch comes into engagement with the cross-shaft that transmits power to the arbors on which the two fresh gear blanks are carried. In this way, disengagement and engagement of the drive is automatic when the table is moved over by hand to bring two fresh blanks into the operating position. The worm-wheels to be hobbled have 48 teeth of 10 diametral pitch, so that they are 4.8 inches in diameter. On this job, the teeth of two worm-wheels were completely cut every seven minutes.

Hobbing Small Worm-wheels on a Milling Machine.— Another milling machine equipped for hobbing the teeth of worm-wheels is illustrated in Fig. 18. This is a No. 21 Garvin plain miller used at the plant of the Frank Mossberg Co., Attleboro, Mass., for generating the teeth of small worm-wheels shown at *A*. The equipment of the machine for this job is rather different from the one shown in the preceding illustration. Only one work-holding fixture is mounted on the table, and a quick-clamping mechanism reduces idle time of the machine as far as possible. A small trunnion projects

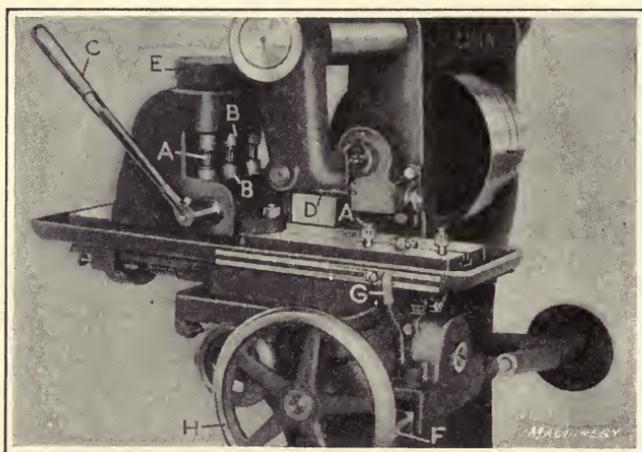


Fig. 18. Milling Machine equipped for generating the Teeth of Small Worm-wheels shown at *A*

out at each side of the worm-wheels *A*. These trunnions hold the work in bushings *B*, which are bored out to receive the trunnions. The three upper bushings occupy fixed positions in the fixture, but the lower bushings have rack teeth cut in them, which mesh with pinions carried by a cross-shaft. Lever *C* is mounted at the end of this cross-shaft, and by pushing the lever down, the three lower bushings are withdrawn so that the hobbed worm-wheels may be removed from the fixture and fresh blanks substituted in their places. During the hobbing operation, the work is rotated by a shaft *D* that takes power from the milling machine spindle through a worm-

wheel and worm. This shaft transmits power to gears contained in case *E*, which are so arranged that all three spindles are driven simultaneously from the single source of power. After the fixture has been loaded, lever *F* is raised to bring the feed-worm into engagement with the worm-wheel, so that the work is fed to the cutters until the automatic stop *G* is engaged, thus tripping the feed at the time that the hobbing operation has been completed. The table is then returned to the starting point by handwheel *H*.

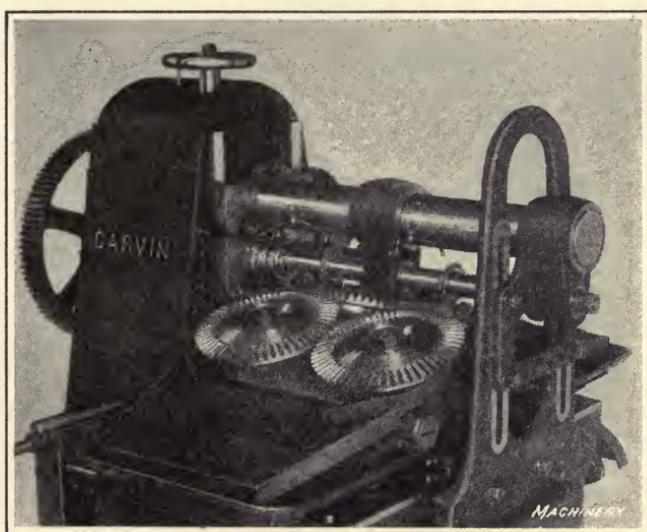


Fig. 19. Indexing Milling Machine equipped with Automatic Fixture for simultaneously roughing out the Teeth of Four Bevel Gear Blanks

Roughing out Teeth of Bevel Gear Blanks.— Experience has shown that in operating various types of bevel gear generators, more satisfactory rates of production can be obtained by performing the operation in two steps—first, roughing out the teeth, and second, generating the teeth to the required form. Several types of machines have been developed for use in roughing out the teeth of bevel gear blanks which are to be finished on a special generating machine. Figure 19 shows an automatic machine developed for this purpose. It con-

sists of a Garvin No. 9 indexing miller equipped with a fixture on which four gear blanks can be mounted. Two rotary gear-cutters are mounted on the arbor of the milling machine, and the gear blanks are mounted in two pairs, each pair of blanks being held on an inclined plane, so that the portions of the faces in which gear teeth are to be cut are held in a horizontal position. Each pair of gear blanks can thus be fed under one of the cutters for milling a tooth space in each of the blanks. After this has been done, the direction of table movement is

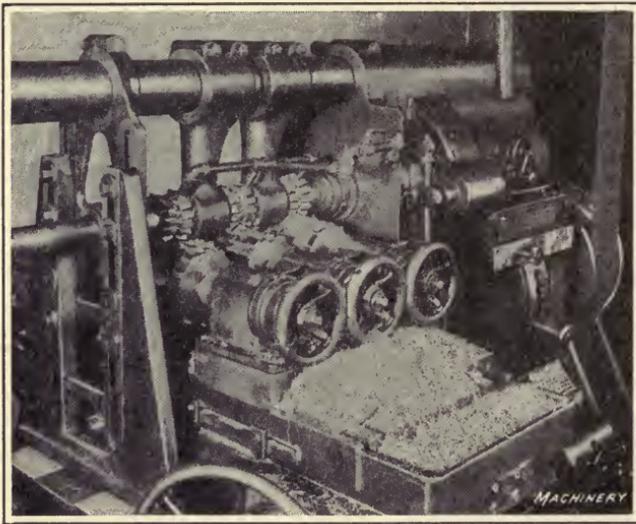


Fig. 20. Plain Milling Machine equipped with Three Sets of Special Single Dial Index-centers for fluting Forgings

automatically reversed and the table is returned to the starting point at high speed. Next, each of the four gear blanks is automatically indexed through one tooth space; then the forward feed movement of the table is again automatically engaged to move the work forward for cutting the next tooth space in each of the blanks. With such an arrangement, it is only necessary for the operator to set the blanks up on the machine, after which the work requires no further attention until all of the teeth have been cut. On this job, the work is fed to the cutters at a rate of 9 inches per minute, and there

are 40 teeth to be cut in gears having a face width of $1\frac{1}{2}$ inches. The machine completes the operation in 13 minutes, 20 seconds.

Milling Grooves in Steel Forgings.— Figure 20 shows a Brown & Sharpe No. 5B heavy-duty plain milling machine equipped with three sets of index-centers for milling two grooves in six steel forgings at each traverse of the table. The grooves are each 1.17 inches wide by $\frac{5}{16}$ inch deep, and two forgings are mounted on the arbor between each pair of index-centers. The cutters are formed in such a way that they mill two

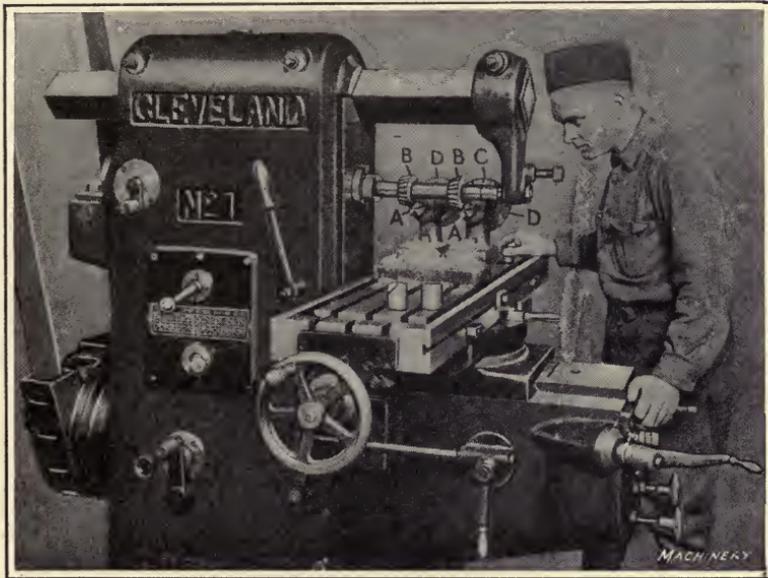


Fig. 21. Universal Milling Machine equipped with Indexing Fixtures for cutting the Teeth in Milling Cutters

grooves and also finish the top of the raised portion of the work between two adjacent grooves. After the cut has been completed, the table is returned to the starting point and the work is indexed ready for taking the next cut. For this exceptionally heavy job, an arbor possessing ample strength must be used; otherwise, there would be a tendency for the arbor to spring. To avoid this, the cutter-arbor, which is of considerable length, is rigidly supported from the over-arm of the

machine by two intermediate yokes placed between the cutters. The cutters and work are lubricated with lard oil to prevent them from becoming overheated.

Fluting Hollow-milling Cutters. — There are many examples of tool-room work, such as the fluting of various types of cutting tools, where it is necessary to produce a number of pieces of a standard form. For such jobs, the use of an indexing milling fixture will often greatly increase rates of production. Figure 21 shows a universal milling machine which is equipped with an indexing fixture for simultaneously fluting two hollow-milling cutters. The cutter blanks *A* are held in collet chucks, and two angular milling cutters *B* are mounted on the arbor of the machine. To save as much time as possible in indexing the work for taking successive cuts, an index-plate *C* is mounted at the rear end of one of the work-spindles, this plate being notched to receive an index-pin which locates the cutter blank held by the fixture in position for milling. A pair of spur gears *D* connects the spindles of the two fixtures, so that when the spindle that carries the index-plate is turned through the required angle to bring the work into position for taking the next cut, the piece of work carried by the other spindle is simultaneously located. The angular milling cutters *B* are made of high-speed steel, and on this job the cutters were driven at 81 revolutions per minute, which corresponds to a cutting speed of 63.6 feet per minute; and the work is fed to the cutters at 2.15 inches per minute.

CHAPTER VIII

OPERATIONS ON MACHINES OF RECIPROCATING TYPE

MANUFACTURERS who have had experience in the operation of milling machines for the quantity production of duplicate parts, or in designing work-holding fixtures for use on milling machines employed in this class of service, are familiar with the so-called multiple-spindle or planer type of machines built by the Ingersoll Milling Machine Co. To meet the requirements of certain classes of work for which the planer-type machine of large size is not ideally adapted, a number of smaller units provided with special means for facilitating the milling of duplicate parts have also been developed by this company.

Although these machines are adapted to meet the special requirements of individual jobs, the building of each machine does not involve a completely new problem of machine design. There are certain recognized principles of construction employed in the various sizes and styles of Ingersoll milling machines. When a customer submits blueprints of a piece to be machined, together with data concerning such matters as the amount of stock to be removed from the different finished surfaces and the rate of production that is required, it is possible for the designers to make recommendations for the construction of a machine of recognized type, the details of which have been modified to fulfill the peculiar requirements of the work. In this chapter it is proposed briefly to explain the fundamental principles of several new types of these milling machines that have been developed to enable small parts to be milled in quantities, with the attainment of a high degree of efficiency in production and economy of labor, floor space, etc.

Milling Tractor Transmission Housings on Reciprocating Milling Machines. — The name "reciprocating milling machine" has been applied to a new machine shown in Figs. 1

and 2, because the table moves back and forth to provide for alternately machining castings held by fixtures that are set up at opposite ends of the table. As the machine was built to meet the requirements of a special repetition milling operation on which it is to be used continuously, it will be evident that no advantage would be secured through providing an

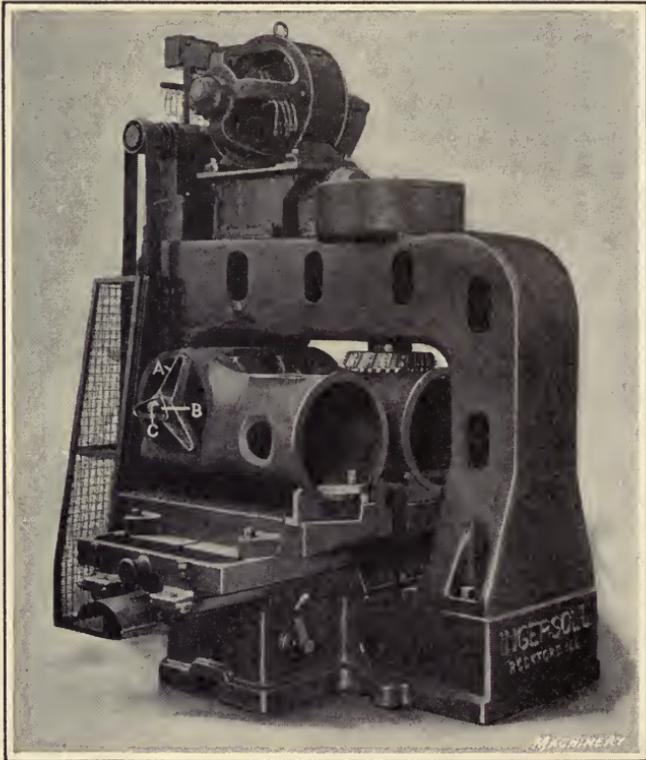


Fig. 1. Reciprocating Type of Miller, designed and built for milling Tractor Transmission Housings

expensive mechanism for obtaining the several selective changes of cutting speed. But it is important to provide means for quickly reversing the table to bring the second piece of work into engagement with the cutters, after the milling operation has been completed on the first piece. For this reason the machine is designed to feed the work under

the cutters at a rate of $4\frac{1}{2}$ inches per minute, and as soon as the operation on one piece of work has been completed, a fast power reverse movement is engaged to withdraw the first piece of work quickly from the cutters. This movement continues until the work held by the fixture at the opposite end of the

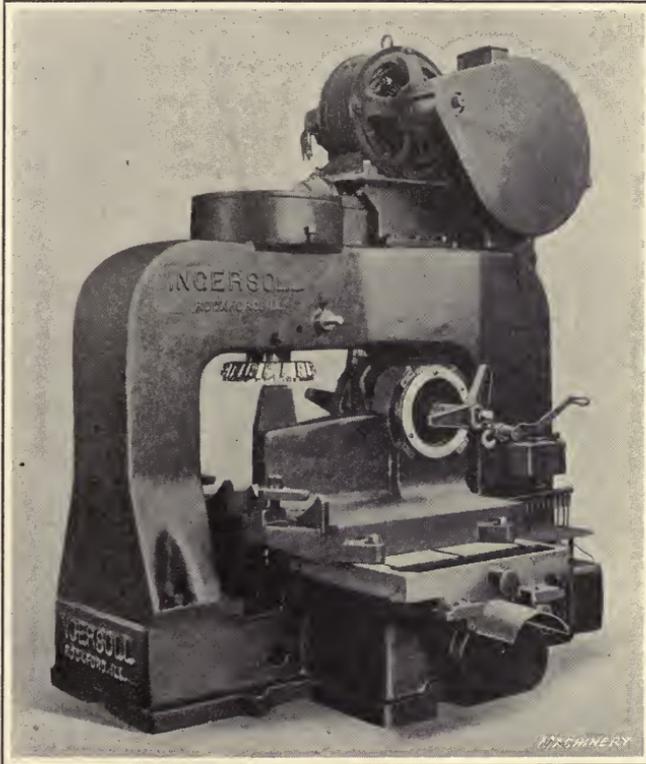


Fig. 2. Opposite Side of Machine illustrated in Fig. 1, showing Method of locating and clamping Work Ready for milling

table is brought up to the cutters. When this piece of work has been advanced to the proper point, the fast traverse is automatically disengaged and the $4\frac{1}{2}$ inches per minute rate of feed once more becomes operative. It is important to note that while the work held in one fixture is being milled, the table is feeding in the opposite direction from that in which it moves while work held in the other fixture is being milled.

While the milling operation is proceeding on one piece, the operator is removing the milled casting from the fixture at the opposite end of the table and setting up a fresh blank in its place; and after the machine has reversed to start milling this casting, the operator at once removes the milled piece from the other end of the table and sets up a casting in that fixture. As a result, both the machine and its operator are kept constantly employed, and losses resulting from non-productive time of machines and labor are reduced to a minimum.

In Fig. 1 there is shown a machine of this type, which has a capacity of 30 by 28 inches by 5 feet. This machine has

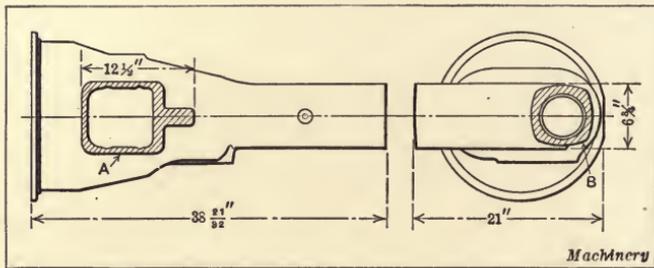


Fig. 3. Tractor Transmission Housing milled on Machine shown in Figs. 1 and 2

two spindles which are furnished with an 8-inch cutter on the horizontal spindle and a 14-inch cutter on the vertical spindle. There is an adjustment of 6 inches for each spindle quill. As shown by the illustrations, the work-holding fixture has been designed with a view to allowing the maximum rapidity to be attained in setting up blanks and removing finished pieces of work. At the right-hand end, as illustrated in Fig. 1, the casting rests in a cradle that embraces the circumference of the flange; and at the center of the fixture there is a vertical column or wall that carries two pilots on its opposite sides, these pilots being of sufficient size to enter the bore in the work, as shown at the left-hand end in Fig. 1. Each pilot locates a piece of work in the fixture, and the casting is held back against a vertical locating face by means of the three-

legged spider *A* that is furnished with a pivoted latch *B*, so that it is merely necessary to loosen the nut *C* through half a turn and then swing back the latch, after which the spider may be lifted over the nut. A clearer idea of the construction of the work-holding fixture on this machine will be gathered from Fig. 2; and at *A* and *B* in Fig. 3, the shaded areas in-

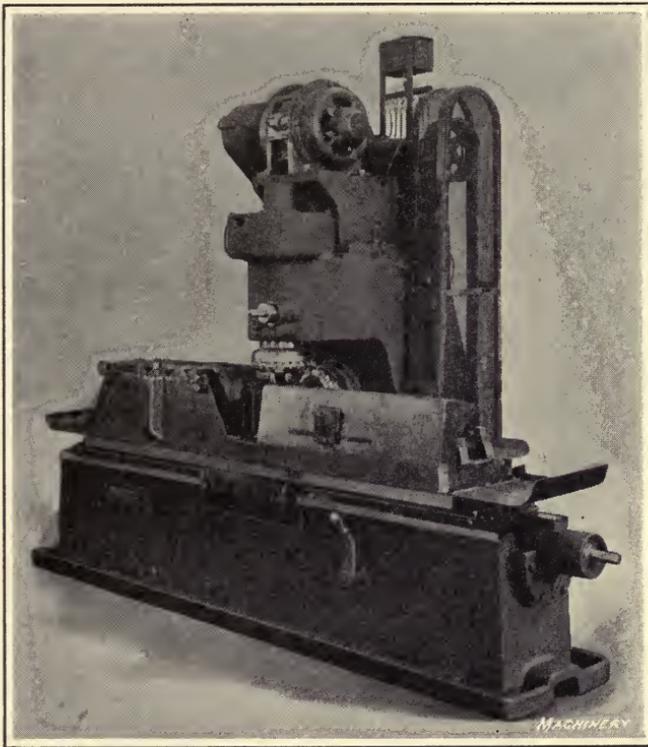


Fig. 4. Another Type of Reciprocating Milling Machine, designed and built for machining Four Surfaces on Motor Car Cylinder Blocks

dicating the surface that is milled on these machines. The rate of production obtained on this milling job is 150 pieces in an eight-hour day.

Milling Flange and Manifold Surfaces on Cylinder Blocks.
— Figures 4 and 5 show a reciprocating milling machine for use in machining four surfaces on motor car cylinder block

castings, two settings of the work and two operations being required for completing the work on each piece. By comparing Figs. 1 and 4, the reader will gain a comprehensive idea of the way in which special machines are built to suit the requirements of individual jobs, with the incorporation of the standard principles of design in all machines of a given

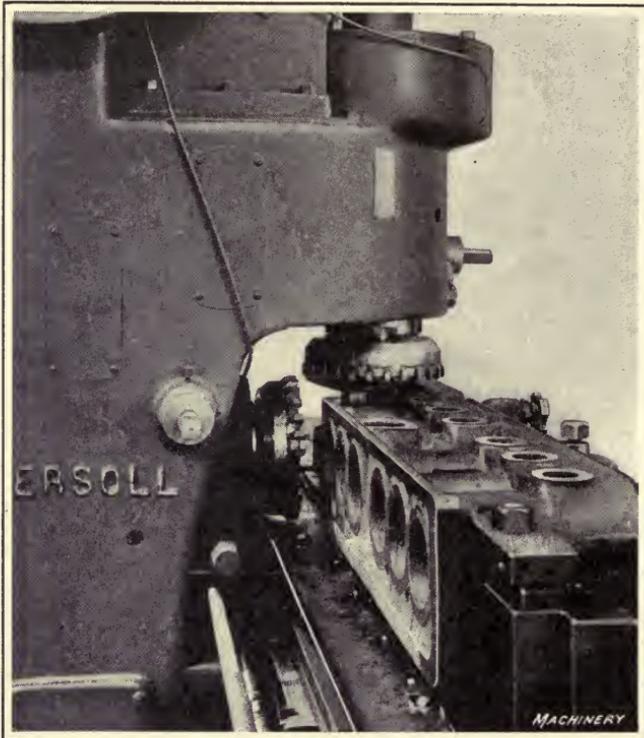


Fig. 5. Close-up View of Cutters and Work on the Machine illustrated in Fig. 4, showing Flanged Surface and Manifold Seat to be milled

type. Superficially, there is little resemblance between these two machines, but actually they are both reciprocating milling machines with two fixtures mounted at opposite ends of the table and the mechanism arranged to move the table back and forth, so that the cutters may first mill two surfaces on one casting and then start work on another casting, after

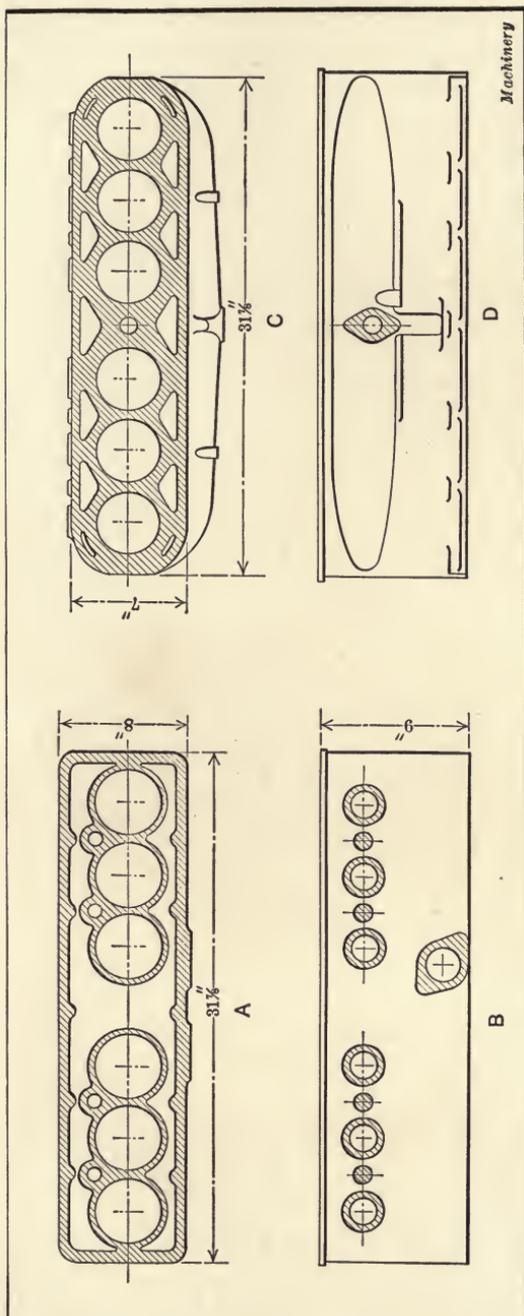


Fig. 6. Four Views of Cylinder Block to be milled. The Cross-sectioned Areas A and B are finished at the First Setting, and Shaded Areas C and D are finished at the Second Setting of the Work

reversal of the machine, which enables the operator to unload and reload the idle fixture while work is proceeding on a casting held in the second fixture, in the manner which has already been described. On this machine the work is of such a character that it can be handled at rather higher speed than was possible in the case of tractor transmission housings. The rate of feed employed for milling cylinder blocks is $6\frac{1}{4}$ inches per minute, and the rapid power traverse of the table is accomplished at a rate of 10.6

feet per minute. A 10-inch inserted-tooth cutter is carried by each spindle. The capacity of this machine is up to 20 by 17 inches by 6 feet. Adjustment of the cutters is obtained through the standard quill mechanism, each spindle having an adjustment of 4 inches.

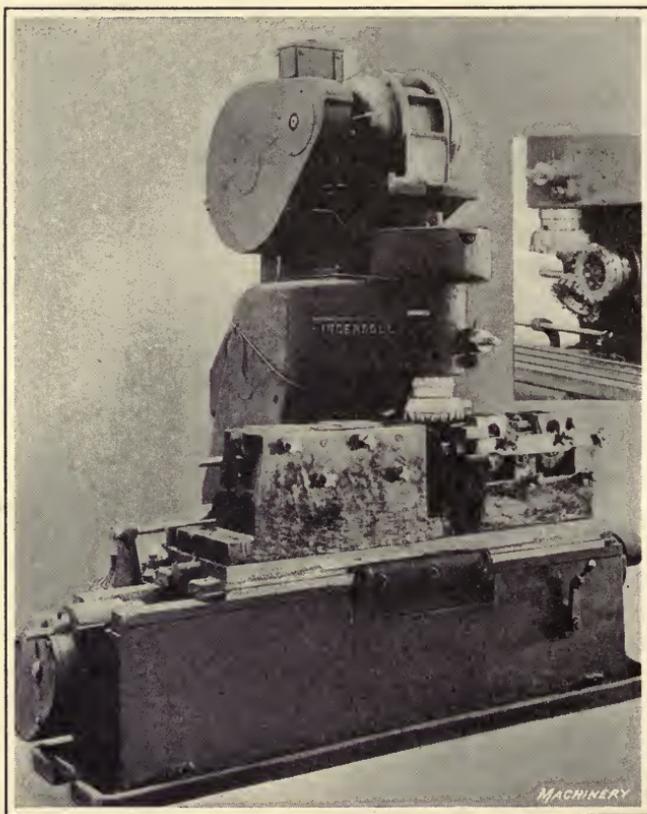


Fig. 7. Reciprocating Continuous Milling Machine designed and equipped for milling Two Types of Transmission Cases

There are two pairs of surfaces to be milled on these castings, and two cutters on the machine complete this work by first milling two surfaces and then resetting the cylinder block in a fixture at the opposite end of the machine for milling the second pair of faces. It will be apparent from Fig. 4 that the fixtures at opposite ends of the table are of different design,

the reason for this being explained by the fact that different operations are performed on the work held in them. The first operation is to mill the flange face of the casting and the manifold surface, for which purpose the fixture shown in Fig. 4 at the left-hand end of the machine is used, the casting being

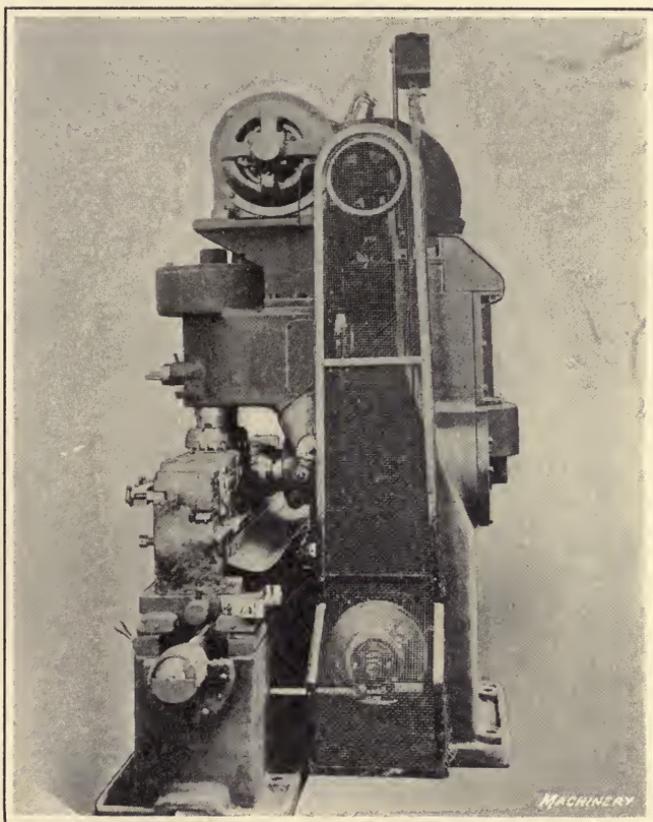


Fig. 8. End View of Machine shown in Fig. 7, illustrating how Work is held for simultaneously milling Two Surfaces

strapped down in this fixture on locating pads which afford an approximate setting of the work by engaging the rough cast faces. This casting is then reset in the fixture at the opposite end of the table, with the milled faces used as locating points, so that an accurate setting is obtained, thus enabling the cylinder-head contact and the carbureter pad, which are

milled at the second setting, to be brought exactly at right angles to the previously milled faces. Figure 5 shows a close-up view of the cutters and work set up for performing the first operation; and in Fig. 6 the shaded areas at *A* and *B* are those finished at the first setting of the work, while *C* and *D* are the surfaces milled at the second setting.

Milling Operations on Two Types of Transmission Cases. — In Figs. 7 and 8 there is shown a type of machine known as a reciprocating continuous milling machine which is employed for machining two different types of transmission cases. So



Fig. 9. Close-up View of Fixtures of the Type which are shown in Place on the Machine illustrated in Figs. 7 and 8

far as general exterior appearance is concerned, this machine is quite similar to the equipment for milling cylinder blocks which is illustrated in Fig. 4. Also, it is furnished with the same arrangement of slow feed and rapid power traverse, although the rates are somewhat different, being $4\frac{1}{2}$ inches per minute and 11.8 feet per minute, respectively. One of the transmission cases milled on this machine has simply two surfaces to be finished at right angles to each other, and for handling this job there is a 9-inch inserted-tooth cutter on the vertical spindle and an 8-inch cutter on the horizontal spindle. The second type of transmission case has the two surfaces

at right angles, in addition to which there is an angular face. For milling such work, the machine is equipped with a third spindle mounted at an angle so that an 8-inch cutter can be set up for finishing the inclined face of the work. There is a 4-inch adjustment for the quill of each of the three spindles. This machine has a capacity of 14 by 20 inches by 4 feet.

For handling these two different types of work, fixtures of different designs must, of course, be provided. The best idea of the fixtures employed for milling the simpler of these two

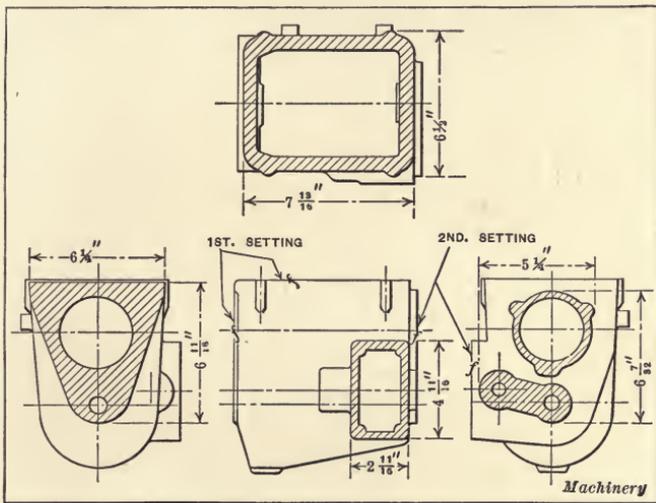


Fig. 10. Transmission Case on which Four Surfaces have to be milled, Two Faces being milled at Right Angles at Each of Two Successive Operations

castings, which has faces to be machined at right angles, will be derived by referring to Figs. 8 and 9 which show the work set up for milling, and rear views of the empty fixtures, respectively. On this job, one pair of faces is milled with the work held at one end of the table, after which the casting is reset in a fixture at the opposite end of the table for milling two additional faces, which completes the operation. Figure 10 shows four views of the work and illustrates the surfaces to be milled. The rate of production is 150 milled transmission cases in a nine-hour day, which includes two milling operations on each case.

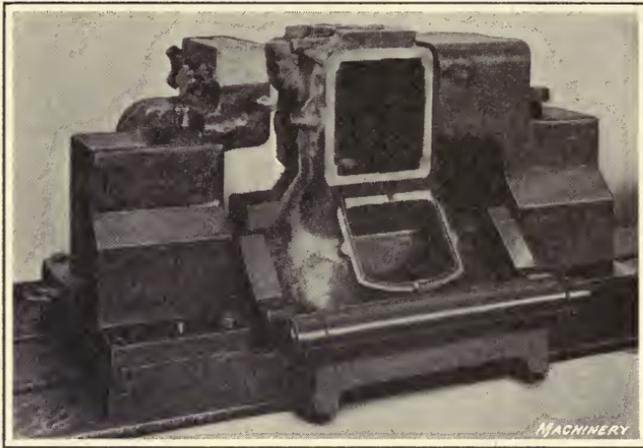


Fig. 11. Close-up View of Fixture for Transmission Cases

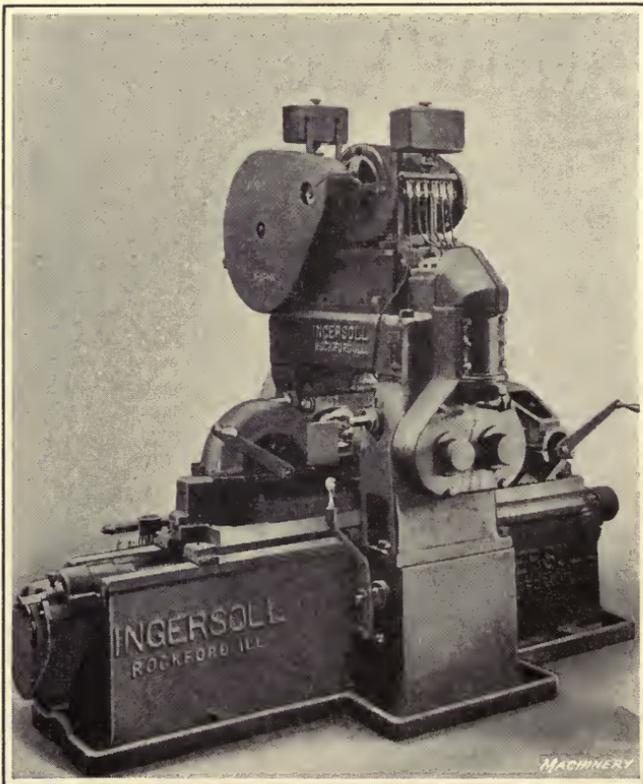


Fig. 12. Four-spindle Reciprocating Continuous Milling Machine

Figure 11 shows a rear view of a fixture used for milling the type of transmission cases on which there are three surfaces to be machined, and in Fig. 13 there are illustrated three views of the transmission case, with the milled surfaces shown in cross-section. For this job only one setting of the work is required, so the fixtures at the opposite ends of the milling machine table are of identical design.

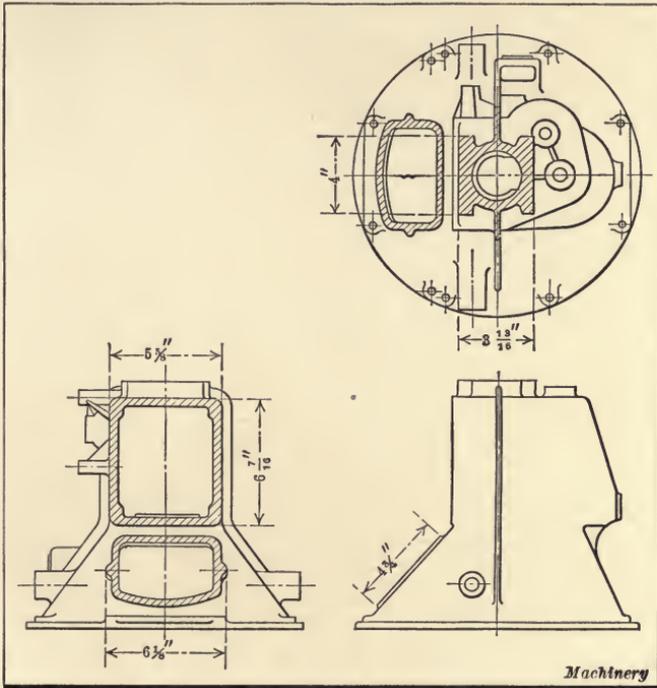


Fig. 13. Transmission Case on which Three Surfaces are milled simultaneously

Milling Two Surfaces on Transmission Case Covers. — In Figs. 12, 14, and 15 there is shown another reciprocating type of continuous milling machine, which serves as a further example of how different the superficial appearance of these machines may be, although they are actually of the same type. This machine was designed and built for milling two surfaces on transmission case covers, and it will be seen that there are four spindles which carry inserted-tooth cutters, two

of which operate on the casting held in a fixture at one end of the table, while the other two cutters operate on work held by a fixture at the opposite end of the table. This form of machine construction was necessitated by the shape of the work which has a shoulder, on the ends of which there are faces

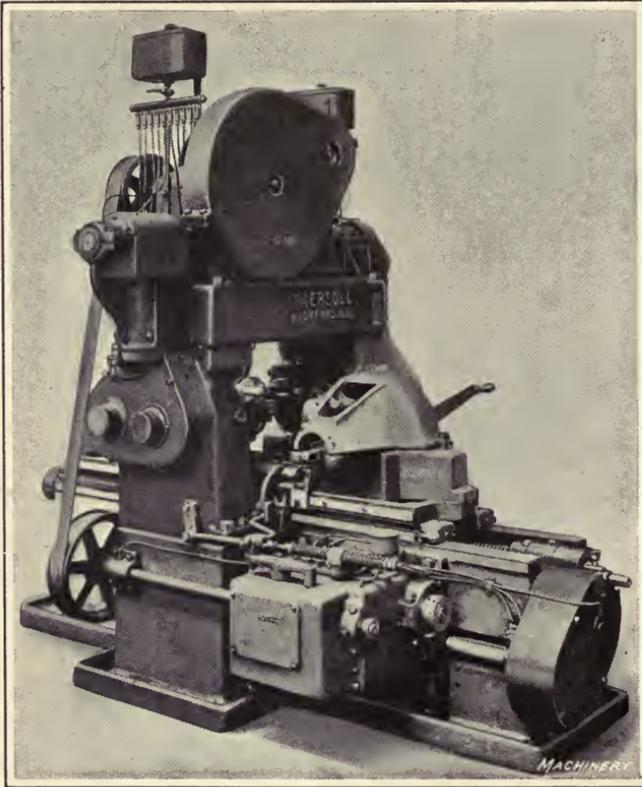


Fig. 14. Opposite Side of Four-spindle Reciprocating Type of Continuous Milling Machine. This Illustration shows the Second Surface to be milled

to be milled. The overhanging portion of the work would interfere with the cutters in traversing the table unless the space between the housings of the machine was substantially widened. This would not only add to the cost of building the machine, but would also make it take up a greater amount of floor space. As a result, it was considered a more economical

proposition to use the four-spindle design. On this machine a feed of $6\frac{1}{4}$ inches per minute is employed, while the rapid table traverse is at a rate of 10.6 feet per minute. The cutters are 4 inches in diameter, and each spindle quill has an adjustment of 2 inches. The capacity of the machine is 14 by 14

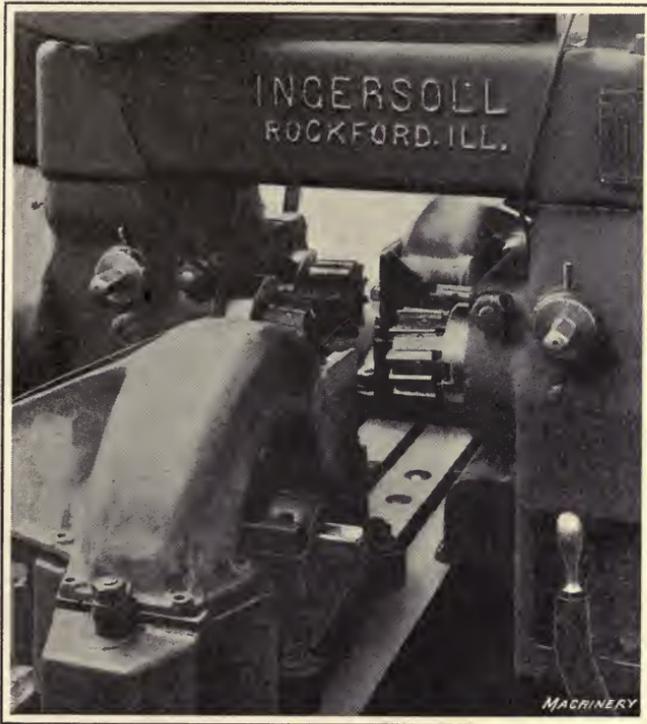


Fig. 15. Close-up View of Cutters and Work on Four-spindle Reciprocating Type of Continuous Milling Machine shown in Figs. 13 and 14

inches by 5 feet. In Fig. 16, the shaded areas show the surfaces that are milled at opposite ends of the work.

Milling Timing Gear Case Covers on Semi-automatic Machines. — In Figs. 17 and 18 there is shown a semi-automatic milling machine which was built for use in two successive operations on timing gear case covers, but in this instance the method of handling the work is essentially different from that which was employed in the case of cylinder blocks and trans-

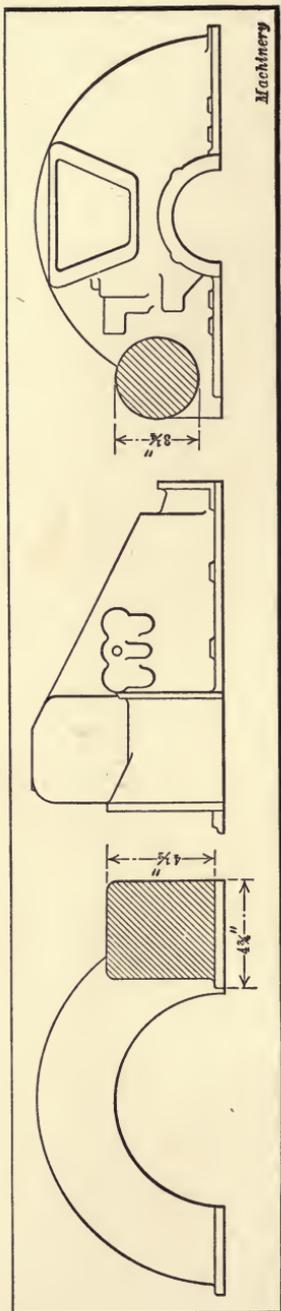


Fig. 16. Transmission Case Cover to be milled

mission cases. Here, instead of employing a single machine for two successive operations, two separate machines are used on which the first and second operations are performed. On the first machine, all of the cutters are 5 inches in diameter; and on the machine for performing the second operation there are 5-inch cutters on the horizontal spindles and 7-inch cutters on the vertical spindles. A 2-inch adjustment is provided for all of the spindle quills. The rate of feed is $6\frac{1}{4}$ inches per minute, while the rapid traverse back to the starting position takes place at the rate of 10.6 feet per minute. The

capacity of the machine is 14 by 12 inches by 4 feet.

In their general form these machines are rather similar to the planer-type milling machines, but they are intended for the quantity production of small work, and to meet the requirements of this special service, several modifications of design were found necessary. Most important among these is the arrangement of the feed mechanism for controlling the table movements, which can best be explained by telling how the operator loads and unloads the fixtures that are furnished on the table. While the

table is still at rest the operator loads the first fixture, after which he throws in a feed-lever that starts the table carrying the work under the cutters at a rate of $6\frac{1}{4}$ inches per minute. As soon as the operator has engaged the feed movement, he proceeds to load the balance of the fixtures as rapidly as pos-

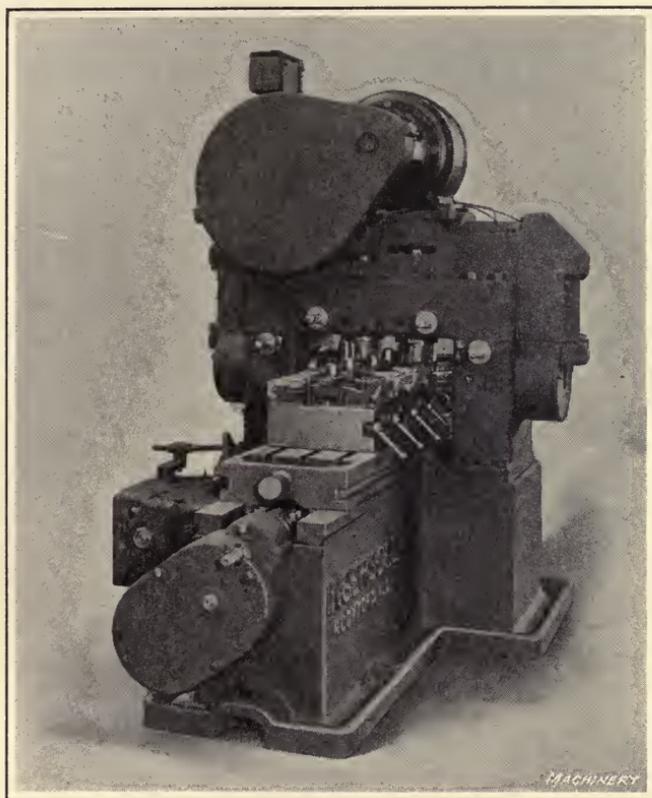


Fig. 17. Semi-automatic Milling Machine, for performing Two Operations on Timing Gear Case Covers

sible, the design of the clamping mechanism having been worked out in such a way that no trouble is experienced in loading the fixtures more rapidly than the table carries them under the cutters. After the operator has loaded the last fixture of the string (it will be seen that there are two rows of fixtures running parallel along opposite sides of the table),

he goes to the opposite side of the arch and unloads milled castings which have passed out from under the arch.

When the cutter has cleared the last piece of work, a stop is engaged to throw out the $6\frac{1}{4}$ -inch power feed automatically and engage a rapid traverse movement which takes place at

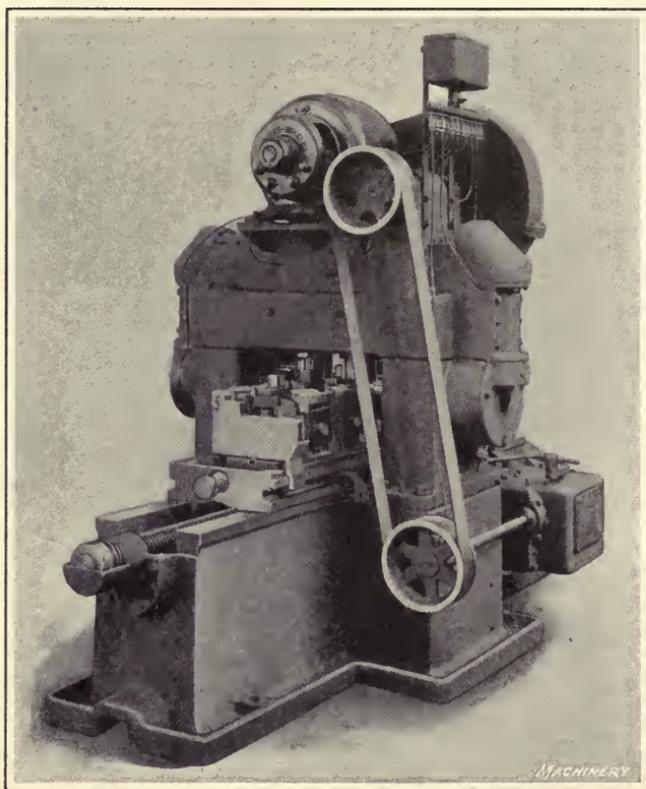


Fig. 18. Opposite Side of Machine illustrated in Fig. 17. At this Point in the Table Travel, the Operator starts unloading Castings

a rate of 10.6 feet per minute. This quickly carries the balance of the pieces of work out from under the arch, after which a second stop disengages the fast table movement, leaving the table at rest. The operator now removes the balance of the pieces of work from the fixtures, after which he throws in a return lever to start the table traveling back to the

initial position at a rate of 10.6 feet per minute. When the table reaches the starting position, it stops automatically. The cycle is then repeated by the operator's putting two castings in fixtures at opposite sides of the table and re-engaging the forward feed movement, after which he proceeds to reload the balance of the fixtures and go through the other movements of the cycle that have just been described. It will be

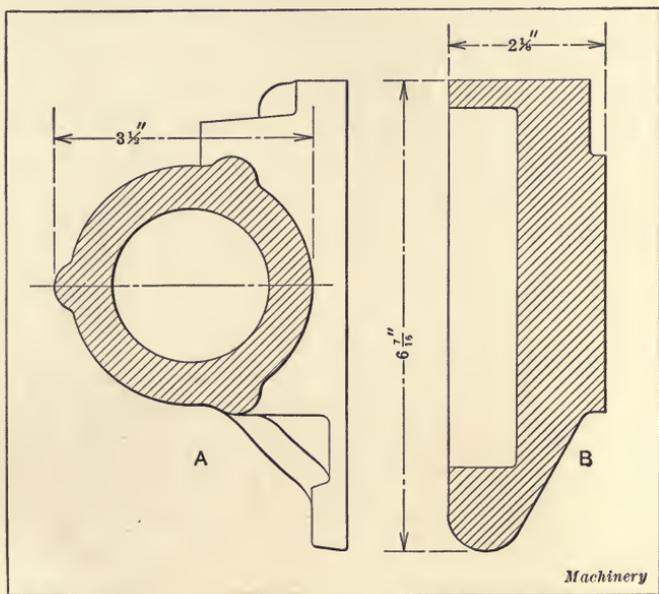


Fig. 19. Two Views of the Timing Gear Covers, where Cross-sectioned Areas show Surfaces to be milled

seen that on each of the timing gear case covers milled on this machine, there are two surfaces to be milled at the first operation. Four spindles enable these two surfaces on each casting in the two rows carried at opposite sides of the table to be simultaneously milled as they are carried under the arch of the machine. After the work has been completed on this machine, the castings are sent to a second machine on which another milling operation is employed. Figure 19 shows the two shaded areas *A* and *B* that are milled on the machine shown in Figs. 17 and 18.

CHAPTER IX

ECONOMY IN MILLING OPERATIONS

THERE are four factors, known as the equipment factor, the direct labor cost factor, the tool cost factor, and the quality factor, each of which affects the final manufacturing cost of milling operations. In order to obtain the maximum economy, careful consideration must be given to the importance of each of these factors for the conditions under which any milling operation is performed. This is one of the numerous cases where scientific management is merely an application of common-sense methods of procedure in deciding upon the most satisfactory procedure in handling industrial work. A study should be made of the way in which each factor that affects milling economy will increase or reduce the final cost of the work, and the method of operating milling machines must then be so arranged that the most advantageous combination of results will be secured. It will frequently happen that where the most satisfactory method is employed, one or more factors will tend to increase the cost of manufacture, but this will be more than offset by the reduction effected through the influence of other factors. In this chapter, a brief outline will be presented of conditions which were discovered during an investigation of the efficiency of methods used for milling operations in a plant engaged in the manufacture of small arms. These data are presented as an illustration of the effect of the different milling factors upon production costs; they also show the tendency toward economy that is made possible through handling work in large quantities. This discussion is merely presented to assist the reader in drawing general conclusions in regard to the most satisfactory methods of operating milling machines. Detailed informa-

tion concerning the milling of rifle parts would be of value to only a small number of readers.

The Equipment Factor. — Items of manufacturing expense resulting from the factor of machines and equipment include the initial cost of the machinery, the cost of maintenance, loss through depreciation, interest on the investment, cost of power, rent for factory floor space, etc. A reduction of the amount of equipment used to produce a given quantity of work will naturally result in a material decrease in the items of expense resulting from this factor. There are two possible conditions, however, that must be considered in regard to the equipment factor, before it is possible to determine definitely the most economical method of milling. First, if there is plenty of equipment and factory space available, which would otherwise remain idle, there would be no economy in utilizing only a small part of it, if so doing would tend to increase the items of expense resulting from some of the other factors which affect the final cost of manufacturing. Second, if it is necessary to provide new equipment, the saving effected by using a minimum amount of equipment should be carefully balanced against the increased expense resulting from the other factors under such conditions. The least expensive total would be the cheapest method, regardless of the separate items of expense resulting from the individual factors.

There are three possible methods of procedure in operating milling machines with a view to obtaining the maximum economy in manufacturing costs. The first method is to require each operator to run a large number of machines, the object being to keep the men busy, even if this entails more or less idle time for a part of the machinery placed in their charge. The second method is to time-study the individual operations carefully and so arrange the work that the machines are kept constantly employed and lost time of the operators is reduced to a minimum for such working conditions. If there is any preference between these two methods it is probably in favor of keeping the machines busy, even if this should result in a slightly higher proportion of idle time

for the operators. The third method is to time-study and arrange the operations, as mentioned for the second method, but in addition, to increase rates of production by raising the speeds and feeds of the machines as much as seems advisable.

In Table 1, the equipment factors are tabulated for milling operations on rifle parts, performed according to the first, second, and third methods of milling, which were outlined in the preceding paragraph. In looking over these figures it should be borne in mind that they are to be used only comparatively, remembering that there are numerous special conditions resulting from the peculiar nature of each job. This table shows the average number of machines required per operation, to mill the parts for different numbers of rifles.

Table 1. Equipment Factors for Milling Operations performed by First, Second, and Third Methods

Method of Milling	Number of Operations	100 per day *	200 per day	300 per day	400 per day	500 per day	1000 per day	1500 per day
First	262	1.01	1.2	1.4	2.3	2.4	4.7	6.5
First (corrected)...	262	1.01	1.12	1.4	1.8	2.2	4.35	6.6
Second	184	1.01	1.1	1.6	1.7	2.1	3.8	5.7
Third	271	1.00	1.02	1.06	1.16	1.24	1.97	2.86

* A day is considered as ten hours.

For example, the equipment factor for a production of 500 rifles per day is 2.4, when the first method of milling is used, and there are 262 milling operations to be performed, so that the number of milling machines required is 629. This table shows that, with a small production, the equipment factors for the three methods are nearly constant, so that the way in which the other factors affect manufacturing efficiency will determine the best procedure to adopt for operating the milling machines. But as the number of rifles per day increases, the equipment factor for the third method of milling decreases so rapidly that, unless the effect of other factors changes sufficiently to offset the beneficial influence of the equipment factor, the third method of milling would be the proper one to adopt.

Figure 1 presents in graphical form the same data that appear in Table 1. From this illustration it will be noted that several of the curves cross each other at the start, this being due to the imperfect method of grouping the various operations.

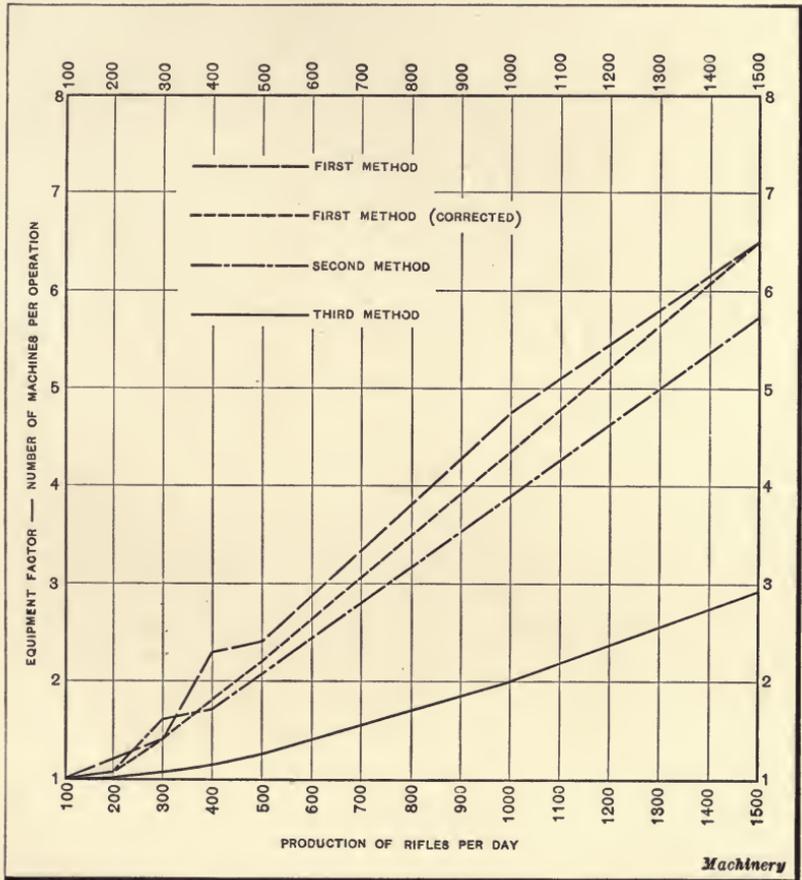


Fig. 1. Diagrams showing Equipment Factors for Various Daily Rates of Production

A corrected curve is also presented, to indicate what would be the tendency with the first method, if the operations were grouped under the more advantageous conditions.

The Direct Labor Cost Factor. — There appears to be practically no change in the average piece price per milling opera-

tion where the first, second, or third method of milling is used. That this factor should remain constant is to be expected, because it will be evident the work of men employed to operate automatic milling machines consists of unloading and reloading the work-holding fixtures, and starting the machines. This work is practically constant, regardless of whether a man handles his quota of pieces on one machine or on a number of machines placed in his charge.

The Cutter Cost Factor. — Another factor that must receive consideration in determining the most economical method of milling is the question of cutter cost. On some classes of milling operations, where the cutter cost is very low, this factor does not have an important effect upon manufacturing costs; but where expensive formed cutters are required, the influence of this factor becomes a matter of vital importance. As the cutting speed is increased, with a corresponding increase in the rate of feed, the machine hour time of the operation is correspondingly reduced. But under these new operating conditions, there is also a marked reduction of the number of pieces that each cutter will mill before it is worn out. If it is estimated that an average cutter should be reground twenty-five times before it is worn out, the total cutter cost may be readily obtained by adding the expense of resharpener to the original cost of the tool. With this information available, it is easy to calculate the number of pieces milled by the cutter, and the cutter cost per piece. It is a matter of general knowledge that the number of pieces that can be machined by a tool during its operating life will be increased by reducing the cutting speed and feed; and there will be a corresponding decrease in the cutter cost factor where such a procedure is adopted. It is evident, however, that the economy secured through following such a course is offset by the increase in expense items resulting from the equipment factor. Hence, it is a question of carefully regulating the cutting speed so that the most advantageous balance of these two factors will be secured.

Table 2 presents the results of an investigation of how the cutter cost factor affected the cost of performing milling opera-

tions in the small arms plant. These figures are for machines operated according to the third method of milling. It will be seen from this table that the cutting speed is from 70 to 80 feet per minute. The cutting speed of machines operated according to the first method of milling was from 30 to 40 feet per minute. Probably the average cutter cost per 100 pieces milled on machines operated according to the third method is more than four times as great as the cutter cost of

Table 2. Data Showing Influence of Cutter Cost Factor on Manufacturing Expense

Surface Speed, Feet per Minute	No. of Pieces per Cutter	Length of Cut per Cutter, Inches	Variation in Size, Inch	Cost of Cutter, Dollars	Cutter Cost per 100 Pieces, Dollars	Type of Cut
80	2900	1450	0.016	31	0.043	Short-Rough-Scale
69	5500	2750	0.014	31	0.023	Short-Rough-Scale
80	3300	2475	0.018	46	0.056	Short-Rough-Scale
69	4800	3600	0.023	46	0.038	Short-Rough-Scale
72	2353	2060	0.013	45	0.075	Medium-Rough-Scale
61	6950	6080	0.021	45	0.026	Medium-Rough-Scale
74	850	2870	0.026	20	0.094	Long-Rough-Scale
62	1200	4050	0.030	20	0.067	Long-Rough-Scale
72	3300	2890	0.009	59	0.072	Medium Finish
61	7800	6830	0.006	59	0.030	Medium Finish
74	600	2025	0.008	14	0.094	Long Finish
62	1900	6410	0.009	14	0.030	Long Finish
80	2400	8100	18	0.030	Long Finish
69	3075	10380	18	0.023	Long Finish
80	3000	2620	0.008	14	0.019	Short Finish
69	8100	7070	0.006	14	0.007	Short Finish

parts milled according to the first method, but this increase is more than offset by economies effected by other factors, when the milling machines are driven at high speed.

Attention is called to the fact that the operations reported in Table 2 were performed in pairs with the same cutter used on the same work for each pair of operations, but at different cutting speeds. In this table the second and third columns represent the amount of work done by each cutter between successive grindings. If twenty-five regrindings are regarded as representative of the average life of a cutter, the total amount of work of which the cutter is capable would be twenty-

five times the amounts specified in the second and third columns of Table 2. Figure 2 shows, in graphic form, the data relative to the life of milling cutters which are presented in Table 2. This chart shows that there is a decided difference between the life of cutters engaged in the performance of rough-milling operations and of finish-milling operations. As

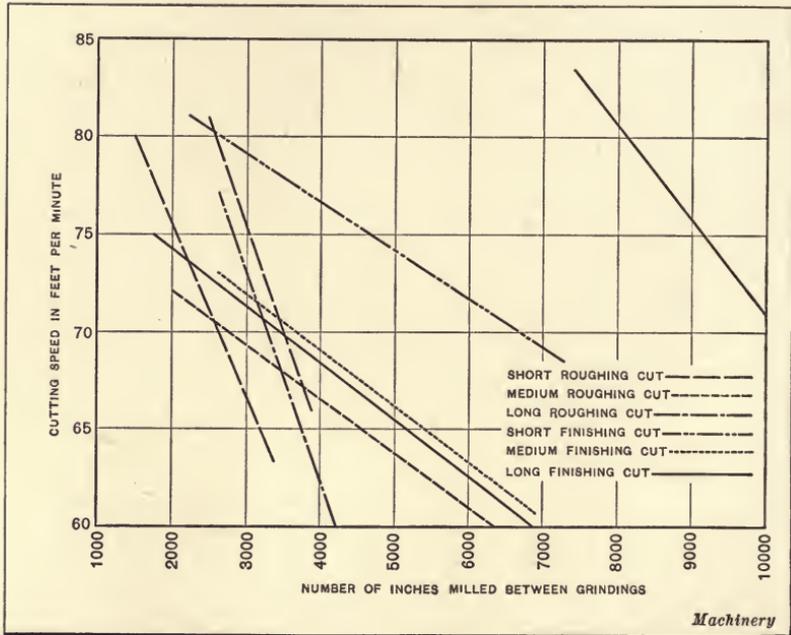


Fig. 2. Diagram showing Effect of Cutting Speed on Durability of Milling Cutters for Roughing and Finishing Cuts

the type of cutter used also has an important effect on the amount of work produced, it is necessary to determine the most economical cutting speed for each individual type of cutters.

The Quality Factor. — The factor governing the quality of workmanship is, in the final analysis, the controlling factor on any job where the product is required to come up to a high standard. The quality of workmanship may be overlooked in performing machining operations, but sooner or later this neglect must be paid for, either by damaging the firm's reputation, by performing additional operations to correct errors

in dimensions, or by actually scrapping those parts which cannot be made to pass inspection. It is difficult to place a cash value on the quality of workmanship factor, because it is hard to put a trustworthy valuation on a firm's reputation. This factor is partially dependent upon cutting speeds and feeds at which milling operations are performed. On work which was milled in this small arms plant according to the third method of procedure, the amount of scrap ranged from 7 to 66 per cent, with an average of over 20 per cent, which was entirely too high. Ten per cent should more than cover this item. This high percentage of scrap was due to many causes, among which may be mentioned the necessity of employing unskilled operatives and of forcing machines beyond their normal productive capacity. The machine adjuster stated that new arbors on these machines would be bent sufficiently to cause them to take a permanent set, after being in service for two days. Such conditions are certainly not conducive to the production of work of good quality. Many filing and fitting operations were required after the machining had been finished, in order to have the work meet all requirements. There are always a considerable number of burring and cornering operations to be performed by hand, but an excessive amount of this work represents a needless labor cost against the job. On rifle parts milled according to the third method, this investigation showed that the filing cost per hundred pieces was \$0.233.

Reference to Table 2 will show that the variations from the specified size of those parts which come closest to the required dimension is 0.006 inch, and that the error ranges from that amount up to 0.030 inch. With such wide variations from specified dimensions, the cost of filing the work is bound to be too high. A toolmaker can easily hold milled work within a limit of 0.002 inch, without any special facilities of the nature that are usually provided on manufacturing jobs. With these special means for locating and holding the work, it would not be unreasonable to expect milled parts to come within 0.002 and 0.003 inch. Where such a degree of

accuracy is not obtained, most of the trouble can be traced to inefficiency of the milling machine operator.

Effect of Quantity Production on Manufacturing Costs. — After investigating the effect on manufacturing costs of each of the four milling factors that have been mentioned, the available data was used to draw a chart, presented in Fig. 3, that shows the way in which the quantity of parts to be manufactured affects the production cost. It will be evident from this illustration that the first method of milling would be the

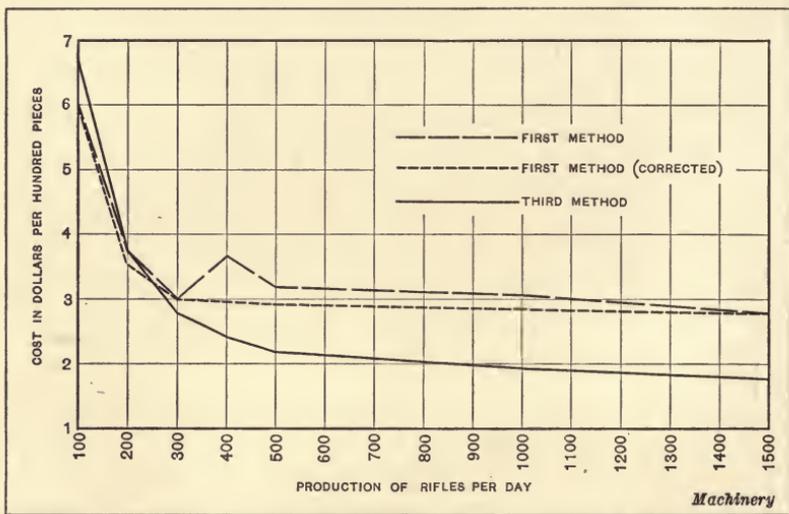


Fig. 3. Diagrams showing how the Unit Cost of Production is reduced by increasing the Volume of Production

most economical in cases where only a small number of pieces have to be produced, that is to say, up to 200 pieces per day. After this volume of production has been passed, the third method of milling begins to show far better results. The sudden elevation in the curve for the first method of milling could be greatly reduced by a careful rearrangement of the operations, the result of such a rearrangement being indicated by the "corrected" curve for the first method. If the price for the machine hour cost was higher, or if the price for cutter cost was lower, it would still tend to make the third method of milling the more economical, even in cases where the number

of parts to be produced is less than 200 per day. But if these conditions were reversed, the first method of milling would tend to become the more economical, in cases where large numbers of parts have to be produced.

Certain factors show desirable results when using one method of milling, while other factors will reduce costs where some other method of milling is employed. In every case, the aim should be to adopt that method which will give the most economical results. For example, Fig. 3 shows that the third method of milling is more economical for a production of over 300 rifles per day, although the cutter cost, the expense of filing, and the loss of scrapped work, have all been increased. In adopting the third method, an effort should be made to reduce the filing cost and scrap loss as far as possible. In this particular case, the cutter cost probably cannot be brought down much lower. These figures would tend to show that the application of high cutting speeds is the more economical plan, where large quantities of work are to be produced; but all operations involving the use of expensive formed cutters should be performed in a way that will save the cutter as far as possible.

After the minimum number of machines necessary to produce the required number of parts has been determined, the speed and feed should be so selected that they will not only give the necessary output of milled parts, but will also afford an economical balance between the items of expense resulting from the equipment and cutter cost factors. For example, if one machine is able to perform 400 milling operations a day, and it is required to perform this operation on 600 pieces a day, it will be evident that two machines are necessary. Both of these millers will be tied up on this job, and nothing would be saved by running them at top speed for three fourths of the day and then having them idle for the remaining 25 per cent of the time. It will be possible, however, to effect a material saving in the cutter cost by slowing down both of the machines to produce 300 pieces a day, and have them in operation for the full ten-hour working period.

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