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NUMBER 102

AUTOMATIC SCREW MACHINE PRACTICE

PART IV

EXTERNAL CUTTING TOOLS FOR BROWN & SHARPE AUTOMATIC SCREW MACHINES

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CONTENTS

Automatic Screw Machine Practice for the Brown & Sharpe automatic screw machines is covered in eight Reference Books, Nos. 99 to 106, inclusive. Reference Book No. 99, "Operation of the Brown & Sharpe Automatic Screw Machines," deals with the construction of these machines and the setting-up of the tools. No. 100, "Designing and Cutting Cams for Automatic Screw Machines," gives detailed instruction on cam design, and describes a simplified method for milling cams. No. 101, "Circular Form and Cut-off Tools for the Automatic Screw Machine," deals with the general arrangement and the calculations of these tools, and describes the different methods employed in their making. No. 102, "External Cutting Tools for the Automatic Screw Machine," deals with the design and construction of box-tools, taper turning tools, hollow mills, and shaving tools. No. 103, "Internal Cutting Tools for the Automatic Screw Machine," deals with centering tools, cross-slide drilling attachments, counterbores, reamers, and recessing tools. No. 104, "Threading Operations on the Automatic Screw Machine," treats on cam design for threading operations, threading dies, taps and tap drills, die and tap holders, and thread rolling. No. 105, "Knurling Operations on the Automatic Screw Machine," describes the construction of knurling holders, and gives directions for the making of knurls and the design of tools and cams used in connection with knurling operations. No. 106, "Milling, Cross-drilling and Burring Operations on the Automatic Screw Machine," describes screw-slotting attachments, index drilling attachments, and burring attachments, giving directions for their use and for the design of cams for them.

CHAPTER I

BOX-TOOLS FOR AUTOMATIC SCREW MACHINES

The subject of external cutting tools is of wide scope, embracing all the tools which are used in removing material from the exterior of the work. The most common tools used for external work are circular forming tools, box-tools, hollow-mills, swing tools, taper-turning tools, angular cutting-off tools, and shaving tools. All the tools mentioned, with the exception of circular form and cut-off tools, which are dealt with in MACHINERY'S Reference Book No. 101, "Automatic Screw Machine Practice—Part III," will be described in the following pages. External cutting tools are made of different designs to suit the conditions of the work on which they are to be used; therefore a detailed description of the construction and use of each tool will be given. As box-tools are used extensively on the automatic screw machine, and as they are the most common of all the tools used for external work, they will be considered first.

Preparing Work for Turning

Before reducing the diameter of the work by means of a box-tool or other external cutting tool of a similar type, it is necessary to chamfer the front end of the work to permit the starting of the box-tool cutter on a light cut, until the supports are in position to steady the work. Pointing or chamfering the end of the work also facilitates the setting of a hollow-mill concentric with the work.

One method of pointing the end of the work is shown at *A* in Fig. 1. Here the circular cut-off tool has an angular projection on its face next to the chuck, which points the bar before it is fed out for the next piece. This method is generally used when the work is not very long, and when it runs practically true. When it is necessary to cut a thread on a piece, the beveled end of the bar is made small enough to facilitate the starting of the die.

It is sometimes found impossible to point the bar with the cut-off tool, owing to various conditions, and in this case the bar is usually pointed by a combination centering and pointing tool as shown at *B*. This tool can be used when the bar does not project more than three and one-half times its diameter from the face of the chuck, and also when the bar is unfinished or of irregular shape. The tool *a* is used for centering the work, thus preparing it for drilling a hole, and the tool *b* is used for pointing the end of the bar.

Another condition is that shown at *C*. Here the form tool precedes the box-tool, necking the bar at *a*. Now if the face *b* of the circular tool were left square and not chamfered, as shown, a ring or washer would be formed by the box-tool cutter, as there would be no resistance to the pressure of the cut, and hence the thin ring would break off before all the material had been removed. This condition was clearly illustrated and described in Part III of this treatise, Reference Book No. 101.

When it is necessary to turn down a portion of a long cylindrical piece of cold-drawn steel or other material which has a finished surface, and have the part turned concentric with that which has not been reduced, it is usually good practice to weaken the bar with the circular cut-off tool as shown at *D*. For this class of work a supporting bushing held in the box-tool should precede the turning tool, so that the part turned will be concentric with the finished body of the work. Before turning, the bar is pointed with the circular cut-off tool as shown at *A*.

The diameter *a* of the neck should be small enough to allow the bar to be straightened with the box-tool support, so that it will run true.

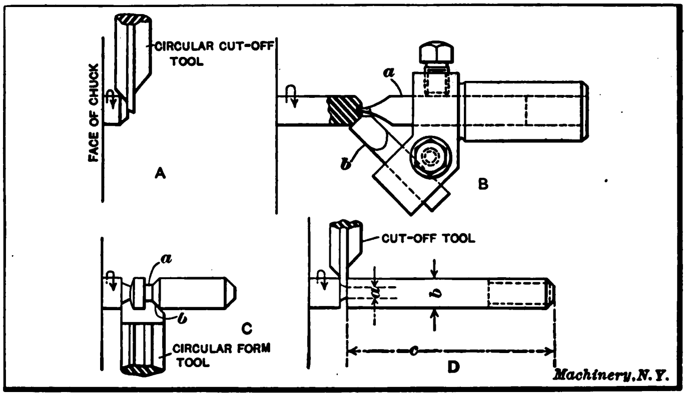


Fig. 1. Methods of Preparing Work for Turning

In the majority of cases the neck *a* may be made from 0.3 to 0.5 times *b*, but, of course, the length *c* of the work, the depth of the chip removed, and the feed used, will govern largely the diameter of the neck. The material being turned will also affect this diameter slightly, but in most cases this latter condition can be disregarded. Rods which have short bends in them should not be used, as it will be found impossible to produce a good surface on the part which is turned. The spring collet should also run perfectly true if good results are to be expected.

Application of Box-tool Cutters to the Work

Box-tool cutters are applied either radially or tangentially to the work. The radial cutter is more commonly used for brass work, while the tangential cutter is used for all classes of steel work, although it is also sometimes used for brass work.

At *A* in Fig. 2 is shown what is termed a "radial cutter." The cutting edge is set slightly above the horizontal center line of the work. The amount that it is set above the center is usually about 0.02 times the diameter to which the work is being turned. This is the preferable

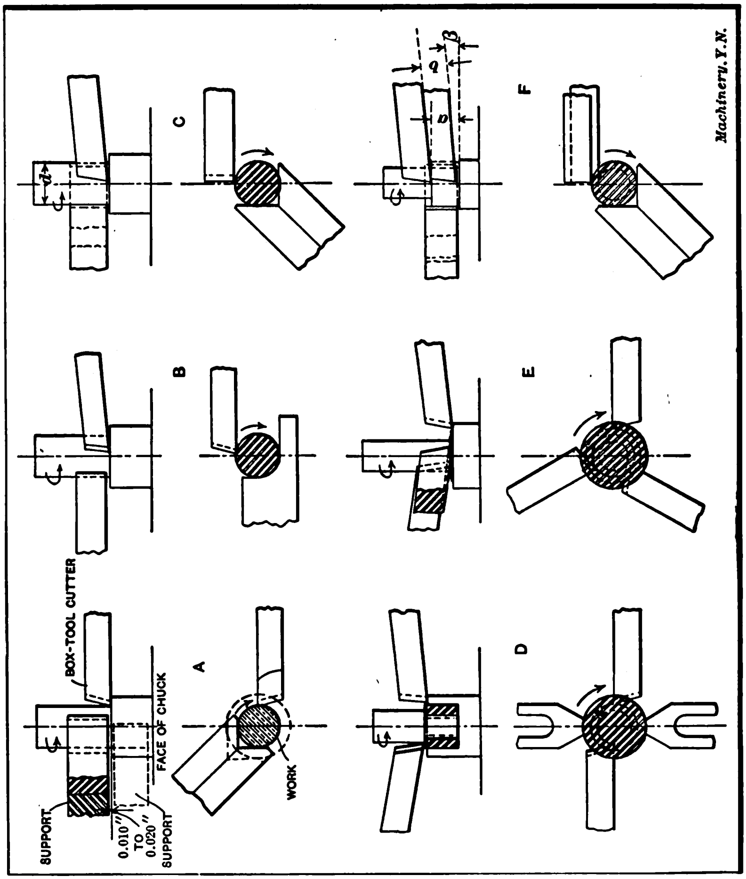


Fig. 2. Various Methods of Applying Box-tool Cutters to the Work

method of applying a turning tool for taking roughing cuts on brass rod. When the stock is rough, or of an irregular shape, the cutter should precede the support by an amount equal to from 0.010 to 0.020 inch, but when the bar is cylindrical and has a finished surface, the support for roughing cuts should precede the turning tool, as is shown by the dotted lines.

At *B* is shown what is called a tangential cutter. Here the cutter is set to take a roughing cut from a bar which is not finished, or of irregular shape. Where the bar has a finished surface and is circular in shape, the support is set in advance of the turning tool as already mentioned.

A tangential cutter set for taking a finishing cut on steel work is shown at *C*. Here the turning tool is set slightly back of the center, an amount equal to about 0.10 of the diameter *d* to which the work is being turned. For cutting brass, the tangential cutter is set in line with the center, and, in some cases, a slight amount in advance of the center.

A method of applying two turning tools for roughing down steel work is shown at *D*, and at *E* is shown a method of applying three turning tools for the same purpose. For taking roughing cuts on brass, where a great amount of material is to be removed, a hollow-mill is generally used, but the method shown at *D* can sometimes be used to advantage. In the case shown at *E* no supports are used, as the tools support the stock. These tools can either be set radially as shown, and a slight amount in advance of each other, or tangentially and at varying heights, so as to distribute the cuts equally among the tools. For taking roughing cuts on steel, it is preferable to set the cutters tangentially to the work.

At *F* is shown a method of applying two tangential turning tools for turning down two diameters on a piece of work. This method is used when the distance *a* is not much greater than from ½ to ⅝ inch. If the distance *a* is much greater than this it is generally advisable to use two separate box-tools, provided there is sufficient room in the turret. When turning tools are used in this manner it is necessary to have the thickness of the first tool, or the distance *b*, such that the second tool, when set tightly against the first one will turn the shoulder to the desired length.

To illustrate clearly how the distance *b* is obtained, we will take a practical example. Let $a = 0.375$ inch, $\beta = 10$ degrees; then $b = a \times \cos\beta = 0.375 \times 0.9848 = 0.3693$ inch. When two turning tools are used in this manner they should be ground on all surfaces and should also be made a good fit in the square or oblong hole cut in the body of the holder to receive them.

Holding and Adjusting Box-tool Cutters

It is conducive to good results to have a box-tool cutter held rigidly in the holder. It should not project any further from the holder than is absolutely necessary in order that the latter may clear the largest diameter of the bar being turned. Means for adjusting the tool to cut different diameters should also be provided. At *A* in Fig. 3 is shown a method which is commonly used for holding a box-tool cutter for brass work. In this case a square hole is cut in the body of the holder to receive the cutter, the latter being held by a set-screw *a*. The cutter is adjusted for different diameters by the collar-head set-screw *b* which bears against the rear end of the tool. It is obvious that this screw can only be used for adjusting the tool in, but by cutting a slot in the turning tool to fit the collar on the screw, this same screw may be used for adjusting the tool both in and out, thus making it more convenient.

The method shown at *B* for holding the turning tool is used particularly for brass work. In this case the turning tool is held in the block *c* by two set-screws *d*, the block being adjustable along the body of the holder. The block *c* has a projecting shank which passes through the body of the holder and is fastened to it by means of the nut and washer shown. It is evident that this method of holding the tool is very convenient for certain classes of work, especially when different

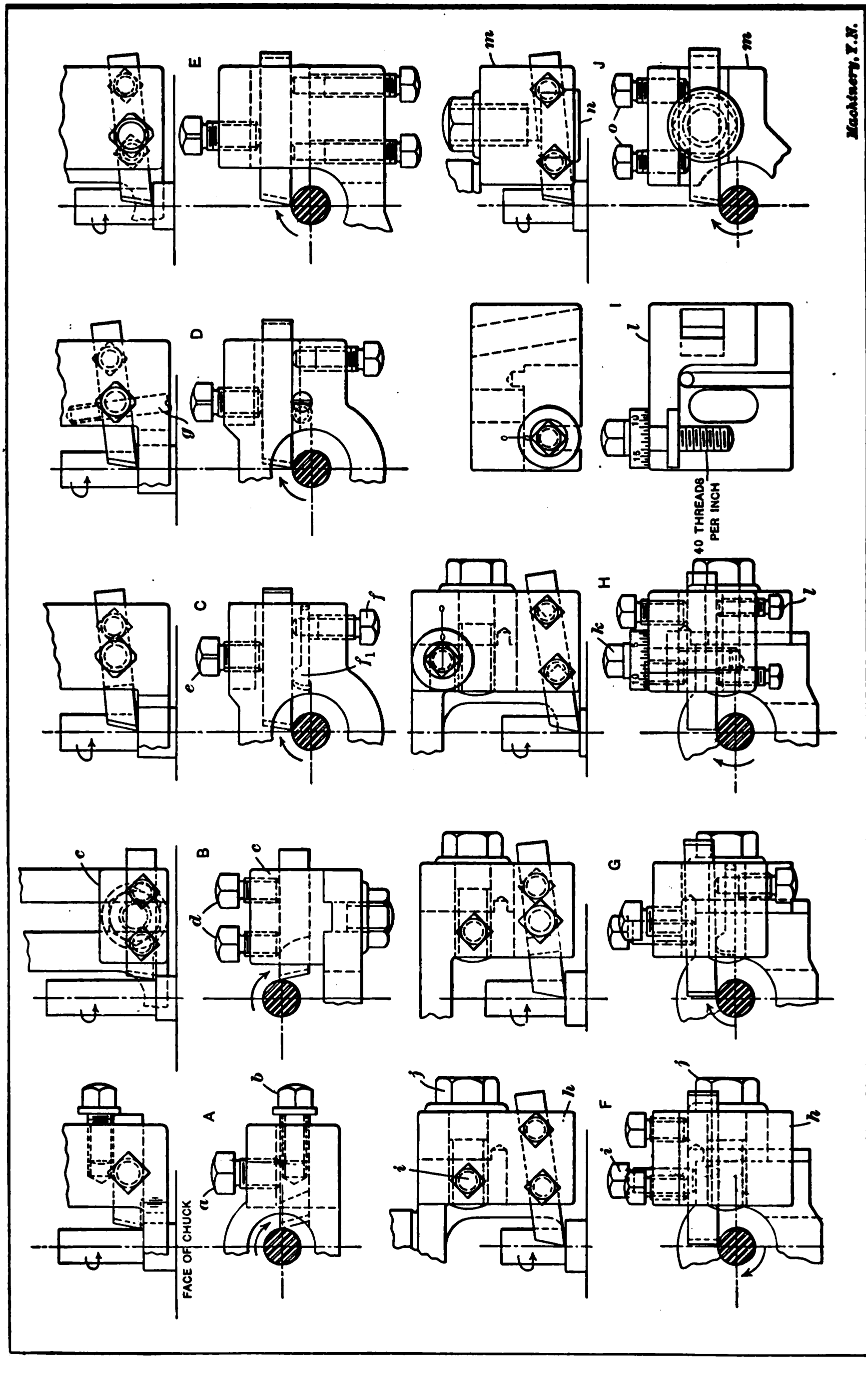


Fig. 8. Holding and Adjusting Box-tool Cutters for Various Conditions

diameters are required, as it is possible to have one or more blocks for holding the turning tools.

A method of adjusting and holding a tangential cutter is shown at *C*. Here the cutter is set off at an angle from the face of the box-tool, and is held in the body of the holder by two set-screws *e* and *f*. The tool rests on a small block f_1, thus allowing it to be adjusted for turning different diameters, the two set-screws being used in connection with this block for adjusting. This method of adjusting and holding the turning tool is limited in its range, very little adjustment being obtained by it.

A method of holding the turning tool somewhat similar to that just described is shown at *D*. Here the tool rests on the body of a screw *g* instead of on a block. These two methods of adjusting the tool can only be used for certain classes of work. A method which allows of more adjustment is shown at *E*. Here the tool is adjusted and held by three set-screws, thus allowing it to be adjusted for various diameters, with the face of the tool held in a plane parallel to the horizontal center line.

The methods shown at *C*, *D* and *E* are very seldom used for finishing box-tools; they are used principally for roughing box-tools. At *F* is shown the method of adjusting the turning tool holder which is usually applied to finishing box-tools. Here the tool is held in a block *h* which is adjusted up and down on the body of the holder by means of set-screw *i*; the block is held, when in the desired position, by cap-screw *j*. This block has a groove in it which fits on a tongue formed on the box-tool body, thus holding the tool-holder rigidly.

At *G* is shown a method similar to that just described, but the turning tool is in this case held in the holder in a manner similar to that shown at *C*. By this means the cutter may be set at a slight angle from the horizontal center line, thus giving it more clearance, as is sometimes necessary, especially when cutting steel. A slight adjustment of the tool, independently of the tool-holder is also possible.

It will be seen from a study of the various methods shown that the setting of the tool cannot be accurately known, so that a number of trial cuts have to be taken before the desired diameter is obtained. To obviate this tedious operation of setting the tool, a micrometer screw is used for setting the box-tool cutter to the correct diameter, as shown at *H* and *I*. This micrometer screw *k* has two shoulders on it and is screwed into the body of the holder, the body of the screw being made a good fit in the block shown in detail at *I*. The hole in block *l* through which screw *k* passes is slotted out to the edge as shown, to facilitate assembling the screw in the block. A 40-pitch thread is cut on this screw, so that for one revolution of the screw the turning tool is moved up or down, as the case may be, a distance equal to 0.025 inch. By making this screw a good fit in the body of the holder and the block, it is possible to get the desired diameter without much trouble. The block is held to the body of the holder in the same manner as that shown at *F* and *G*.

A good method of holding two or more turning tools for roughing is shown at *J*, the holder, of course, being made with the desired number of projecting lugs or tool-holders *m*. The tool in this case is held in a stud *n*, which has a square hole cut in it to receive the tool. This hole is cut at an angle with the face, so that the tool is set at the desired angle. Two set-screws *o* are used to prevent the tool from turning under the pressure of the cut, and also to permit of a slight adjustment of the tool. As can be seen, this tool is limited in its scope, the changes for diameter being accomplished by means of the set-screws *o*, and also by moving the turning tool in or out a slight amount. This method of holding a turning tool is used mostly for roughing work and is applied in a manner similar to that shown at *E*, Fig. 2.

Application of Box-tool Supports to the Work

The type of support to use and the method of applying it are governed largely by the following conditions:

1. Shape of the stock, whether round or otherwise;
2. Character of the cut, whether taper or otherwise;
3. Nature of the material, whether soft or hard;
4. Number of different diameters to be turned;
5. Length of the work being turned;
6. Clearance allowable between the face of the circular form tool and box-tool.

These various points should be taken into consideration before designing a box-tool.

At *A* in Fig. 4 is shown a box-tool support, which is commonly used in roughing box-tools. This support envelopes the work and precedes the turning tool. It is used mainly for turning down cylindrical work in which the finished diameter is to be concentric with the part which is not finished, that is, which has not had a cut taken from it. Where the work being turned projects more than five times its diameter from the chuck, and is of large diameter, it is not advisable to use a bushing support, unless the stock is reduced by the circular cut-off tool, as previously described.

At *B* is shown a support which is recommended by some authorities for finishing box-tools. As a rule this support should be used sparingly, and in fact, the writer would suggest that it be entirely dispensed with, particularly where the work has not been previously turned. There are several objections to this support, especially when it is made solid with the holder, among which the following might be given: As this support does not envelope the work, a bar which is larger in diameter than the hole in the support can be turned; therefore, the support throws the bar to one side, so that it is not in line with the chuck, thus producing work which is not straight, but slightly tapered. At times this is objectionable, and can be avoided if an adjustable support is used. It is also sometimes suggested to drill this support in the machine in which it is to be used, and after hardening, to lap it in the machine also. This seems a roundabout way to make a support for a box-tool, when it is a very simple matter to have the box-tool support adjustable.

The support shown at *C* has none of the objectionable features mentioned regarding that shown at *B*. This support is commonly called a V-support, and has a two-point bearing on the work. As shown in the illustration, the thrust from the tool is against both supports. As a rule, this support should not precede the cutting tool, for the reason that if the work is not cylindrical in shape, the irregularities of the bar will be reproduced on the work that is turned. Hence, when using a V-support it is always best to have the cutting tool precede the support an amount varying from 0.010 to 0.015 inch. This V-support can be used for brass, steel and similar materials, and gives satisfactory results when it does not precede the turning tool.

In turning cast iron, aluminum or materials of a similar character, difficulty is sometimes encountered in producing a finished surface on

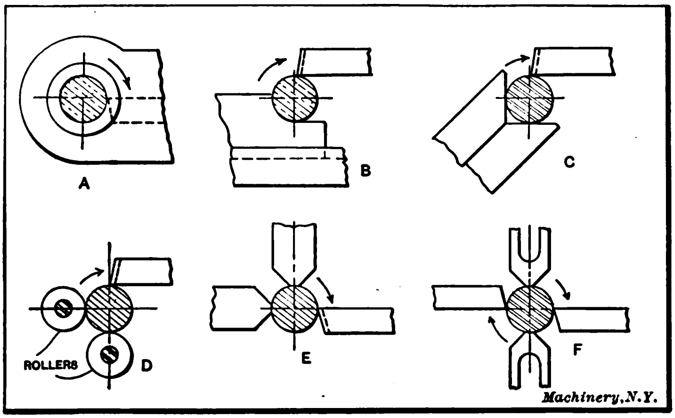


Fig. 4. Method of Applying Box-tool Supports to the Work

the work. This is usually due to fine chips or dust getting in between the supports and the work, thus causing an abrasive action which roughens the work. It is, therefore, advisable when turning aluminum, cast iron or materials of a similar character, to use roller supports. One method of applying the roller supports is shown at *D*. These rollers should be hardened and ground, and it is usually preferable to lap them also, so that they are very smooth. This support is also used when turning machine steel, and is made to bear rather hard against the work, which gives it a burnished appearance.

Another support which is sometimes used for cast iron is shown at *E*. This gives a two-point bearing, and allows the tool to be set radially to the work. This support, however, is not as good as the roller support.

At *F* is shown a method of supporting the work when applying two turning tools to it. This method is used principally for roughing down steel work. The supports, as shown, are set at right angles to the tools. This manner of turning steel work is used largely when it is necessary to rough down the work from a large to a small diameter in the least possible time.

As a rule, supports for box-tools should be made from high-carbon steel, left glass hard, and given a very smooth finish, which is one of the chief requirements of a box-tool support.

Holding and Adjusting Box-tool Supports

There are various methods used for holding and adjusting box tool supports, some of which are shown in Fig. 5. At *A* is shown a common method of holding a bushing support. The bushing is driven into the body of the holder and is held with a cone-pointed screw *a*, which is located in a spot drilled in the bushing. The bushing as shown is straight, but it is sometimes advisable to make the bushing with a shoulder on it, so that if a large piece of stock is encountered, it will not force the bushing back against the cutting tool. Of course, this is an extreme case, and where the stock varies to such an extent, the bushing support should not be used. At *B* is shown a method of holding a support similar to that shown at *B* in Fig. 4. The adjustment in this case, however, is only longitudinally along the body of the holder, there being no provision for variations in diameter. At *C* is shown one method of holding a V-support. A rectangular hole is cut in the body of the holder in which the supports fit. When in position, the supports are held by the set-screw *b*. This method of holding a V-support is commonly used for both roughing and finishing box-tools, when one cutting tool is applied to the work, and sometimes when two cutting tools are used so close together that it is only necessary to support the work at one place.

At *D* is shown a method of holding a V-support when it is necessary to apply more than one support to the work, as in the case when turning down to more than one diameter at a time. This support is held in a movable block *c*, which is adjusted along the body of the holder. This block *c* is held to the holder by the cap-screw *d*. A slot is cut in the body of the holder, in which this cap-screw is adjusted, and a groove is also cut in the holder to fit a projection formed on the base of the block *c*. The supports are held in the block by means of a set-screw, as at *C*.

These last two methods are principally for box-tools used for turning brass or a similar class of materials, in which the cutter is set radially to the work. At *E* is shown a common method of applying the V-support to a box-tool used for cutting steel and work of a similar character. This method of applying the support is used when the cutting tool is set tangentially with the work. The support is held in a rectangular hole cut in the body of the box-tool, by a set-screw, as shown.

The methods shown at *C*, *D* and *E* are limited in their scope, to a certain extent, owing to the fact that they cannot be used in conjunction with a circular form tool when it is necessary to have the tool work closer to the forming tool than the thickness of the web *e*. For this class of work the method of holding the support shown at *F* is commonly used. This support is beveled as shown, and set in a correspondingly beveled slot cut in the front end of the box-tool body. As

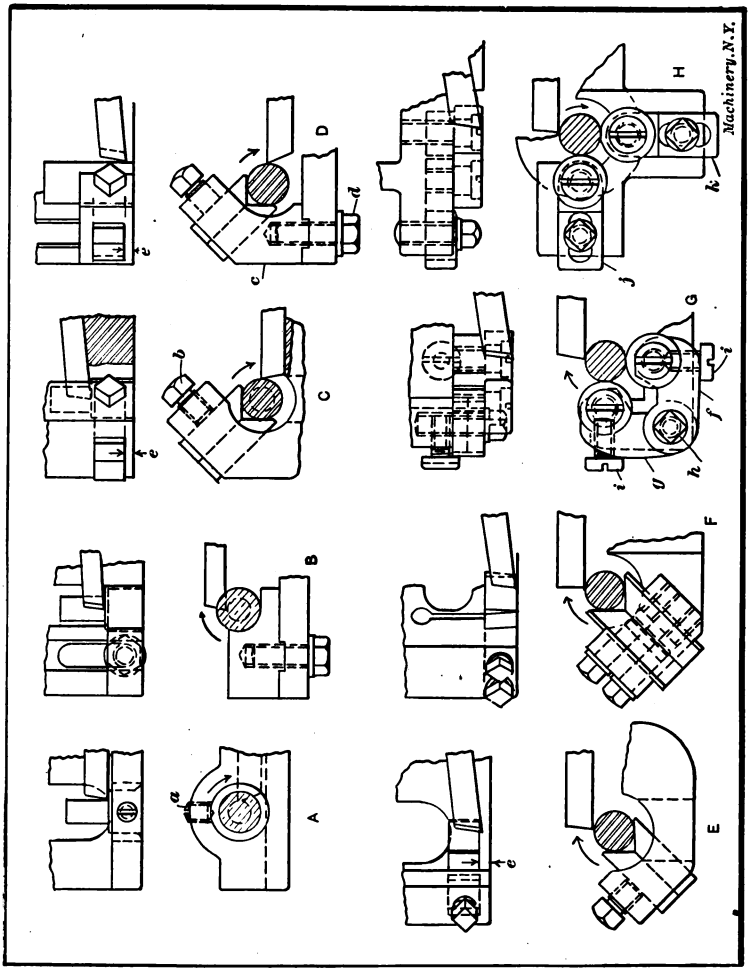


Fig. 5. Methods of Holding and Adjusting Box-tool Supports

it would be impossible to bind these supports by having a screw pressing on top of them, it is necessary to split the body of the holder, and have screws pass through the two parts, binding them together. A clearance hole for the body of the screw is drilled in the upper part, while the lower part is tapped out to fit the screw. As this method depends on the elasticity of the material, it is usually best to drill a hole of from ¼ to ⅜ inch in diameter at the rear end of the slot, to facilitate the drawing of the two parts of the body together, which is necessary to bind the supports in a rigid manner. There is one objection to this method of holding the support, *viz.*, the difficulty of applying the turning tool (in some cases), due to the fact that it comes very close to the face of the box-tool.

As was previously mentioned, difficulty is sometimes encountered in turning cast iron, aluminum and materials of a similar character, owing to fine chips or dust getting in between the box-tool supports and the work. It was also mentioned that roller supports were advisable for this class of work. At *G* is shown a method of applying roller supports. These roller supports are held in two movable members, *f* and *g*, which, in turn, are fastened to the body of the holder by the clamping screw *h*. These members, *f* and *g*, are cut out so that they fit into each other and form a sort of "mortised" joint. As the clamping screw *h* would not be sufficient to hold these roller-support holders against the pressure of the cut, they are held in the correct position by large-headed screws *i*, which are screwed into the body of the holder.

At *H* is shown another method of applying roller supports. In this case the supports are held on two sliding holders, *j* and *k*, which slide in grooves cut in the box-tool body. They are adjusted in and out to the required diameter, and held by the clamping screws, as shown. This method of holding the supports is more rigid than that described in connection with *G*, and should in most cases be used in preference. There are numerous other methods of holding roller supports, but they are all of a somewhat similar character to those already shown. Naturally, there are various conditions which govern the method of applying these supports.

The methods of holding supports illustrated in Fig. 5 are those generally used in standard box-tools, and do not include those used for special conditions. Special applications of box-tool supports will be dealt with in a following chapter.

Cutting-angles for Box-tool Cutters

It is not sufficient to hold a box-tool cutter rigidly, and support the work well, to obtain good results, but it is also necessary to have sufficient clearance, and the correct cutting angle on the tool. That is, the tool must have sufficient clearance and rake, so as to remove the material with the least possible resistance and power. The manner in which the tool is applied to the work, and the material on which it operates, govern the cutting angle on the tool. Generally, in automatic screw machine work, for cutting brass, the box-tool cutter is set radially to the center, as shown at *A* in Fig. 6. For taking a roughing cut on brass with the turning tool set radially to the work, the tool should be ground to the shape here shown.

When taking a finishing cut on brass work, the tool is ground to the shape shown at *B*. Here a portion of the cutting surface, equal to the distance *b*, is made straight, so as to produce a smooth finish on the work. For usual conditions *b* equals 1/5 of the smallest diameter of the work being turned. It will be noticed in both these cases that the tool is not set at an angle with the face of the work, but is set parallel with it. While this method of setting the tool can be used for brass work, it is not advisable for steel work. A turning tool set tangentially with the work is shown at *C*. The angles on the tool for cutting the materials specified in the following are as follows:

Cutting-angles for Machine Steel	Cutting-angles for Tool Steel
$a = 10$ degrees,	$a = 8$ degrees,
$b = 10$ degrees,	$b = 8$ degrees,
$c = 8$ to 10 degrees,	$c = 8$ to 10 degrees,
$d = 70$ to 72 degrees.	$d = 72$ to 74 degrees.

The method of grinding the tool shown at *C* is commonly used for roughing cuts, and will not produce an absolutely square shoulder on the work. For finishing cuts the tool is ground as shown at *D*, which produces a square shoulder on the work. The cutting angles for the materials specified below are as follows:

Cutting-angles for Machine Steel	Cutting-angles for Tool Steel
$e =$ from 10 to 12 degrees,	$e =$ from 8 to 10 degrees,
$f =$ from 15 to 18 degrees,	$f =$ from 8 to 10 degrees,
$g =$ from 60 to 65 degrees.	$g =$ from 70 to 74 degrees.

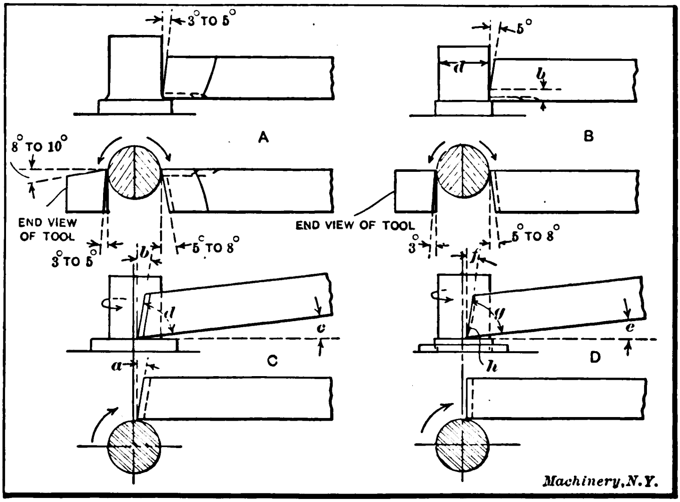


Fig. 6. Cutting-angles for Box-tool Cutters

While the cutting face on the tool shown at *D* is straight, it is usually advisable, especially when cutting machine steel and Norway iron, to give more "lip" to the tool, as is clearly shown by the dotted line *h*. This produces a curling chip and is conducive to better and more efficient cutting. It is also advisable in most cases to make the turning tools for box-tools from high-speed steel, especially for cutting machine steel, Norway iron, etc., because better results are obtained by using a high peripheral velocity and a fine feed.

Adjusting the Tangent Cutter for Turning Different Diameters

The use of the so-called "tangent" cutter has been found to be the most satisfactory method of applying a box-tool cutter for cutting machine steel, Norway iron, etc., although this method of applying the cutter is also sometimes used for cutting brass. In Fig. 7 is shown the manner of setting a tangent cutter. The face of the cutter should be set at a distance *d* back of the center. This gives the tool more clearance, and is conducive to a cleaner and better cutting action. The distance *d* should be equal to about $1/8D$ for tool steel, and $1/10D$ for Norway iron and machine steel, where *D* equals the diameter to which the work is being turned. When the tangent cutter is adjusted for a larger diameter, it should also be set back enough so that d_1 bears the same relation to the larger diameter as *d* does to the smaller. (See the dotted lines.) It is also sometimes advisable, especially when cutting machine steel, to set up the tool from the horizontal at an angle of from 1 to 2 degrees, which increases the clearance of the tool. This is accomplished by means of adjusting screws, as is clearly illustrated in Fig. 3.

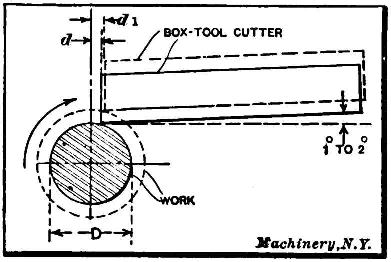


Fig. 7. Adjusting a Tangent Cutter for Turning Different Diameters

Sections of Steel used for Box-tool Cutters

Box-tool cutters should not be made of too weak a cross-section, especially for roughing, although a rigid tool is also required for finishing. The conditions under which a box-tool cutter is used govern to a large extent the cross-section of the tool. For special conditions, the tool is sometimes made of rectangular section, but for standard box-tools, it is made from square stock. The square sections recommended for box-tool cutters are as follows:

Largest Diameter of Work in Inches	Square Section of Tool in Inches	Largest Diameter of Work in Inches	Square Section of Tool in Inches
$\frac{1}{4}$	$\frac{3}{16}$	$\frac{3}{4}$	$\frac{5}{8}$
$\frac{3}{8}$	$\frac{1}{4}$	1	$\frac{7}{16}$
$\frac{1}{2}$	$\frac{5}{16}$	..	..

Where box-tools are to be used exclusively for taking light finishing cuts, the sections given above can be slightly decreased.

CHAPTER II

DESIGNING BOX-TOOLS

The designer of screw-machine tools is frequently confronted with difficulties when designing special box-tools, owing to the fact that the Brown & Sharpe automatic screw machines are very compact. This makes it necessary to design all the tools so that they will not interfere with any part of the machine or the tools which are used on the cross-slides. The following considerations must also be borne in mind:

1. Character of material, whether rough or cold-drawn.
2. Cross-section of the material, whether cylindrical, square, or hexagonal, etc.

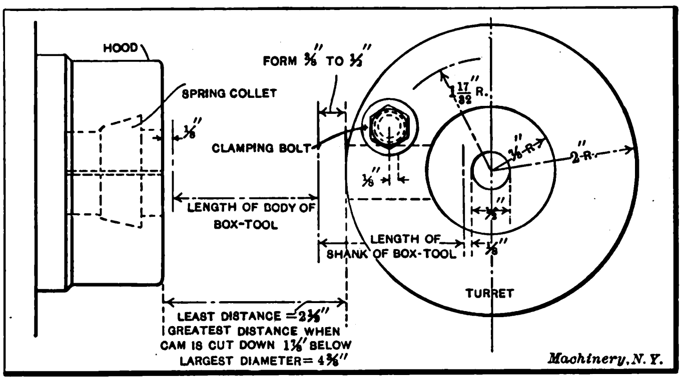


Fig. 8. Method of Determining Length of Body and Shank of Box-tool

3. Character of the longitudinal cut, whether straight, tapered or irregular.
4. Length of the work to be turned.
5. Number of different diameters to be turned.
6. Position of the box-tool in relation to the cross-slide tools, when in action on the work.
7. Amount of material to be removed from the diameter.

In addition to the factors mentioned, one of the first things to consider when designing a box-tool is the length of the body and shank of the tool. As a rule, the length of the body is governed by the length of the work to be turned, especially when the hole in the shank cannot be made large enough to let the smallest diameter of the work pass through. Another consideration to take into account is the distance from the center of the hole in the turret to the side of the chute. This limits the width of the box-tool, and is a governing factor in its design. Still another point which might be mentioned is the distance between the point where the box-tool cutter finishes on the work, and the face of the chuck. When this is less than 1/8 inch it is usually necessary to have the cutter project slightly in advance of the face of the box-tool body.

If a special box-tool is to be designed, it is advisable to make a lay-out of the machine on which this tool is to be used. A plan and side elevation of the turret and cross-slides should be drawn, and the tools used on the cross-slide should also be drawn in the positions they will occupy when the box-tool is in operation on the work.

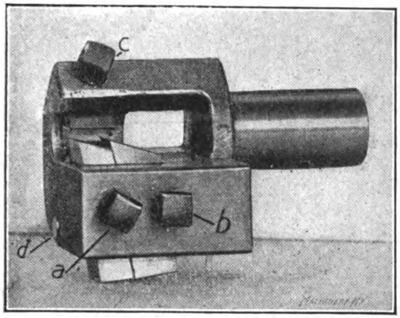


Fig. 9. Standard Box-tool made by the Brown & Sharpe Mfg. Co.

A method of laying out a box-tool for determining the length of the body and shank is shown in Fig. 8. This diagram is for a No. 0 machine, but the same principle can be used for the other sizes. When designing a standard box-tool, the body is made about 5/8 inch less than the least distance between the face of the turret and the face of the chuck. The shank is allowed to project through the turret to within 1/8 inch of the 1/2-inch hole through the turret spindle. All the other important points regarding the design and uses of supports, turning-tool holders, etc., have been dealt with in the previous chapter, so it will not be necessary to enlarge on them here.

Various Types of Box-tools

As there are so many designs of box-tools in use, it will be impossible to mention all of them, but a few of the most common designs will be described. In Fig. 9 is shown a standard box-tool, as made by the Brown & Sharpe Mfg. Co. This box-tool, as shown, carries two cutting tools. The tools rest on a pin *d* and are held by set-screws *a* and *b*, and by two other set-screws, not shown, which are on the under side of the box-tool. The support, which is of the V-type, is located at the back of the box-tool at an angle of 45 degrees with the vertical center line, and is held by the set-screw *c*. This box-tool is used for general work, for turning both one and two diameters, as required. When one diameter is being turned, the cutter in the rear is pushed back, out of action.

In Fig. 10 is shown a standard finishing box-tool which is used largely for steel work. In this box-tool the turning tool is held in an adjustable block *A* which is adjusted up and down on the body of the holder by the set-screw *B*, and held to the body by the cap-screw *C*. A projection is formed on the body of the box-tool and a corresponding groove is cut in the block to guide. The turning tool is held by means of two set-screws *D* and the headless screws *E*. These latter are for adjusting the turning tool, in order to increase the clearance between the tool and the periphery of the work.

The V-support is held in beveled grooves, cut in the body of the holder, by two screws *F* which pass through the two parts of the body separated by a saw cut, thus binding them together. The cutting edge of the turning tool is located from 0.010 to 0.012 inch in advance of the face of the supports. A hole is drilled through the shank of the

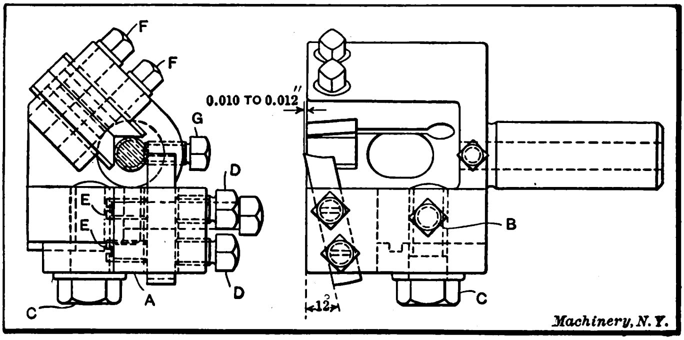


Fig. 10. Finishing Box-tool largely used for Steel Work

box-tool for holding a pointing tool or other internal cutting tool, which is held with the set-screw *G*.

The value of roller supports for turning aluminum, cast iron, etc., has been referred to, and in Fig. 12 is shown a box-tool of the roller-support type, as made by the Brown & Sharpe Mfg. Co. This box-tool, as may be seen, is provided with roller support for the front cutter, and V-support for the rear cutter.

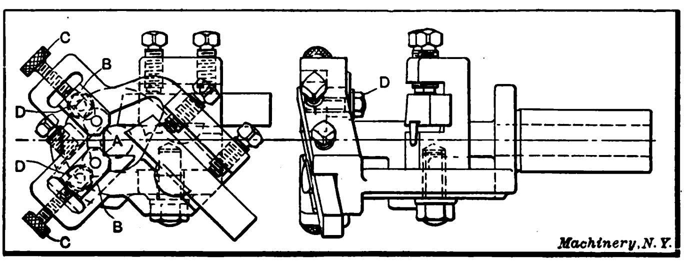


Fig. 11. Details of Box-tool shown in Fig. 12

The general design of this box-tool can be seen in Fig. 11. This illustration shows the method of holding and adjusting the roller supports. The supports *A* are held by pins in a slot cut in the two blocks *B*, which are adjusted in and out by the knurled-head screws *C*. The blocks *B* are held to the body of the box-tool by cap-screws *D* which are tapped into them. A slot is cut in the body of the holder in which the bodies of the cap-screws slide, thus providing adjustment for turning different diameters. All the other details of this box-tool can be clearly seen from the illustration.

Some interesting designs of box-tools are shown in Fig. 13. These tools are all made by the Brown & Sharpe Mfg. Co., and are used for various classes of work. At *A* is shown a box-tool which is equipped with three turning tools, and three sets of V-supports. The turning-tool and V-support holders *a*, *b* and *c* are made in one piece and are held to the body of the box-tool by cap-screws. A tongue is formed on the base of the holders, which fits in a longitudinal groove cut in the box-tool body. It will be noticed that the supports in this case are double supports, that is, they are notched on both ends, the purpose of this being to increase their range. The end of the support shown facing the turning tool is for work of small diameter, while the end projecting from the box-tool is for work of a larger diameter. This box-tool can

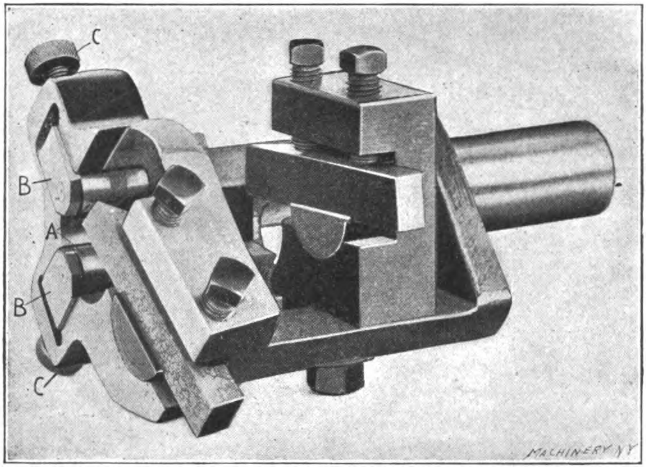


Fig. 12. Box-tool of the Roller Support Type

be used either for roughing or for finishing work, and is especially adaptable to work having three different diameters.

At *B* is shown a box-tool with two cutting tools, but with only one support. It will be noticed in this case that the holders for the turning tools are very narrow, thus permitting the tools to be set close together. The box-tool shown at *C* has two turning tools which are set close together. A hole is drilled through the shank, and a set-screw is provided for holding a centering or other internal cutting tool. At *D* is another box-tool similar to that shown at *C*, except that the supports in this case are double-ended. *E* is a finishing box-tool having two turning tools. *F* is a box-tool of similar design, but carrying only one turning tool. *G* is a pointing and centering tool, the bushing for which is shown at *H*. *I* is a pointing tool of a somewhat similar design to that shown at *G*. *J* and *K* are also pointing tools which are used largely for small work. These illustrations show clearly the design of box-tools which are used, in general, for automatic screw machine work.

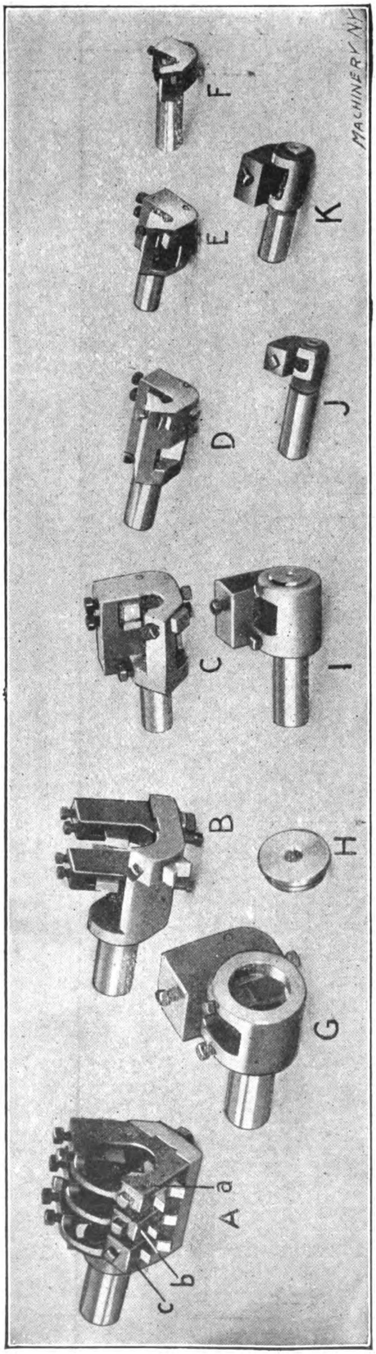
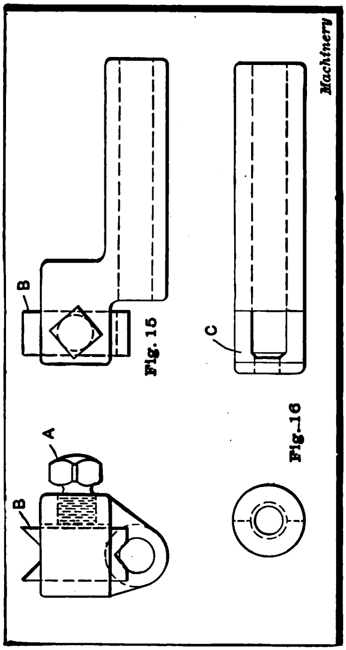


Fig. 13. A Collection of Interesting Designs of Box-tools



Figs. 15 and 16. Supports used in Connection with Swing Tools

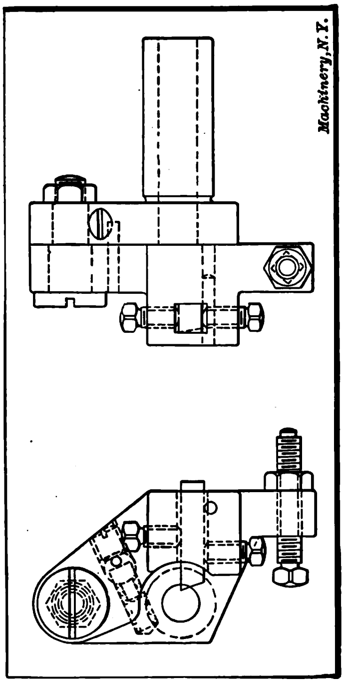


Fig. 14. Swing-tool used for External Cutting

Swing Tools for External Work

Swing tools, besides being used extensively for internal cutting, are also used for external work. There are some cases where a box-tool or a circular form tool cannot be used, owing to the irregular contour of the work, or its length in proportion to its diameter. A form tool can be used where the length of the work being turned is not more than from 2½ to 3 times its diameter, but when it exceeds this, it is necessary to use some other type. For this class of work, a swing tool such as that shown in Fig. 14 can be used to advantage. The work can be roughed down with this tool and finished with a shaving tool, which will bring it to the correct shape, and also to the desired diameter. (The use of shaving tools will be taken up in a subsequent chapter.) This tool, of course, can only be used when the diameter of the work is large enough to make a support unnecessary.

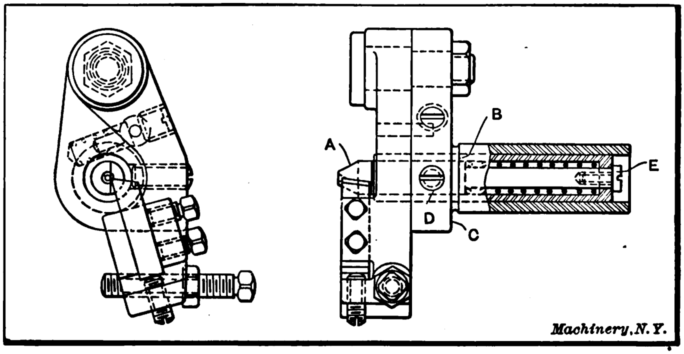


Fig. 17. Swing-tool used when the Work Turned must be Supported

The swing tool shown in Fig. 14 can be used on work of small diameter by the insertion of the support shown in Fig. 15. This support is inserted in the hole in the shank of the holder and is held by a set-screw screwed into the shank. The support *B* is of the V-type and is held by a set-screw *A*. They are set in advance of the turning tool, so that the work will be well supported while being turned. In cases where there is not sufficient room to use a support as shown in Fig. 15, a support as shown in Fig. 16 can be used. This support precedes the cutting tool, and half of the support is cut away at *C*, about ⅛ inch from the end, so that the turning tool can reach the work.

Another tool which gives very satisfactory results for this class of work is shown in Fig. 17. This tool is provided with a telescopic support which recedes into the holder as the tool advances on the work. The other features of this tool are similar in design to the standard swing tools. Mention might be made, however, of the method of holding the telescopic support *A*. A sleeve *B* is driven into the body and shank of the holder *C*, and is held by the headless screw *D*. The support proper is turned down on the shank, so that an open-wound coil spring can be inserted behind it. The support is kept from being forced out of the holder by a screw *E* which is tapped into it, and which has a head larger than the hole through the end of sleeve *B*. This method of supporting the work is found to give satisfactory results when turning work of very small diameter. It is preferable, when using this tool, to point the end of the work so that it fits snugly in the cone-pointed hole in the end of the support.

A tool for delicate turning similar to that in Fig. 17, is shown in Fig. 18, where the rising block which operates it is also shown. The only difference in this tool from that just described is that the turning tool *W* is off-set. The turning tool is held as shown in the swinging member *V*, which is pivoted to the front end of the shank *T* by a stud *U*. The tool *W* is fed in to the work by the pusher *S* pressing against the set-screw *Y*, tapped into the swinging member *V*.

Thus far we have confined our attention to tools used for straight turning; but, of course, taper work can also be done on the automatic screw machine if a suitable tool is provided. A tool which can be used for taper turning is shown in Fig. 19. This is the standard taper turning tool made by the Brown & Sharpe Mfg. Co. and is recommended for taper turning when accurate work is desired. The illustration shows the taper turning tool and the rising block for operating it. This rising block can be set at any desired angle; the angle to which the rising block is set, governs the taper on the work. When in operation, this rising block presses on the point of screw *a*, which forces the holders carrying the supports and turning tool out from the center.

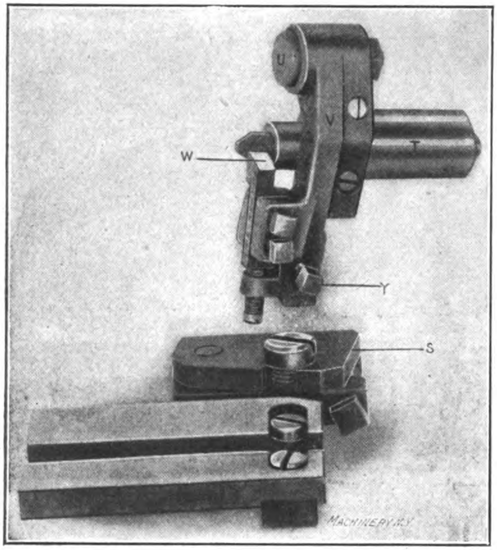


Fig. 18. Swing Tool for Delicate Turning

A clearer idea of the operation of this taper turning tool can be obtained by referring to Fig. 20. In this illustration an end view, longitudinal section and cross-section are shown at *A*, *B* and *C*, respectively, to illustrate the working mechanism of this tool. As the rising block (shown in Fig. 19) presses against the point of the screw *a*, which is tapped into sleeve *b*, it forces the latter in the direction of the arrow. Now as the sleeve *b* is forced in, it pulls on the band spring *c*, which is attached to the circular block *d*, thus turning the latter around in the direction of the arrow. The band spring is made from sheet steel, 5/16 inch wide by 0.012 inch thick, which is left soft. This spring, as shown, is fastened in a slot cut in the circular block *d*. The circular block *d* has eccentric projections *e* formed on it, which fit in slots cut in the tool-holder *f* and support-holders *g*. From a study of the illustration it can be seen that as the sleeve *b* is forced in, it carries the spring *c* forward, thus rotating the circular block *d* in the direction of the arrow and forcing the holders carrying the supports and turning tools out from the center.

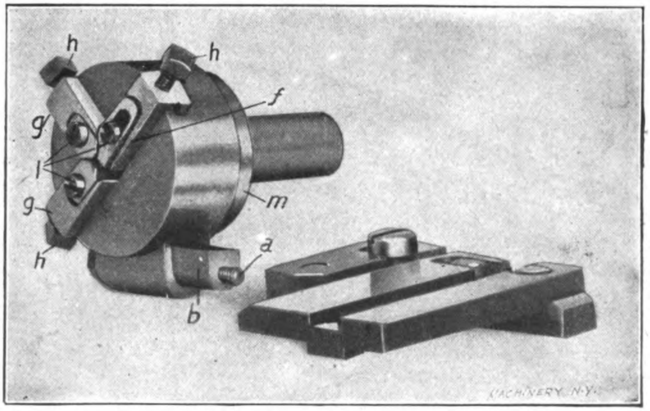


Fig. 19. Standard Taper Turning Tool

In the end view shown at *A* the turning tool and support holders are shown in the position they occupy before the rising block operates on the holder. The supports and turning tool can be adjusted independently of each other by the set-screws *h*, and are held by the fillister

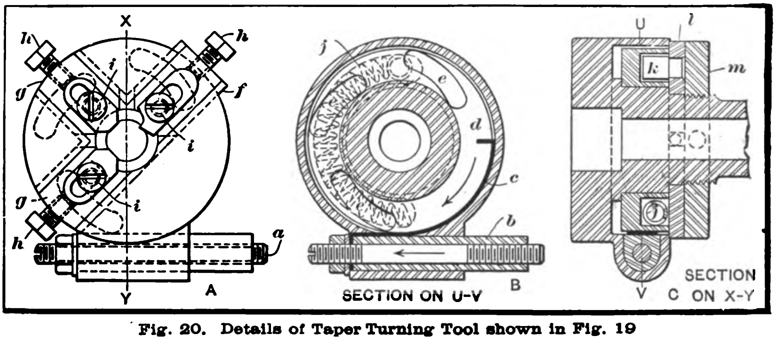


Fig. 20. Details of Taper Turning Tool shown in Fig. 19

screws *i*. After the turret drops back, disconnecting the screw *a* from the rising block, the turning tool and supports are returned to their former position by means of the coil spring *j* (shown at *B*) which is held in an annular groove cut in the rear of the circular block *d*. The spring *j* presses against a pin *k* (shown at *C*) which is riveted to a plate *l*; this plate is held to the shank of the holder by a pin fitting in a slot. Plate *l* is held up against the outer casing of the holder by the nut *m*, screwed onto the shank of the holder.

CHAPTER III

HOLLOW MILLS—SPEEDS AND FEEDS

For roughing down work, especially brass work, a hollow mill is found to give very satisfactory results. Two hollow mills of the solid type are shown in Fig. 21. These hollow mills are ground for steel work, a rake being given to the cutting edge. This is found to give better results on steel than having the cutting faces of the blades parallel with the center line.

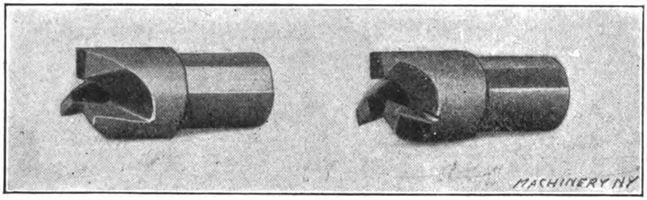


Fig. 21. Hollow Mills of the Solid Type

The proportions for hollow mills and the cutting angles for various materials are given in Table I. The sizes from 0.065 to 0.462 inch given in column *A* are worked out for roughing mills for the A. S. M. E. standard and special machine screw sizes, an allowance of from 0.005 to 0.015 inch being made for finishing. These mills can be made to cut smaller by using a collar on them. In making these hollow mills, they should be reamed out tapering from the rear, so that the blades will clear

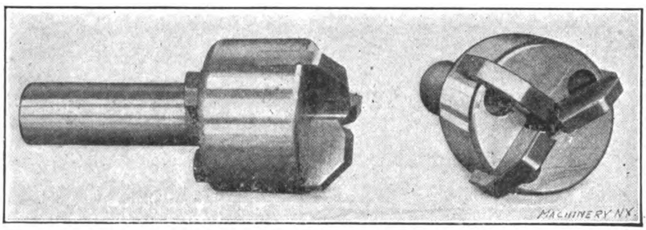
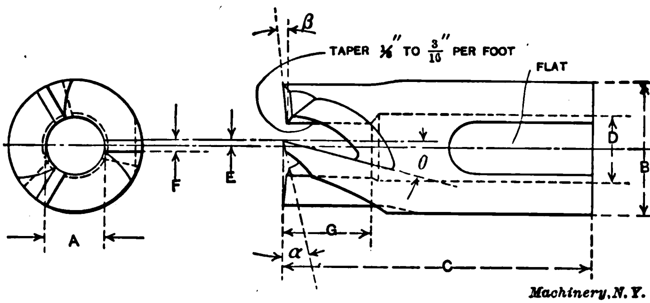


Fig. 22. Hollow Mill of the Inserted-blade Type

and not drag on the work. A taper of from about 1/8 to 3/16 inch per foot is generally satisfactory. For steel work the cutting edge is set about 1/10 of the diameter ahead of the center, but for brass work it should be on the center line. Hollow mills for cutting steel are, as a rule, made either from steel containing a very high percentage of carbon, or from high-speed steel. When high speeds are used, high-speed steel is preferable.

A hollow mill of the inserted-blade type is shown in Fig. 22. This is used extensively for screw machine work; although its use is

TABLE I. CUTTING ANGLES AND PROPORTIONS FOR HOLLOW MILLS



Cutting Angles for Hollow Mills

Angle	Brass Rod	Machine Steel	Tool Steel
α	8 degrees	15 degrees	10 degrees
β	8 degrees	5 degrees	3 degrees
θ	....	15 degrees	10 degrees

Proportions for Hollow Mills

A	B	C	D	E	F	G
0.065	1/2	1 1/4	1/4	0.007	0.020	1/4
0.078	1/2	1 1/4	1/4	0.008	0.020	1/4
0.091	1/2	1 1/4	1/4	0.009	0.025	1/4
0.105	1/2	1 1/4	1/4	0.011	0.025	1/4
0.120	1/2	1 1/4	1/4	0.012	0.025	1/4
0.135	1/2	1 1/4	1/4	0.014	0.030	1/4
0.148	1/2	1 1/4	1/4	0.015	0.030	1/4
0.161	1/2	1 1/4	1/4	0.016	0.035	5/16
0.174	1/2	1 1/4	1/4	0.017	0.035	5/16
0.187	1/2	1 1/4	1/4	0.019	0.040	5/16
0.200	5/8	1 1/2	3/8	0.020	0.040	5/16
0.226	5/8	1 1/2	3/8	0.023	0.045	5/16
0.252	5/8	1 1/2	3/8	0.025	0.045	5/16
0.280	5/8	1 1/2	3/8	0.028	0.050	3/8
0.305	5/8	1 1/2	3/8	0.031	0.060	3/8
0.332	5/8	1 1/2	3/8	0.033	0.065	3/8
0.358	5/8	1 1/2	3/8	0.036	0.070	7/16
0.385	1	2 1/4	3/4	0.039	0.075	7/16
0.410	1	2 1/4	3/4	0.041	0.080	7/16
0.436	1	2 1/4	3/4	0.044	0.085	1/2
0.462	1	2 1/4	3/4	0.046	0.090	1/2
0.480	1	2 1/4	3/4	0.048	0.095	5/8
0.515	1	2 1/4	3/4	0.052	0.100	5/8
0.578	1	2 1/4	3/4	0.058	0.105	3/4
0.640	1	2 1/4	3/4	0.064	0.110	3/4
0.703	1	2 1/4	13/16	0.070	0.115	7/8
0.765	1	2 1/4	13/16	0.077	0.120	7/8

mainly confined to hand screw machines it is sometimes also applied to the automatics. This mill is provided with three cutting blades, which are held in the body of the holder by clamp-bolts fitting in beveled slots cut in the blades. The clamp-bolts are held by means of nuts located at the rear of the body. The blades are sharpened by grinding on the ends, and can be adjusted for diameter by simply releasing the nuts and moving the blades out or in by hand.

Hollow Mill Holders

When hollow mills of the solid type are used, it is necessary to have a holder which can be set so that the mill will cut concentric. A

TABLE II. FEEDS FOR ROUGHING BOX-TOOLS—CUTTERS MADE FROM HIGH-SPEED AND CARBON STEEL

1/32-inch Chip				1/8-inch Chip			
Smallest Diameter of Stock	Brass Rod, Feed per Revolution	Machine Steel, Feed per Revolution	Tool Steel, Feed per Revolution	Smallest Diameter of Stock	Brass Rod, Feed per Revolution	Machine Steel, Feed per Revolution	Tool Steel, Feed per Revolution
1/16	0.0020	0.0015	0.0010	3/8	0.0045	0.0030	0.0020
1/8	0.0030	0.0020	0.0015	7/16	0.0050	0.0035	0.0025
3/16	0.0040	0.0030	0.0020	1/2	0.0060	0.0040	0.0030
1/4	0.0050	0.0040	0.0025	9/16	0.0070	0.0050	0.0035
5/16	0.0060	0.0045	0.0030	5/8	0.0085	0.0060	0.0040
3/8	0.0075	0.0050	0.0035	3/4	0.0100	0.0070	0.0050
1/16-inch Chip				3/16-inch Chip			
1/4	0.0045	0.0030	0.0020	1/2	0.0040	0.0025	0.0015
5/16	0.0060	0.0040	0.0025	9/16	0.0045	0.0030	0.0018
3/8	0.0090	0.0060	0.0030	5/8	0.0050	0.0032	0.0020
7/16	0.0105	0.0070	0.0040	11/16	0.0055	0.0035	0.0023
1/2	0.0120	0.0080	0.0050	3/4	0.0060	0.0040	0.0025
9/16	0.0135	0.0090	0.0060	13/16	0.0070	0.0045	0.0028
5/8	0.0150	0.0100	0.0075	7/8	0.0075	0.0050	0.0030

holder which is used for this purpose, and which gives satisfactory results, is the standard floating holder made by the Brown & Sharpe Mfg. Co. In setting a hollow mill, the screws holding the floating part of the holder to the body proper are released and the mill is set concentric. It is desirable to turn a bevel on the end of the work to facilitate the setting of the hollow mill.

Speeds for External Cutting Tools

The following speeds are for external cutting tools such as box-tool cutters, hollow mills, etc., made from ordinary carbon and high-speed steel, but do not apply to circular cut-off or form tools. The speeds are intended for average conditions on the materials specified.

SPEEDS FOR BOX-TOOL CUTTERS AND HOLLOW MILLS MADE FROM ORDINARY CARBON STEEL

Material	Surface Speed in Feet per Minute
Brass (ordinary quality)	170 — 180
Gun screw iron	70 — 80
Norway iron and machine steel	60 — 70
Drill rod and tool steel	35 — 40

SPEEDS FOR BOX-TOOL CUTTERS AND HOLLOW MILLS MADE FROM HIGH-SPEED STEEL

Material	Surface Speed in Feet per Minute
Brass (ordinary quality)	250 — 270
Gun screw iron	100 — 120
Norway iron and machine steel	90 — 100
Drill rod and tool steel	50 — 60

TABLE III. FEEDS FOR FINISHING BOX-TOOLS—CUTTERS MADE FROM HIGH-SPEED AND CARBON STEEL

0.005-inch Chip				0.020-inch Chip			
Smallest Diameter of Stock	Brass Rod, Feed per Revolution	Machine Steel, Feed per Revolution	Tool Steel, Feed per Revolution	Smallest Diameter of Stock	Brass Rod, Feed per Revolution	Machine Steel, Feed per Revolution	Tool Steel, Feed per Revolution
1/32	0.0020	0.0020	0.0018	3/8	0.0040	0.0040	0.0025
1/16	0.0030	0.0030	0.0020	7/16	0.0045	0.0045	0.0030
3/32	0.0045	0.0045	0.0025	1/2	0.0050	0.0050	0.0035
1/8	0.0060	0.0060	0.0030	9/16	0.0060	0.0060	0.0035
3/16	0.0070	0.0070	0.0040	5/8	0.0070	0.0070	0.0040
1/4	0.0080	0.0080	0.0050	11/16	0.0075	0.0075	0.0045
5/16	0.0100	0.0100	0.0060	3/4	0.0080	0.0080	0.0050
3/8	0.0120	0.0120	0.0080	13/16	0.0090	0.0090	0.0050

0.010-inch Chip				0.030-inch Chip			
1/4	0.0070	0.0070	0.0035	1/2	0.0040	0.0040	0.0020
5/16	0.0080	0.0080	0.0040	9/16	0.0045	0.0045	0.0022
3/8	0.0085	0.0085	0.0045	5/8	0.0050	0.0050	0.0025
7/16	0.0090	0.0090	0.0050	11/16	0.0055	0.0055	0.0028
1/2	0.0095	0.0095	0.0055	3/4	0.0060	0.0060	0.0030
9/16	0.0100	0.0100	0.0060	13/16	0.0070	0.0070	0.0035
5/8	0.0100	0.0100	0.0065	7/8	0.0080	0.0080	0.0040

Feeds for Roughing and Finishing Box-tools

In Table II are given feeds for roughing box-tools in which the cutters are made from high-speed and carbon steel, and in Table III are given feeds for finishing box-tools in which the cutters are made from high-speed and carbon steel. These feeds will give satisfactory results under proper conditions. The feeds for roughing, of course, could in some cases be increased if conditions would permit, but as a rule the feeds given are sufficiently high.

TABLE IV. FEEDS FOR TURNING WITH SWING TOOLS—CUTTERS MADE FROM HIGH-SPEED AND CARBON STEEL

1/32-inch Chip				1/8-inch Chip			
Smallest Diameter of Stock	Brass Rod, Feed per Revolution	Machine Steel, Feed per Revolution	Tool Steel, Feed per Revolution	Smallest Diameter of Stock	Brass Rod, Feed per Revolution	Machine Steel, Feed per Revolution	Tool Steel, Feed per Revolution
1/16	0.0010	0.0008	0.0005	3/8	0.0020	0.0015	0.0010
1/8	0.0015	0.0010	0.0008	7/16	0.0025	0.0018	0.0015
3/16	0.0020	0.0015	0.0010	1/2	0.0030	0.0020	0.0018
1/4	0.0030	0.0020	0.0015	9/16	0.0035	0.0025	0.0020
5/16	0.0035	0.0025	0.0018	5/8	0.0038	0.0028	0.0022
3/8	0.0040	0.0030	0.0020	11/16	0.0042	0.0030	0.0025
1/16-inch Chip				**3/16-inch Chip**			
1/4	0.0025	0.0020	0.0010	1/2	0.0020	0.0010	0.0008
5/16	0.0030	0.0022	0.0018	9/16	0.0025	0.0013	0.0010
3/8	0.0035	0.0025	0.0015	5/8	0.0028	0.0015	0.0012
7/16	0.0040	0.0028	0.0018	11/16	0.0030	0.0018	0.0015
1/2	0.0045	0.0030	0.0020	3/4	0.0035	0.0020	0.0018
9/16	0.0050	0.0032	0.0025	13/16	0.0038	0.0022	0.0020
5/8	0.0060	0.0035	0.0028	7/8	0.0040	0.0025	0.0020

TABLE V. FEEDS FOR HOLLOW MILLS MADE FROM HIGH-SPEED AND CARBON STEEL

1/16-inch Chip				3/16-inch Chip			
Smallest Diameter of Stock	Brass Rod, Feed per Revolution	Machine Steel, Feed per Revolution	Tool Steel, Feed per Revolution	Smallest Diameter of Stock	Brass Rod, Feed per Revolution	Machine Steel, Feed per Revolution	Tool Steel, Feed per Revolution
3/16	0.0045	0.0030	0.0015	1/2	0.0060	0.0045	0.0020
1/4	0.0050	0.0040	0.0018	9/16	0.0065	0.0050	0.0023
5/16	0.0055	0.0045	0.0020	5/8	0.0070	0.0055	0.0025
3/8	0.0060	0.0050	0.0025	11/16	0.0080	0.0060	0.0030
7/16	0.0070	0.0050	0.0028	3/4	0.0090	0.0065	0.0035
1/2	0.0080	0.0060	0.0030	13/16	0.0100	0.0070	0.0040
1/8-inch Chip				**1/4-inch Chip**			
3/8	0.0070	0.0050	0.0030	5/8	0.0050	0.0035	0.0015
7/16	0.0075	0.0055	0.0035	11/16	0.0055	0.0040	0.0018
1/2	0.0080	0.0060	0.0040	3/4	0.0060	0.0050	0.0020
9/16	0.0090	0.0065	0.0050	13/16	0.0070	0.0055	0.0025
5/8	0.0110	0.0075	0.0060	7/8	0.0080	0.0060	0.0030
11/16	0.0130	0.0090	0.0070	..	......	......	......
3/4	0.0150	0.0110	0.0080	..	......	......	......

Feeds for Turning with Swing Tools

Owing to the fact that swing tools are not so rigidly constructed as the ordinary box-tools, it has been found advisable to decrease the feeds slightly below those used for box-tools. Feeds which have been found satisfactory for straight turning with swing tools are given in Table IV. These feeds are about 30 per cent less than those used for box-tools.

Feeds for Taper Turning

For taper or irregular turning with swing tools, the greatest depth of the chip should be considered, and the same feed used as that given in Table IV. For taper turning with the Brown & Sharpe standard taper turning tools, the greatest depth should be considered, and the same feed used as given in Tables II and III for roughing and finishing cuts, respectively. Where the taper is greater than 1/4 inch per foot, it is advisable to use two taper turning tools, one for roughing, and one for finishing.

Feeds for Hollow Mills

In Table V are given feeds for hollow mills which are made from ordinary carbon or high-speed steel. These feeds apply both to hollow mills of the solid and inserted-blade types and are for taking a chip of from 1/16 to 1/4 inch deep. The feeds given are not excessively high, and in some cases could be increased, especially when the work is not exceedingly long, and when the tool would not be on the work for a considerable time.

CHAPTER IV

ANGULAR CUTTING TOOLS

When it is necessary to form the end of the work cone-shaped and produce a sharp point, a tool which is fed in similarly to an ordinary cut-off tool does not give satisfactory results. An example of this class of work and the attachment used for forming it are shown in Fig. 23. The work, which is shown at *A*, is a blank for a combination drill and countersink. The angular cutting-off attachment consists mainly of a bracket *B*, which is fastened to the machine by two cap-screws *C*. These screws are located in the holes which are used for fastening the slotting, cross-drilling and burring attachments to the machine. The sliding member *D*, fitting in dovetailed grooves cut in the bracket *B*, is used for holding an ordinary circular forming tool *E*, which is held to this sliding member by cap-screw *F*. The usual means for adjusting the circular tool is provided; this consists of an eccentric cap-screw *G* and a plate *H*. The eccentric screw *G* is locked by screw *I*.

Attached to the sliding member *D* is a rack *J* held by a screw *K* in a groove cut in the slide. This rack meshes with gear *L* which, in turn, meshes with gear *M* in contact with rack *N*. Rack *N* is attached to the cross-slide by means of a block *O* held in the *T*-slot cut in the cross-slide, by a block *Q* and two screws *P*. The gears *L* and *M* are held on studs *R* and *S* fitted with bronze sleeves on which the gears rotate. These bronze sleeves are provided with oil grooves, and oil holes are drilled through the studs, so that a copious supply of oil is given to the bearings.

The operation of this attachment is as follows: As the cross-slide advances, rack *N* attached to it rotates gear *M* which, in turn, through gear *L* and rack *J*, forces slide *D* in as indicated. Slide *D* is returned to its former position in a similar manner when the cross-slide drops back. The circular tool *E* follows a diagonal line of travel so that the point on the work is turned to the correct angle. Thus a very fine point can be made on the work, as no pressure is brought to bear on the part being severed, the weight of the work alone breaking it off.

An angular turning tool which is constructed on a different principle from that shown in Fig. 23 is shown in Fig. 24. This tool is held in the turret, and is operated by a rising block held on the cross-slide. The construction of this tool is as follows: Attached to the body *A* by a shouldered screw *B* is a plate *C*. Tapped into plate *C* is a screw *D*, checked by a nut *E*. The sliding member *F*, fitting over dovetailed ways formed on the angular face of holder *A*, is attached to block *C* by means of a screw *G*. The tool-holder *H* is made integral with the sliding member *F*, and holds the turning tool *I*, which is held in a slot cut in the holder, by two headless screws *J*, and rests on a pin *K*.

In operation, as the rising block presses on screw *D*, it swivels block *C* on screw *B*, and as block *C* is attached to slide *F* by screw *G*, it carries the slide along the face of the tool-holder, thus turning the recess in the work as shown at *L*. When the rising block drops back, the tool-slide *F* is returned by a coiled spring *M* held in body *A*,

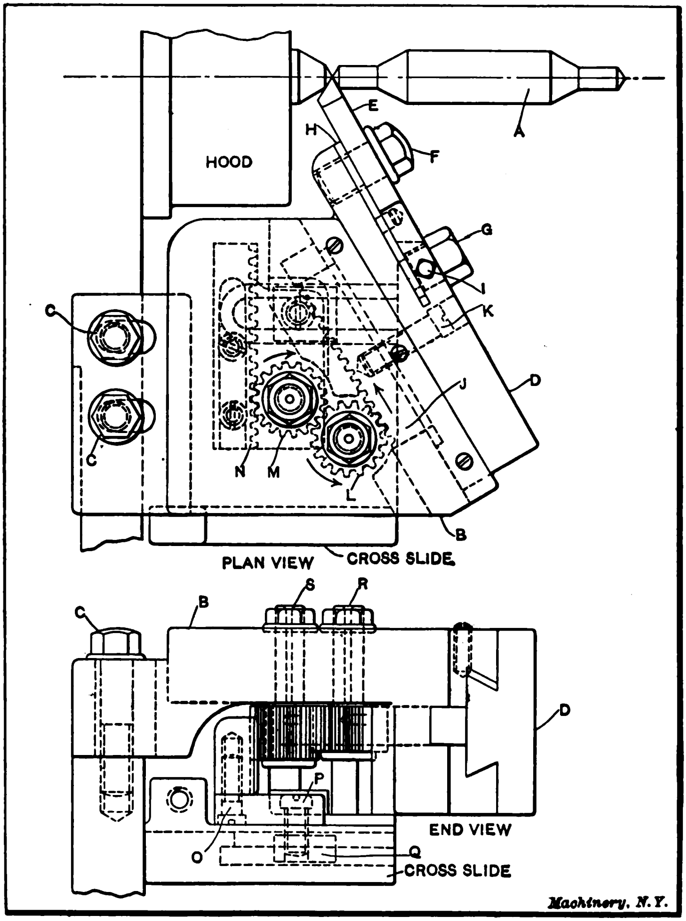


Fig. 23. Cross-slide Angular Cutting-off Tool

through a spring plunger *N* pressing against a pin *O* held in the sliding member *F*. A gib and adjusting screws are also provided to make allowance for wear. A bushing *P* held in the body of the holder by a screw *Q* supports the forward end of the work, while the recess is being turned.

An angular cutting-off tool which is held in the turret and operated by a rising block is shown in Figs. 25 and 26. The rising-block for operating this tool, which is held on the front cross-slide, is shown in Fig. 25. The construction of the holder, however, is more clearly shown in Fig. 26. All the parts in these two illustrations bear the same reference letters. The cutting-off blade *B* is held in a slot in the tool-slide *C* by adjusting-screws *D* and *F* and rests on pin *E*. Slide

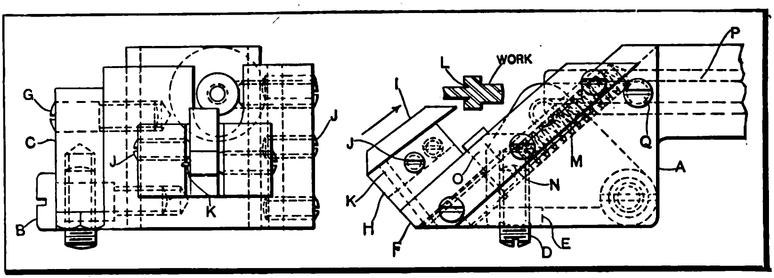


Fig. 24. Back Recessing Tool for Small Work

C is gibbed to a dovetailed guide on slide carrier *G*. This latter member is pivoted to the body *H* of the tool, the center of the pivot being the axis of bolt *J*, and is clamped by screw *K* in the proper location to guide slide *G* in forming the desired angle on the point of the work.

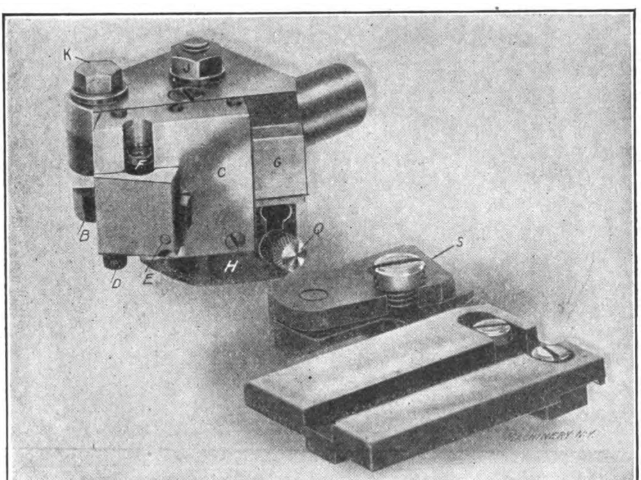


Fig. 25. Angular Cutting-off Tool held in Turret and operated by a Ris ng Block

The tool-slide *C* has attached to it a rack which meshes with the 32-pitch pinion *L*, pivoted to the under side of *G*. Pinion *L* meshes with a similar pinion *M* pivoted in a hole in the body of the tool about the center of bolt *J*, so that the correct relations between them are preserved, whatever the angular adjustment of *G* on *H*. Pinion *M* meshes with rack-teeth cut in plunger *N*. This is best seen in Fig. 26.

This plunger *N*, as can be seen in the side elevation, has at its front end a projection extending upward and bearing against a plunger *O* in the hole above it, which is pressed outward by a spring. By this means *N* is normally kept at the outer end of its movement, being limited in this direction by the seating of screw *P* in the recess provided for it in the body *H* of the tool. In this position the tool slide is withdrawn so that the blade clears the work.

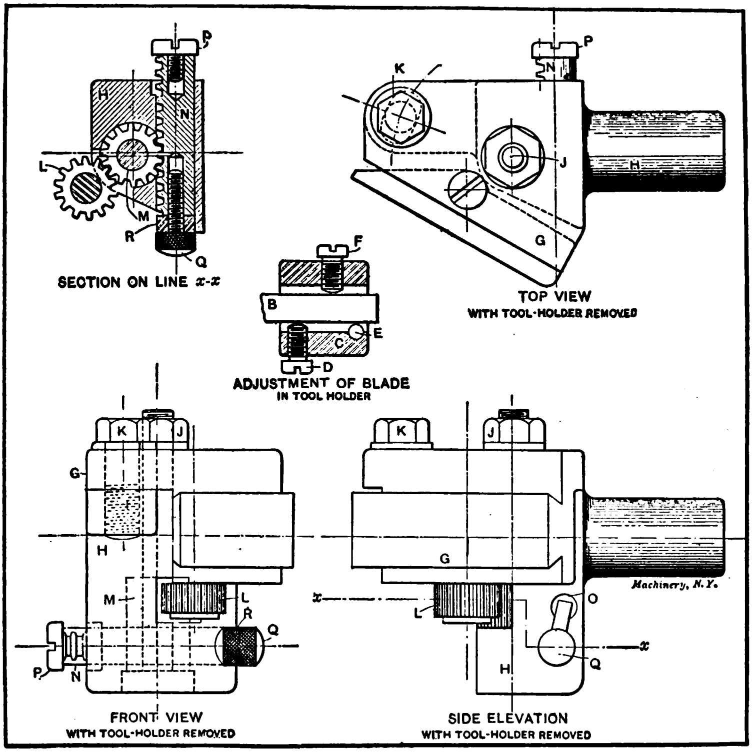


Fig. 26. Details of Tool shown in Fig. 25

The front end of *N* is provided with a knurled screw *Q* and lock-nut *R*. These are so located as to be in line with the pusher *S*, Fig. 25, which is attached to the front cross-slide of the machine. The cutting-off is effected by the movement of the cross-slide and pusher *S*. This bears on screw *Q*, presses plunger *N* inward, revolving pinions *M* and *L*, which, in turn, acting on the rack attached to the tool-slide, move cutter *B* inward, severing the work from the bar and forming the bevel point. The length of the inward travel of the tool is adjusted by screw *Q* and lock-nut *R*. For this operation the swiveled member *S* on the rising block need not be set at an angle, as the turret tool does not travel along its face, the pusher being used for forcing in the cutting-off slide only in a radial direction.

CHAPTER V

SHAVING TOOLS

When forming work of irregular contour, in the automatic screw machine, it is common practice to use a shaving tool, which is operated tangentially to the work and passes either under it or over it as conditions may require. It is customary to place the shaving tool on the rear cross-slide, so that the shaving operation can be accomplished at the same time as the turret operations, when the spindle is running forward.

Shaving tools are made from high-carbon tool steel. On the top face of the tool the irregular contour to be reproduced on the work is

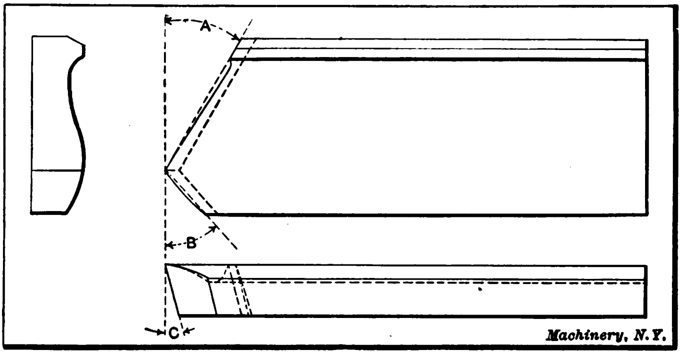


Fig. 27. Shaving Tool for Forming Long Work

formed. High-speed steel, as a rule, does not give very satisfactory results, owing to the fact that to get the best results from this steel, high peripheral velocities must be used; but when high peripheral velocities are used, the extreme cutting edge of a high-speed steel tool becoms ragged and will not produce a smooth finish.

It is not necessary, when applying a shaving tool to the work, to incline it at an angle to the horizontal plane to any great extent. The best results are obtained by holding the tool practically horizontal, so that when passing under the work, the forward end of the tool is at approximately the same height as the rear part. This produces a smooth finish on the work, as the shaving tool burnishes it after removing the material.

Shaving tools are used to follow a circular forming tool to produce a smooth finish, as well as to completely form the work, finishing it without having rough formed it with any other tool. Where the work has not been roughed down previous to shaving, a larger cutting angle is necessary, and if the work is long in proportion to its diameter, the tool should be ground with two cutting angles *A* and *B*, as shown in Fig. 27, so that the extreme point of the tool will be where the greatest amount of material is to be removed. This produces a shearing cut and removes the material more easily. The angles on the type of shaving tool shown in Fig. 27 for cutting the materials specified below are as follows:

Material	Cutting-angles in Degrees
Brass rod	$A=20$, $B=30$, $C=10$;
Machine steel	$A=30$, $B=40$, $C=15$;
Tool steel	$A=40$, $B=50$, $C=15$;

While the shaving tool shown in Fig. 27 is used extensively on the automatic screw machine, it is difficult to harden because of its length. If sufficient care is not exercised it will be distorted, and when the contour is of such a shape that it is impossible to grind the form after

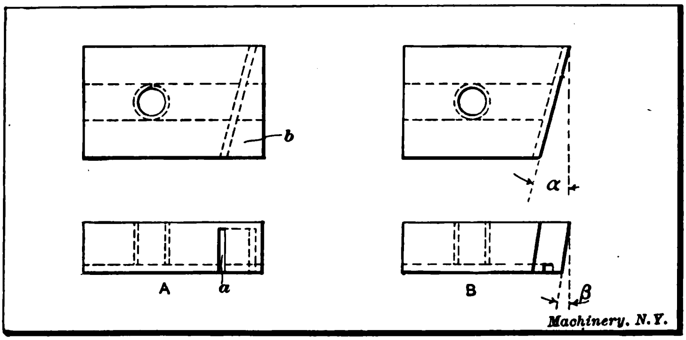


Fig. 28. Type of Shaving Tool used in the Shaving-tool Holder shown in Fig. 29

hardening, this becomes an objectionable feature. A shaving tool which does not present the same difficulty in hardening is shown in Fig. 28. This shaving tool is a short block which is held in the holder shown in Fig. 29. A support is also provided so that the work need not be supported from the turret except when the length being shaved is long in proportion to the diameter. Owing to the rigidity of the support, the cutting-angle can be less than the angle *A* shown in Fig. 27. The cutting-angles on the shaving tool shown in Fig. 28 for cutting various materials are as follows:

Material	Cutting-angles
Brass rod	$\alpha=10$ deg. $\beta=10$ deg.
Machine steel	$\alpha=15$ deg. $\beta=15$ deg.
Tool steel	$\alpha=20$ deg. $\beta=15$ deg.

The chief use of this tool is for finishing work after it has been rough formed with a circular form or other external cutting tool. As the support passes over the work after shaving, a burnished appearance is the result; of course, it is absolutely necessary to have the faces of the shaving tool and support polished if good results are to be expected. The first step in making the shaving tool shown in Fig. 28 is to form it into a block as shown at *A*. A saw slot *a* is cut at the desired angle, so that part *b* can be broken off after the shape required is milled on the top face and the tool hardened and polished. The polishing can be accomplished in a milling machine by holding a piece of brass or copper in a chuck, the outer end of the brass being formed to the contour of the tool. Emery is applied to this lap, and by running the carriage back and forth with the shaving tool held in the vise, a very smooth finish can be obtained. After the tool is polished, part *b* is broken off and the tool ground as shown at *B*. By leaving part *b* on until the tool is polished, the cutting edge will not be rounded and the tool can be more easily polished.

For cutting machine or tool steel it is preferable to make the shaving tool thinner at the rear end to provide for clearance. Making the tool

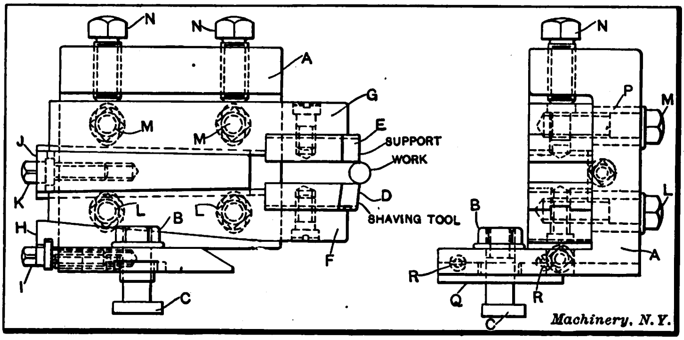


Fig. 29. Shaving-tool Holder which can be used for a Wide Range of Work

from 0.001 to 0.0025 inch thinner at the rear than at the front end, gives the desired result. This can be accomplished by packing up the rear end when milling the form on the tool. This type of shaving tool when used on steel should not be used for rough forming, but for finishing only.

When the work is rough formed before shaving, the amounts to be removed from the diameters are as follows:

Diameter	Amount to Remove in Inches
Up to 1/8	0.0050
1/8 — 3/8	0.0075
3/8 — 5/8	0.0100
5/8 — 7/8	0.0150

Shaving Tool Holders

It is necessary to hold a shaving tool rigidly if good results are to be expected, and if the work is small in diameter in proportion to the length being shaved, it is also necessary to use a support. A shaving-tool holder which will be found satisfactory for this class of work is shown in Fig. 29. This holder is held on the rear cross-slide and consists of a machine-steel body *A*, which is held to the cross-slide by means of the nut and bolt *B* and *C*, the latter fitting in the groove in the cross-slide. The shaving tool *D* and support *E* are held to the two members *F* and *G* by screws as shown. A tongue is formed on members *F* and *G* which fits in grooves cut in the shaving tool and support.

Gib *H* is provided for raising shaving tool *D* to the correct height. It is operated by collar-screw *I*, fitting into a slot in the gib and screwed into the base of holder *A*. The gib *J* is provided for increasing and diminishing the distance between shaving tool *D* and support *E*, thus governing the diameter of the work. A collar-screw *K*, fitting in a slot cut in gib *J* and tapped into the holder, is used for adjusting the gib. When members *F* and *G* are set correctly, they are held in the body *A* by means of screws *L*, *M* and *N*. Elongated slots *P* are

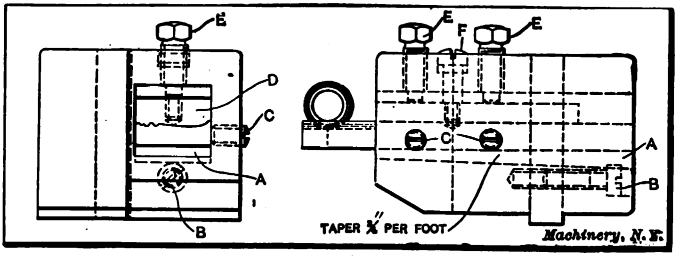


Fig. 30. Shaving-tool Holder of the Box Type

provided in holder *A*, so as to allow screws *L* and *M* to be moved up and down, which provides for adjustment for different diameters.

The ordinary adjustable block provided in the toolposts for holding circular tools is also provided in this holder. This block *Q* is adjusted by screws *R*, and is used for setting the side of the shaving tool parallel with the face of the chuck. The front edge of the support *E* should have the same face angle as the shaving tool *D*, but should be set a distance equal to 1/40 of the diameter of the work back from the face of the shaving tool.

In Fig. 30 is shown a shaving-tool holder for holding a shaving tool of the type shown in Fig. 27, which is operated from the rear cross-slide. This holder is of the box type, and a tapered gib *A* is provided for adjusting the tool for various heights. This gib is actuated by screw *B*, fitting in a slot cut in the gib and screwed into the holder. Set-screws *C* prevent lateral movement of the shaving tool, and a pad *D*, operated by two set-screws *E*, holds the shaving tool down on the adjustable gib. This pad *D* is made with the same contour on its lower face as the shaving tool so that it will hold the latter rigidly. Where the contour of the tool is of a shape difficult to make, it is, however, customary to have the pad bear only on two or three points. A screw *F* is provided for holding the pad when the shaving tool is removed. The shaving-tool holder is held to the cross-slide in the same manner as the circular-tool holder.

A shaving-tool and cut-off-tool holder combined is shown in Fig. 31. This type of holder is used when one of the cross-slides is occupied by a forming tool. The construction is similar to that shown in Fig. 30, except for the additional provision for holding the cut-off tool blade *A*. This is held in a groove cut in the holder, by a block *B* which, in turn,

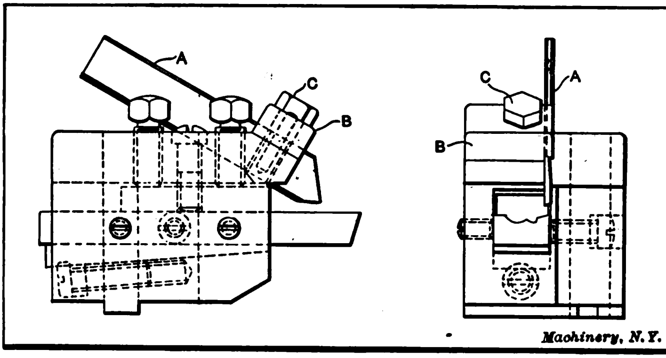


Fig. 31. Combination Cut-off and Shaving-tool Holder

is held by the cap-screw *C*. When using a combination shaving and cut-off tool of this kind, provision must be made so that the work when cut off will not stay on the shaving tool. A simple device for overcoming this difficulty is shown in Fig. 32. This consists simply of a split ring *A* which is held on the hood over the chuck by cap-screw *B*.

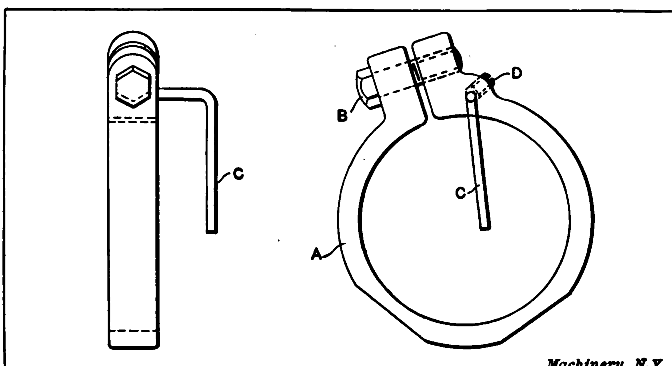


Fig. 32. Ejector used in Connection with the Shaving-tool Holder shown in Fig. 31

A wire rod *C*, which is so located that it will remove the work from the shaving tool when the cross-slide drops back, is held in ring *A* by a headless screw *D*.

In Fig. 33 is shown the holder which was used for holding the shaving tool shown in Fig. 27. This holder differs somewhat from those previously described in that provision is made for raising the front end of the shaving tool. The shaving tool rests on a pin *A* and is

TABLE VI. FEED PER REVOLUTION FOR SHAVING TOOLS

Width of Shaving Tool, in Inches	Smallest Diameter to be Shaved, in Inches										
	$\frac{1}{8}$	$\frac{5}{32}$	$\frac{3}{16}$	$\frac{7}{32}$	$\frac{1}{4}$	$\frac{5}{16}$	$\frac{3}{8}$	$\frac{1}{2}$	$\frac{5}{8}$	$\frac{3}{4}$	$\frac{7}{8}$
$\frac{1}{4}$	0.0025	0.0030	0.0035	0.0040	0.0045	0.0050	0.0060	0.0080	0.0100	0.0120	0.0150
$\frac{5}{16}$	0.0020	0.0025	0.0030	0.0035	0.0040	0.0045	0.0055	0.0075	0.0095	0.0115	0.0145
$\frac{3}{8}$	0.0015	0.0020	0.0025	0.0030	0.0035	0.0040	0.0050	0.0070	0.0090	0.0110	0.0140
$\frac{7}{16}$	0.0010	0.0015	0.0020	0.0025	0.0030	0.0035	0.0045	0.0065	0.0085	0.0105	0.0135
$\frac{1}{2}$	0.0025	0.0010	0.0015	0.0020	0.0025	0.0030	0.0040	0.0060	0.0080	0.0100	0.0130
$\frac{5}{8}$	0.0020	0.0008	0.0010	0.0015	0.0020	0.0025	0.0035	0.0055	0.0075	0.0095	0.0125
$\frac{3}{4}$	0.0015	0.0030	0.0035	0.0010	0.0015	0.0020	0.0030	0.0050	0.0070	0.0090	0.0120
$\frac{7}{8}$	0.0010	0.0025	0.0030	0.0040	0.0010	0.0015	0.0025	0.0045	0.0065	0.0085	0.0115
1	0.0008	0.0020	0.0025	0.0035	0.0045	0.0010	0.0020	0.0040	0.0060	0.0080	0.0110
$1\frac{1}{8}$		0.0015	0.0020	0.0030	0.0040	0.0008	0.0015	0.0035	0.0055	0.0075	0.0105
$1\frac{1}{4}$		0.0010	0.0015	0.0025	0.0035	0.0050	0.0010	0.0030	0.0050	0.0070	0.0100
$1\frac{3}{8}$		0.0008	0.0010	0.0020	0.0030	0.0045	0.0060	0.0025	0.0045	0.0065	0.0095
$1\frac{1}{2}$			0.0008	0.0015	0.0025	0.0040	0.0055	0.0020	0.0040	0.0060	0.0090
$1\frac{5}{8}$				0.0010	0.0020	0.0035	0.0050	0.0015	0.0035	0.0055	0.0085
$1\frac{3}{4}$				0.0008	0.0015	0.0030	0.0045	0.0010	0.0030	0.0050	0.0080
$1\frac{7}{8}$					0.0010	0.0025	0.0040	0.0080	0.0025	0.0045	0.0075
2					0.0008	0.0020	0.0035	0.0075	0.0020	0.0040	0.0070
$2\frac{1}{8}$						0.0015	0.0030	0.0070	0.0015	0.0035	0.0065
$2\frac{1}{4}$						0.0010	0.0025	0.0065	0.0010	0.0030	0.0060
$2\frac{3}{8}$						0.0008	0.0020	0.0060	0.0100	0.0025	0.0055
$2\frac{1}{2}$							0.0015	0.0055	0.0095	0.0020	0.0050

adjusted by two set-screws *B*. The object in making this adjustment is to provide for clearance, which is necessary on account of the wide bearing surface.

Speeds and Feeds for Shaving

As a rule, shaving tools can be operated at the same speed as circular form tools, the speeds for which were given in Part III of this treatise, MACHINERY's Reference Book No. 101, "Circular Form and Cut-off Tools for the Brown & Sharpe Automatic Screw Machine."

The feed at which a shaving tool can be operated satisfactorily is governed largely by the following conditions:

1. Amount of material to be removed.
2. Character of the material.
3. Angle of the cutting edge.
4. Length of the work in proportion to the diameter.

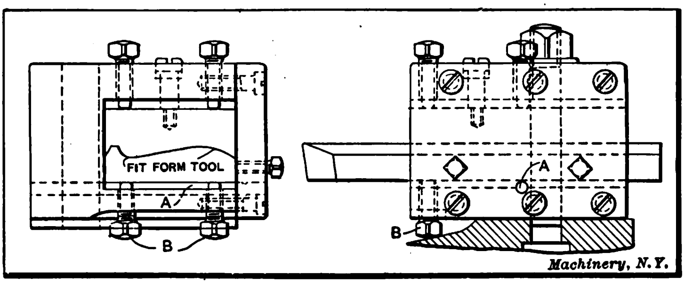


Fig. 33. Shaving-tool Holder for Long Work

The amount of material to be removed should, to a large extent, govern the angle of the cutting edge, and is a more important factor than is the nature of the material. Owing also to the extra amount of cutting surface and insufficient clearance, a shaving tool cannot be fed at the same rate of feed as a circular form tool can. That is to say, to remove the same amount of material requires a greater number of revolutions with a shaving tool than with a circular form tool. Where the length of the work is more than three and one-half times its diameter, a support should be used. This has been taken into account when arranging Table VI, and it should be understood that the feeds given under the heavy lines should be used only when the work is supported.

It is evident from the foregoing that the feed should be decreased when the cutting angle is decreased, and, on the other hand, the feed should be increased when the cutting angle is increased. The feeds given above the heavy lines in Table VI are applicable to shaving tools having the angles given in reference to Fig. 27, while the feeds below the heavy lines are for shaving tools having the angles given in reference to Fig. 28, and also for the angles given in reference to Fig. 27 when a support is used. When a shaving tool and support of the type shown in Fig. 29 are used, the feeds above the heavy lines in Table VI can be increased 50 per cent with satisfactory results.