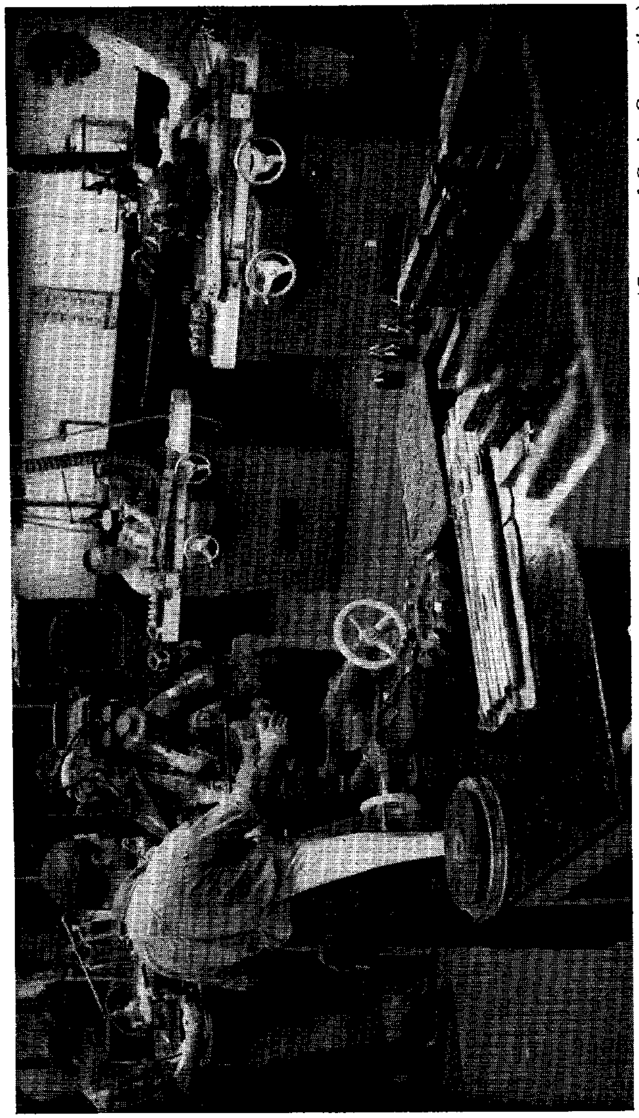


(Courtesy of Carrier Corporation)

View of a typical central tool grinding room showing single-point carbide tool grinder at extreme left and two different types of cutter grinders for sharpening face mills, milling cutters, reamers, etc. Note neatly stacked tools in foreground waiting to be sharpened

NORTON ABRASIVES

CHAPTER II

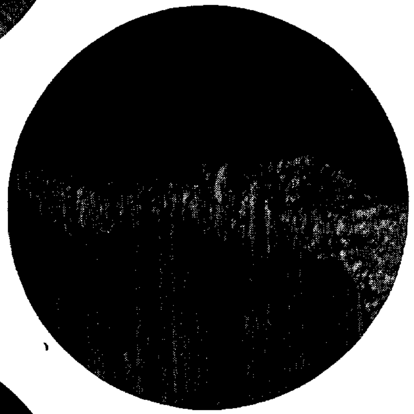
Sharpening High-Speed Steel and Cast Alloy Multi-Tooth Cutters

In general, it may be said that the working efficiency of a cutter is largely determined by the keenness of its cutting edges. Consequently, it is important to sharpen a cutter at the first signs of dullness. A dull cutter not only leaves a poorly finished surface, but the continued use of such a cutter leaves it in a condition where it becomes necessary to grind away a considerable portion of the teeth to restore the cutting edges. When the cutter is maintained in good working condition by frequent sharpening, it is certain to be cutting rapidly and effectively at all times. Furthermore, when such a cutter does need resharpening, it is necessary to grind the teeth only a very small amount to restore its keen cutting edges.

Cutters and reamers are usually ground on tool and cutter grinding machines. The universal type of cutter grinder, as the name implies, can be set up for a variety of grinding operations, including light cylindrical, surfacing and internal, as well as for sharpening cutters of all kinds, reamers, etc.

The grinding machine for sharpening cutters should be kept in good repair. The wheel spindle must be free running, but the bearings should be snug so that there is no tendency to chatter, nor must there be any end play. Table ways must be kept straight and true if accurate work is to be obtained. The tooth rest should be substantial enough to avoid springing

Cutting edge normally dulled and ready for sharpening (Magnification 20x)



Cutting edge burned and broken down as a result of delayed sharpening (Magnification 20x)

Cutting edge properly sharpened (Magnification 20x)

and the tip shaped so as to provide a smooth and solid contact under each tooth being sharpened.

Grinding Wheels Recommended

The grade of the grinding wheel used for sharpening cutters must be in the soft range to insure a free cutting action and to avoid drawing the temper of the cutting edge. At the same time, if the wheel is too soft, its rapid wear makes it difficult to keep the cutter a true cylinder or to produce a keen edge.

32A46-K8VG, 32A60-J8VG and 32A46-J8VG Alundum vitrified, in the order named, are the most preferred specifications of small straight cup and tapered cup wheels for sharpening carbon steel, high-speed steel and cast nonferrous alloy cutters of the profile type, which are ground on the back of the cutting edge. Included in this class of cutters are plain and side milling cutters, end mills, reamers, etc. When the machine set-up calls for a straight wheel, 38A46-K8VG is most commonly used.

Formed cutters, including rotary gear cutters, are generally ground with dish shaped wheels, 38A46-K8VG or 38A60-J8VG Alundum vitrified. For sharpening Fellows Gear Shaper cutters, slightly finer grit wheels, 32A80-I8VG, should be used. A complete list of wheels to use for sharpening various types of cutters is included in the table of grinding wheel recommendations, beginning on page 184.

Dry grinding is generally recommended for most high-speed steel cutter sharpening operations because experience has shown that satisfactory results are readily obtained in this way and the operations are such that wet grinding causes inconvenience to the operator. However, where machines expressly provide for wet grinding, they should continue to be so used.

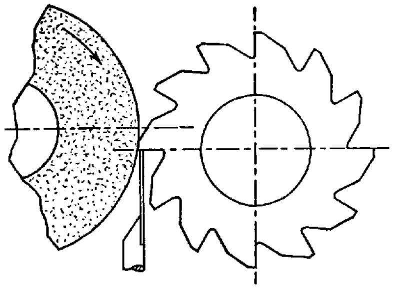


Figure 1—Showing method of grinding with wheel rotating off the cutting edge

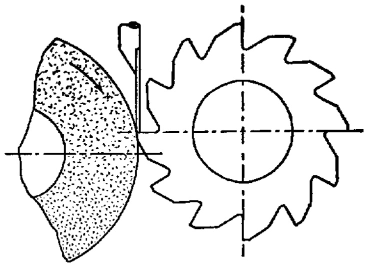


Figure 2—Showing method of grinding with wheel rotating on to the cutting edge

Direction of Wheel Rotation

Cutters and reamers may be ground with the grinding wheel rotation either off or toward the cutting edge as shown above:

If the wheel is run off or away from the cutting edge as shown in figure 1, the wheel holds the cutter against the tooth rest. As this is the safer method it is more commonly used. It has the objection, however, of throwing up a burr on the cutting edge of the tooth which should be oilstoned off. Furthermore, there is some danger of burning the tooth at the cutting edge.

If the cutter is ground by rotating the wheel on to the cutting edge as shown in figure 2, there is less tendency to burn the tooth and a keener cutting edge, free from burr, is possible. Care must be taken, however, to hold the cutter firmly against the tooth rest as otherwise the rotation of the wheel will carry the tooth into the wheel and cause it to be ground away.

While straight wheels are shown in the above illustrations, the same comments regarding direction of grinding wheel rotation apply to the use of cup wheels.

Relief Angle

Relief may be defined as the amount of stock removed from the teeth behind the cutting edge to permit the teeth to cut freely and to clear the material after the cutting edge has done its work.

It is important that the relief angle be correct. If it is insufficient, the teeth will have a dragging cut, while if it is too great, the teeth will wear rapidly and the cutter is likely to chatter. Too much relief, however, is less objectionable than too little.

The proper relief angle depends upon a number of factors, principally the type and diameter of the cutter and hardness of the material to be machined. For example, cutters employed on soft materials like brass can stand more relief than those employed on steel or cast iron. Likewise, the relief must be greater for small cutters than for large ones. For these reasons, it is generally agreed that the correct relief angle for a given cutter must be determined by experience. Once the relief angle (as well as cutting speed and feed) that gives the best results on a certain operation has been determined, it should be recorded for future reference.

In general, the relief angle is 5° or 6° on peripheral cutting teeth, and 3° or 4° on side cutting teeth. The following table may also be used as a guide in selecting the proper relief angle according to the material to be cut:

Low-Carbon Steels	3° to 5°
High-Carbon and Alloy Steels	3°
Steel Castings	3° to 5°
Cast Iron	4° to 7°
Brass and Soft Bronze	10° to 12°
Medium and Hard Bronze	4° to 7°
Aluminum Alloys	10° to 12°

Relief on New Cutter

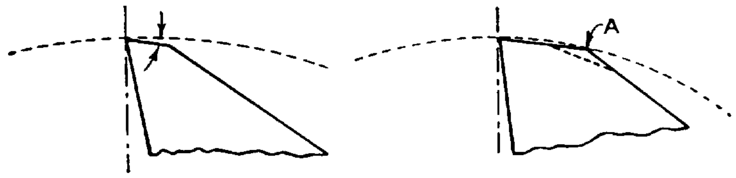


Figure 3—Width of land increases with repeated sharpenings, causing interference at A. Grind clearance angle as shown by dotted line to control width of land

Width of Land

The land, which is the narrow surface immediately behind the cutting edge that is ground to the relief angle, should be about $\frac{1}{32}$" to $\frac{1}{16}$" wide, depending upon the type and size of the cutter. As a result of repeated grinding, the land may become so wide as to cause the heel of the tooth to drag on the work. To control the width of the land, a clearance angle, usually double the relief angle, is ground as shown in figure 3 above.

The relief on the end teeth of end mills should be about 3° to 5°. On formed milling cutters or involute gear cutters, relief does not have to be considered in resharpening, because the teeth are so formed that when ground radially on the face, the relief remains the same.

Producing the Relief Angle

The relief angle is determined by the setting of the grinding wheel, the cutter and the tooth rest. Either a straight wheel or a cup wheel may be used. If the lands on the cutter teeth are narrow, a straight wheel is frequently used. If the lands are wide, a cup wheel should be used. (See figure 4.)

It is possible to use a straight wheel on wide lands by swiveling the wheel head about 1° from the zero line so that the cut approaches a straight line.

The general procedure in obtaining the setting for the relief angle is to bring the center of the wheel and the work as well as the tooth rest all in the same plane and then raise or lower the wheel head (or the table) the proper distance to give the desired relief angle. When using a straight wheel, this distance varies with the diameter of the wheel; when using a cup wheel, the distance varies with the diameter of the cutter.

On some of the cutter grinding machines, the work head unit is provided with a dial graduated in degrees for quickly setting the cutter to the exact relief angle desired.

Still other cutter grinders, such as the Norton No. 20 Cutter and Tool grinding machine, have a tilting wheel head which greatly simplifies setting up. With this improved fea-

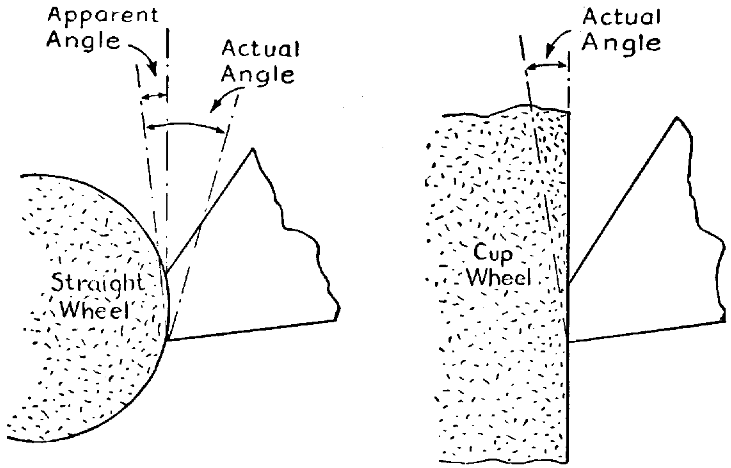


Figure 4—Showing effect of wheel shape on relief angle

ture, it is not necessary to go through the procedure of bringing the center of the wheel and the work into exactly the same plane. Simply adjust the tooth rest to the same height as the center of the work, and, using a cup wheel, in approximately the same plane as the cutter, tilt the wheel head to the desired degree. Relief angle is read on the vertical dial.

If this attachment is not available, the tooth rest setting for the relief angle must be obtained either from tables (see pages 200 and 201) or by the following methods and calculations.

Setting the Tooth Rest, Using a Straight Wheel

Figure 5 illustrates a milling cutter being ground with a straight wheel. The distance C between the center lines of the wheel and cutter varies with the relief angle. The method of producing the desired relief angle, when using a straight wheel, is as follows:

1. Bring the center of the wheel and the work into the same plane.
2. Fasten the tooth rest to the table of the machine and adjust the tooth rest to the same height as the center of the work, using a height gauge.
3. Raise (or lower, depending upon the direction of wheel rotation) the wheel head the proper distance by means of the graduated hand wheel (on Norton tool and cutter grinding machines). On some machines, where the wheel head is stationary and the table moves, the same effect is obtained by lowering the table.

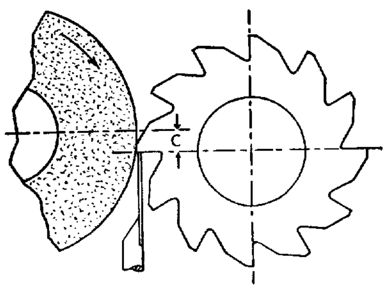


Figure 5—Developing the relief angle when using a straight wheel

The distance to raise or lower the wheel head when using a straight wheel may be calculated as follows: Multiply the relief angle in degrees by the diameter of the wheel in inches, and this product by the constant .0087.

Example: To determine the distance to raise or lower the wheel head for a 7° relief angle, using a straight wheel 6″ diameter.
Solution: C = 7° x 6″ x .0087 = .365″.

Setting the Tooth Rest, Using a Cup Wheel

Fig. 6 shows the use of a cup wheel for sharpening a cutter. The setting for producing the desired relief angle, of a spiral milling cutter, for example, is obtained as follows:

1. Fasten the tooth rest to the wheel head and line up the tooth rest and center of the cutter in the same plane, using a height gauge.
2. Raise or lower the wheel head with the tooth rest the required distance.

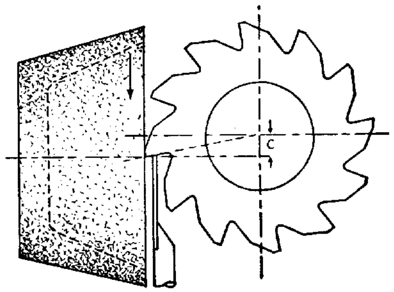


Figure 6—Developing the relief angle when using a cup wheel

To calculate this distance when using a cup wheel, multiply the required relief angle by the diameter of the cutter in inches and this product by the constant .0087.

Example: To determine the distance to raise or lower the wheel head beyond the center of a cutter 3″ in diameter in order to produce a relief angle of 5°, using a cup wheel 4″ in diameter.

Solution: C = 5° x 3″ x .0087 = .130″.

If the cutter grinder is equipped with a tilting wheel head, this is simply set to the desired relief angle as read on the vertical scale.

Typical Set-Ups for Sharpening Cutters

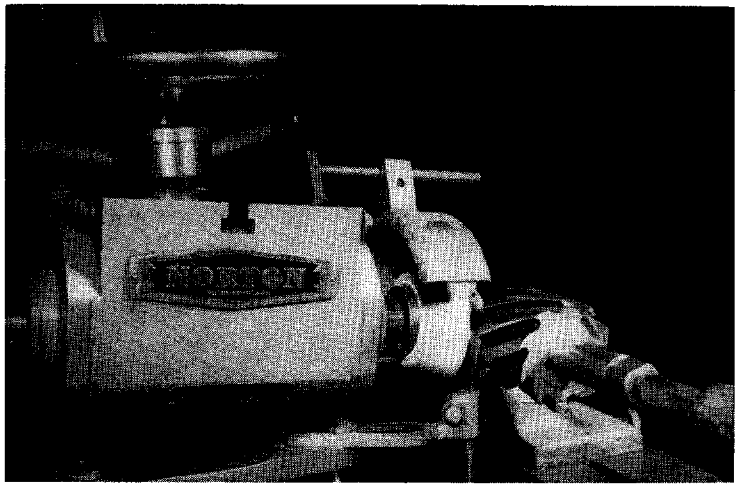
To give the reader a general idea of the methods commonly employed in the setting-up and sharpening of cutters, reamers and similar tools, the following pages illustrate a number of typical set-ups, together with a brief description of the set-up and the grinding procedure employed in each case.

From the standpoint of design and method of sharpening, cutters may be classified into two general groups:

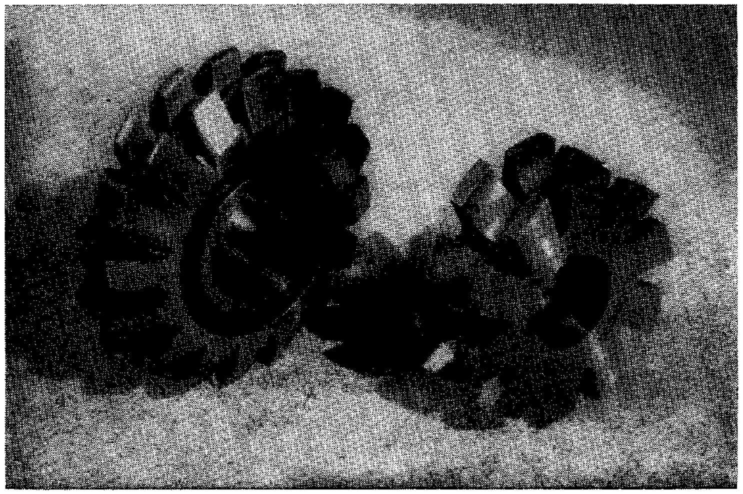
1. Cutters which are sharpened on the periphery, or sides, by grinding the relief angle behind the cutting edge of the tooth. Included in this group are plain milling cutters (straight and spiral teeth), side milling cutters, face milling cutters, end mills, slitting saws, and reamers.
2. Cutters which are sharpened by grinding the front, radial cutting faces of the teeth so as not to alter their profile. This group includes formed cutters, involute gear cutters, hobs, taps, and forming tools.

Plain (Spiral) Milling Cutters

The cutter is mounted on an arbor which is supported between centers and set sufficiently below the center of the



Sharpening a spiral milling cutter



Formed cutters

wheel spindle to produce the desired relief; or, on tilting wheel head cutter grinders, the wheel head equipped with cup wheel is tilted the desired amount of relief in degrees.

The tooth rest must be mounted on the wheel head and adjusted so that it has a complete bearing on the tooth to be ground at the point of grinding contact. Holding the cutter against the tooth rest with a slight hand pressure to maintain a uniform spiral, the cutter is traversed across the wheel face, either by moving the table or sliding the cutter on a cutter bar.

In sharpening plain milling cutters the greatest difficulty lies in keeping the peripheral cutting edges radially equal (a cutter out of truth cuts with a constant pounding action). If the wheel wear during the sharpening operation is equalized, it follows that the cutter is kept cylindrical. This is achieved by grinding around the entire cutter, then revolving it 180°, starting anew on a tooth just opposite the original starting point and taking another light cut all the way around the cutter. This method is repeated, taking light cuts until the cutter has been sharpened sufficiently. With the new Norton "G" bond wheels, slightly harder wheels can be often used which hold size all around a cutter, making this procedure unnecessary.

A straight wheel can also be used for grinding plain cutters. A cup wheel, however, has the advantage of producing a straight angle of relief back of the cutting edge. To prevent the opposite side of the cup wheel from striking the cutter, the wheel head should be swiveled slightly from the zero line.

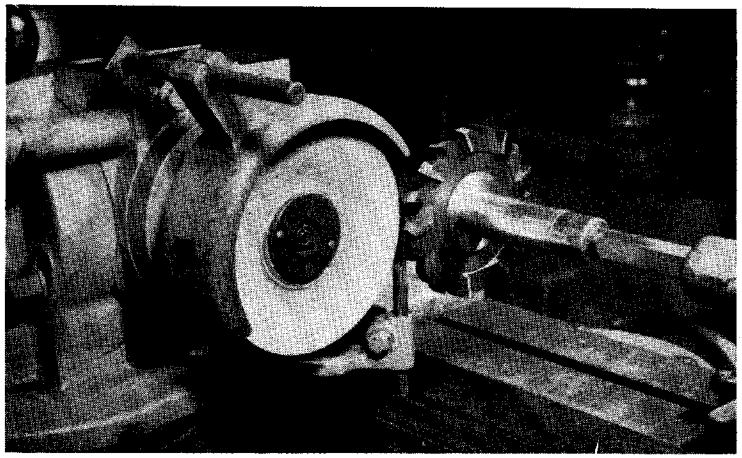
Some tool rooms have found that cutters for use on steel and cast iron will cut with less chatter and stand up longer between regrinds, if they are first ground cylindrically and then backed off to leave a land from .005″ to .010″ wide at the cutting edge.

Staggered Tooth Milling Cutters

Staggered tooth milling cutters, having alternately right and left-hand spiral teeth, may be sharpened at one set-up by using a tooth rest with the top of the blade either rounded or shaped with a double angle. The operation is similar to grinding a plain spiral mill, with the cutter mounted on an arbor between centers and the tooth rest fastened to the wheel head.

The blade of the special tooth rest shown in figure 7 (page 38) is ground to coincide with the right and left spiral angles of the cutter teeth. The high point (c) of the tooth rest must be located in the center of the cutting face of the wheel. The wheel head is raised sufficiently to give the desired relief.

The cutter is traversed across the wheel with the spiral edge of the tooth resting on the corresponding edge of the tooth rest. In grinding the next tooth, having the alternate spiral, the cutter is traversed in the opposite direction, using the other



Sharpening a staggered tooth milling cutter. Here a dish wheel is being used as straight wheel with advantage of narrow face at periphery

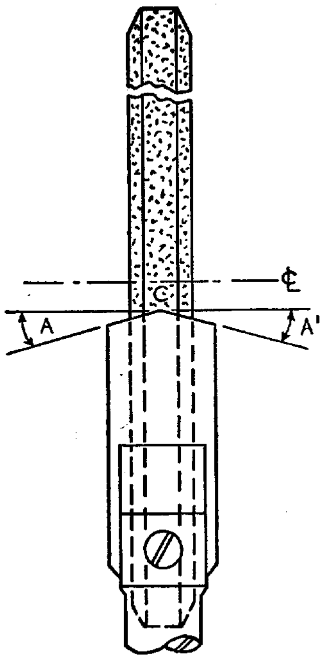


Figure 7—Shape of blade of tooth rest for sharpening staggered tooth milling cutters

edge of the tooth rest. Best results will be obtained if the face of either the straight wheel or dish wheel is beveled to about ⅛″ wide at the periphery or the rim.

Side Milling Cutters

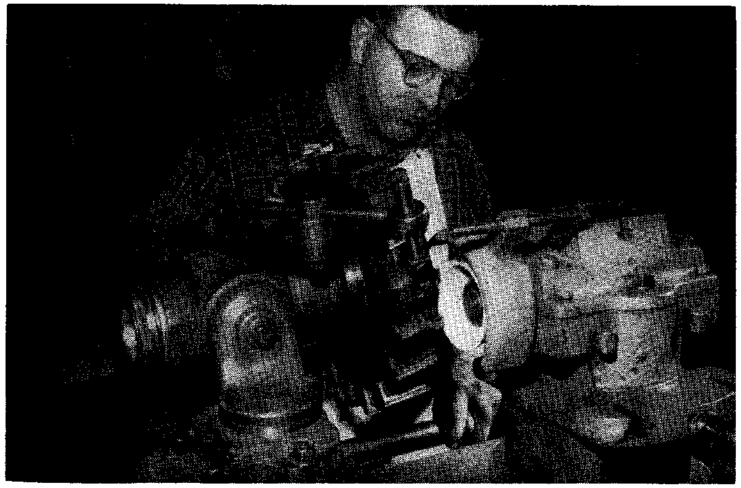
The cutter is mounted on a stub arbor and clamped in the Vee of the combination attachment or in the universal work head as shown on the next page. The tooth rest is usually fastened to the work head.

While the set-up illustrated shows the use of a cup wheel and tilting wheel head, a straight wheel can also be used, in which case the cutter arbor is set in a horizontal position and the wheel head raised, or lowered, to produce the required side tooth relief. The peripheral teeth of side milling cutters are sharpened in exactly the same manner as previously described for plain cutters.

Face Milling Cutters

Special machines of suitably heavy construction are available for sharpening large face milling cutters. However, if they are not too large they can be sharpened on a universal tool and

Regrinding the side cutting teeth on a side milling cutter. Relief angle is set on tilting wheel head



Sharpening 16″ HSS milling cutter on tool and cutter grinder

cutter grinder. They should be mounted on a tapered shank supported in the work head spindle, in the same manner as they are supported on the milling machine. The operations involved in sharpening a face milling cutter are similar to those of sharpening a shell end mill and include grinding the periphery, face or sides and corners of the blades.

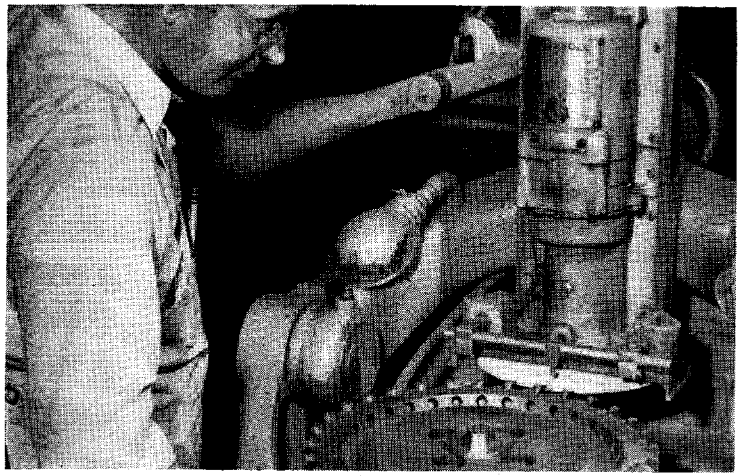
The set-up for one of these three steps is shown in the lower illustrations on the preceding page. For cast iron, the peripheral relief angle should be about 4°; for soft steel, about 6°. A secondary clearance may be ground to leave a land $\frac{1}{16}$″ to $\frac{3}{32}$″ wide.

The same relief angles are used for the face edges which, for rough milling, should have a land about ⅜″ wide, with the remaining portion of the edge ground off at an angle of about 3° toward the center of the cutter. Finish milling is a thin shearing operation and for best results the face of the cutter should be ground off at an angle of 1° to 2° to give it a slight lead into the work. The corners of the blades are usually chamfered 45° by swiveling the work head or table and left $\frac{1}{16}$″ to ⅛″ wide.

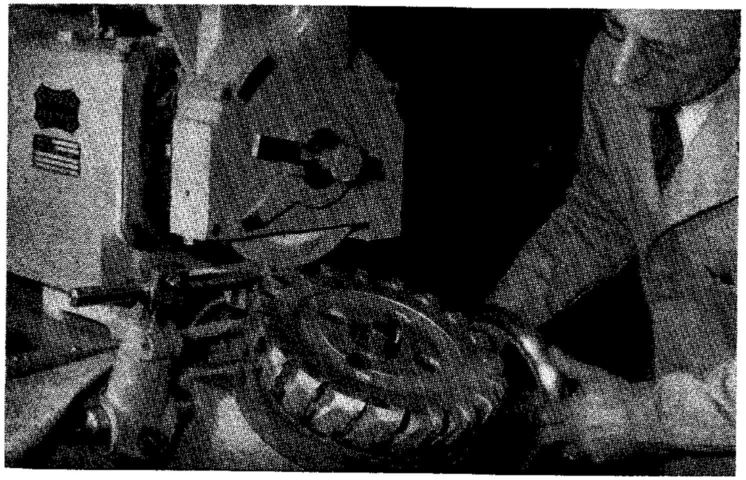
After grinding, the cutter should be carefully checked on the face with a dial indicator. If the cutter has been properly ground, taking light finishing cuts of not more than one half thousandth inch per pass, tooth height should be uniform. Here again, the new G bond wheels permit a heavier cut with less wear, making it possible to more easily hold tooth height.

End Mills

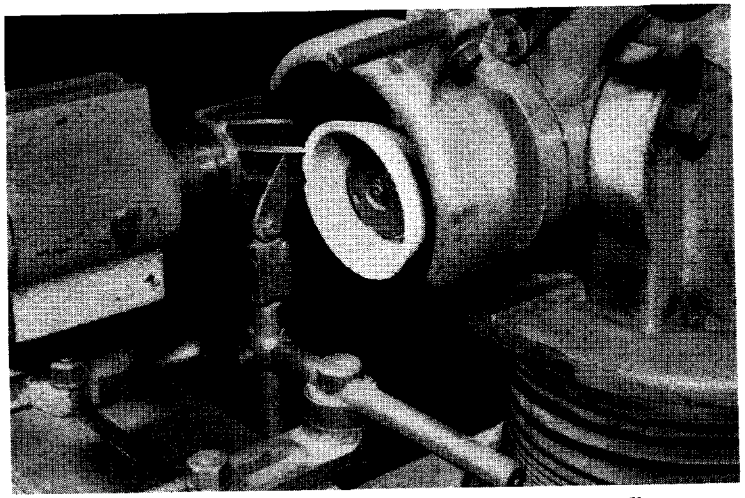
End mills with shanks are supported in the universal work head or in the combination attachment; if of the shell type they must first be mounted on a suitable arbor. In sharpening the end teeth, the work head is generally swiveled horizontally



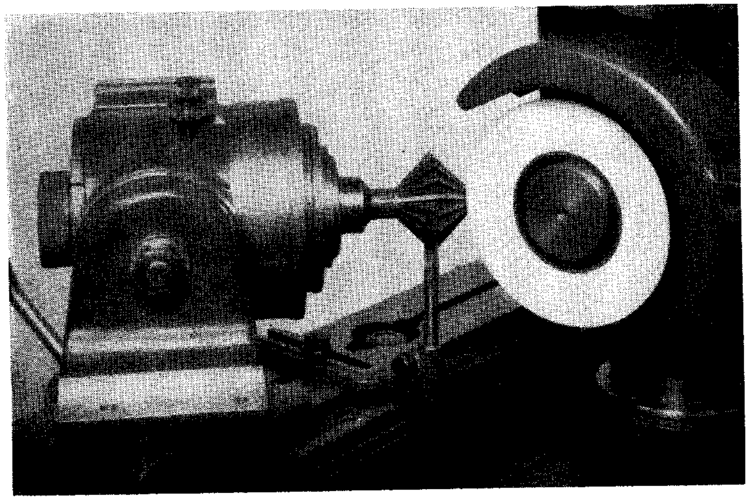
Sharpening peripheral cutting edges of large HSS inserted blade face mill on a special cutter grinder



Sharpening the 45° chamfer on another type of cutter grinder



Set-up for backing off face cutting edges of end mill



Sharpening a double angular cutter

about one-half degree from the zero line so as to grind the teeth slightly low in the center of the mill and thus prevent dragging. The work head is swiveled vertically to give the desired relief (or the tilting wheel head is tipped).

The illustration shows an end mill set up for backing off the end teeth. The tilting type wheel head is tipped down to give the desired relief.

Angular Cutters

An angular cutter may be considered as made up of a number of plain milling cutters of different diameters. When grinding any cutter with a cup wheel on a conventional tool and cutter grinder, the relief angle is determined from the diameter of the cutter. It follows that this method would lead to difficulties when applied to angular cutters because of the variation in the diameter of the cutter along the cutting edge. For this reason, a straight wheel is commonly used.

On modern cutter grinders with tilting wheel head feature, a cup wheel can be used without need of "trial and error" tactics and the relief angle is constant for the full tooth length.

The cutter is mounted on an arbor and supported in the universal work head or in the Vee of the combination attachment which is then swiveled to the angle of the cutter. The tooth rest is fastened to the swivel table and adjusted against the tooth to be ground. The wheel head is then raised (or tilted) to give the desired relief. The cutter is held against the tooth rest by hand as it is traversed across the wheel face.

Formed Cutters

Formed cutters are ground radially on the cutting face with a dish wheel. Various methods are employed for controlling the spacing of the teeth.

Two methods are illustrated on the next page. At the top is shown a formed cutter sharpening attachment (in-feed type). An index center providing exact indexing of all the common peripheral tooth spacings can also be used.

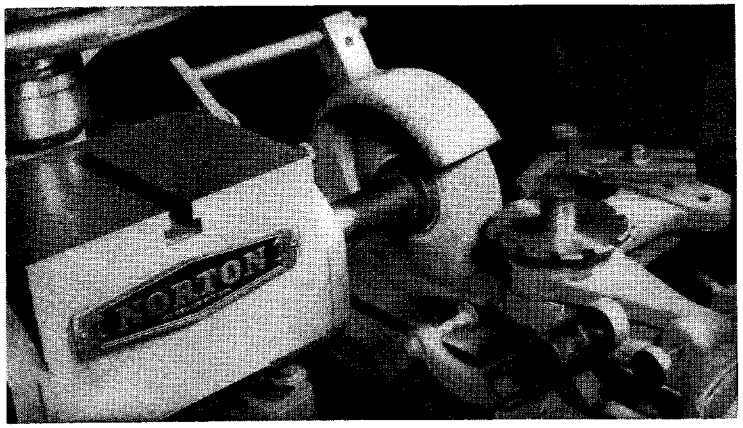
In the method shown in the lower photograph, the cutter is revolved until the face of a tooth just touches the cutting face of the grinding wheel. Previously, the wheel face and the center of the radial tooth cutter have been brought into the same vertical plane. The tooth rest is then adjusted against the back of the tooth to be ground.

Some form cutters are made with a forward rake or undercut tooth. In sharpening these, care must be taken to offset the wheel face so as to maintain the original rake angle. The amount of this offset, measured on a horizontal plane, is usually stamped on the cutter in thousandths of an inch.

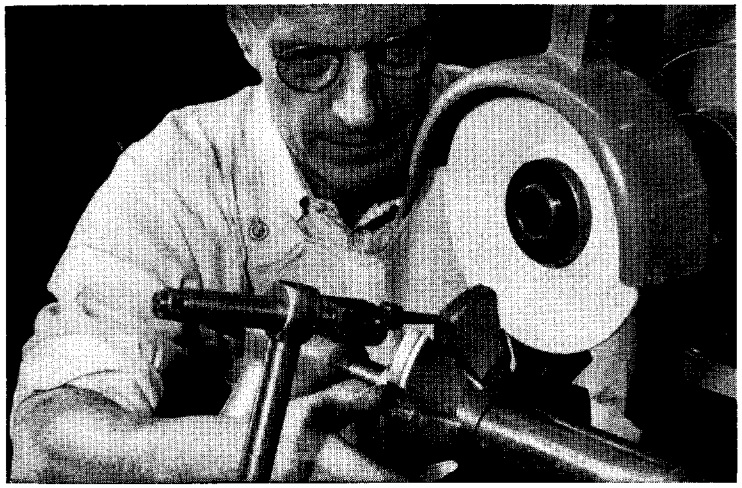
The cutter is passed across the wheel face with a steady motion, using the hand traverse. While grinding, the crossfeed must not be changed as this would change the radial line of the cutter face. Instead, the cutter is given a slight forward rotation toward the wheel by slightly advancing the tooth rest. If the cutter is badly worn and there is much grinding to be done, compensation for wheel wear can be made by resetting the wheel radially just previous to a light finishing cut. To insure correct spacing of the teeth using this method, it is advisable to first grind the backs of the teeth, especially on a new cutter.

Fellows Gear Shaper Cutters

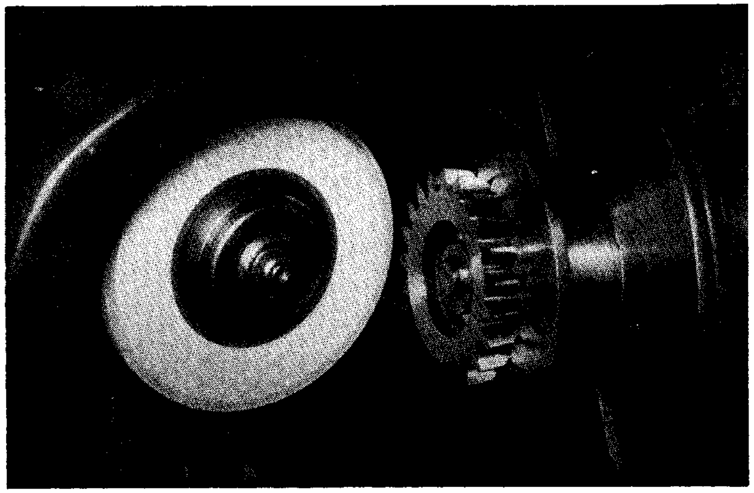
The set-up for sharpening a Fellows Gear Shaper cutter is shown in the illustration on page 46. The cutter is supported on a face plate and tapered stud mounted in the universal work head which is swiveled horizontally to an angle of



Sharpening a circular form cutter, using special attachment for sharpening cutters with radial tooth faces



In this set-up for sharpening a form cutter, the tooth rest is adjusted against back of tooth being ground



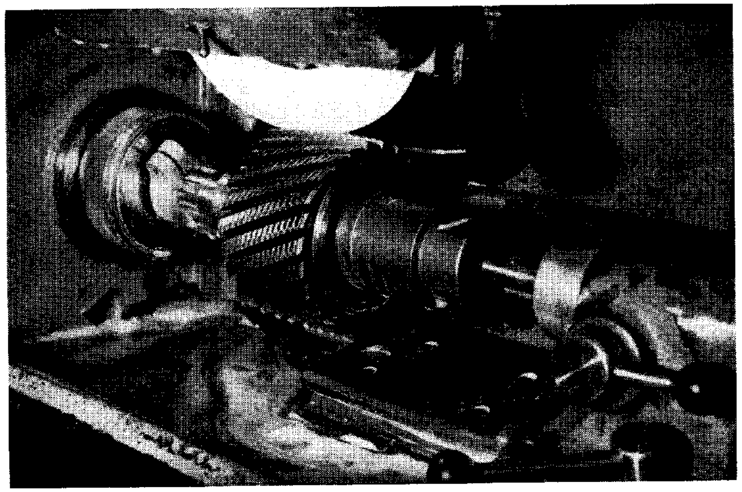
Sharpening a Fellows Gear Shaper cutter on a cutter and tool grinder

5°, representing the rake of the cutter. After grinding, the accuracy of the cutter angle should be checked with a gauge to be sure it is exactly 5°.

Hobs

Like formed cutters, the teeth of hobs are made with uniform relief and are sharpened by grinding radially on the faces of the teeth, using the beveled side of a dish wheel, or a "B" face straight wheel. The most important precaution to be observed in setting up for this operation is to line up the cutting face of the wheel with the center of the hob. Also, after each cut, the hob should be revolved toward the wheel for taking additional cuts and not adjusted to the wheel by means of the cross screw.

In the actual sharpening operation, whether it is done on



Sharpening a hob on a special purpose hob sharpening machine

a tool and cutter grinding machine or on a special hob grinder provided with automatic work spindle indexing arrangement, care must be taken to remove the same amount of stock from each tooth. It can readily be seen that if some teeth are ground back more than others, those which are left high will have all the work to do, resulting in irregular cutting action which will affect the accuracy and finish of the teeth produced.

Hobs of average size are ground successfully with 32A60-J8VG or 19A60-I8VG Alundum vitrified wheels, dish shaped. For larger hobs, 19A54-J8VG has been found a very satisfactory specification.

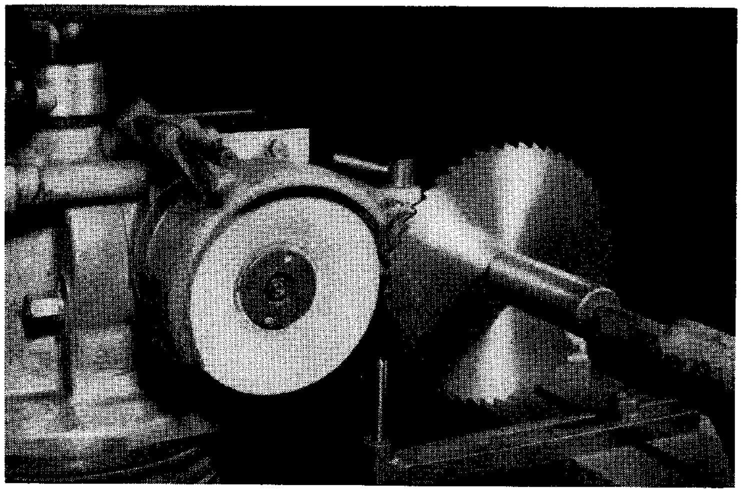
Metal Cutting Saws

Small saws are ground in essentially the same manner as milling cutters—usually with a 5° relief angle. On very small saws the angle may advantageously be increased to about 7° while on larger saws, around 10″ in diameter, for example, it should be reduced to about 3°. To minimize the effect of wheel wear, a light finishing cut should be taken completely around the saw.

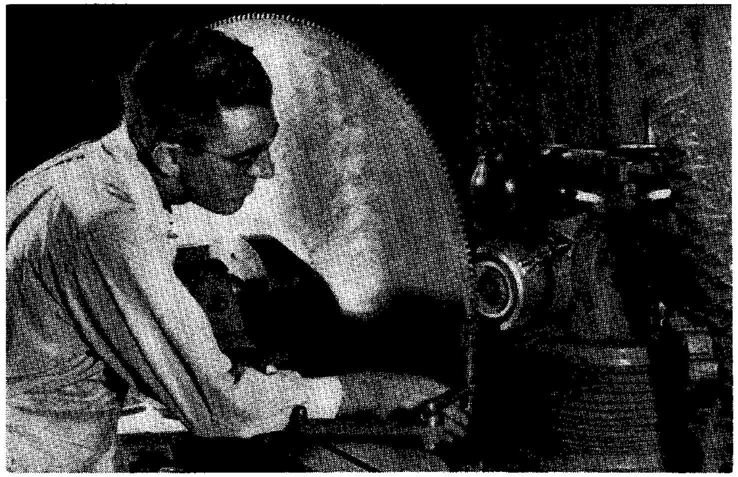
Except in the case of very small saws, the same grain and grade of grinding wheels may be used as for sharpening milling cutters, such as 32A46-K8VG Alundum vitrified.

While a straight wheel or a cup wheel can be used, some operators prefer to grind these saws with the narrow periphery of a dish wheel to avoid overheating and possibly burning the teeth. The method of setting up to produce the desired clearance angle is described on page 32.

Large metal cutting saws are generally sharpened on special, automatic saw sharpeners. If such a machine is not



Sharpening (backing off) the teeth of a small metal cutting saw on periphery of dish wheel



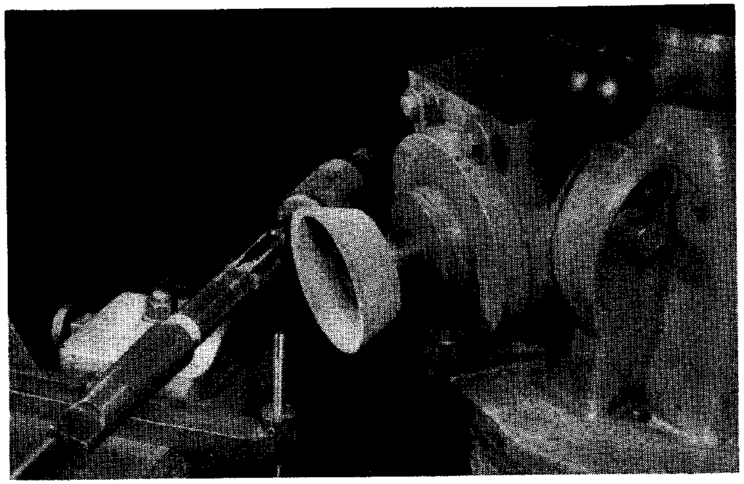
Sharpening a large metal cutting saw on a tool and cutter grinder

available, the saws can still be sharpened on a tool and cutter grinder by using the setup shown above for a 39″ diameter carbide-tipped saw. In the case of high-speed steel saws, to offset the effect of wheel wear, divide the saw into quarters and start grinding on a new quarter with each complete rotation of the saw.

Chucking Reamers

There appears to be no standard method of sharpening reamers. In the case of machine or chucking reamers of the solid type, the size obviously is lost as soon as the periphery is touched with a grinding wheel. Inasmuch as most of the cutting is done by the entering corners of the blades, it is common practice to sharpen such reamers by simply grinding the lead or front bevel, usually at an angle of 45°.

When the straight cutting edges become dull to the point



Sharpening a machine reamer by backing off the front cutting edges (wheel guard removed to show set-up details)

of requiring sharpening, the reamer is ground cylindrically to the next smaller size. The cutting edges are then backed off, leaving a land from a few thousandths to about $\frac{1}{32}$" wide depending upon the material being reamed and the size of the reamer. The reamer will be found to cut better if it is left .001" to .002" smaller at the back end than at the front.

Chucking reamers of the expansion or adjustable type, before resharpening, are first set up oversize a sufficient amount. They are then usually ground cylindrically to the exact desired size, with the reamer supported between centers and using a straight wheel. The cutting edges are then backed off in the conventional manner for milling cutters, leaving a land of the proper width for the material being reamed.

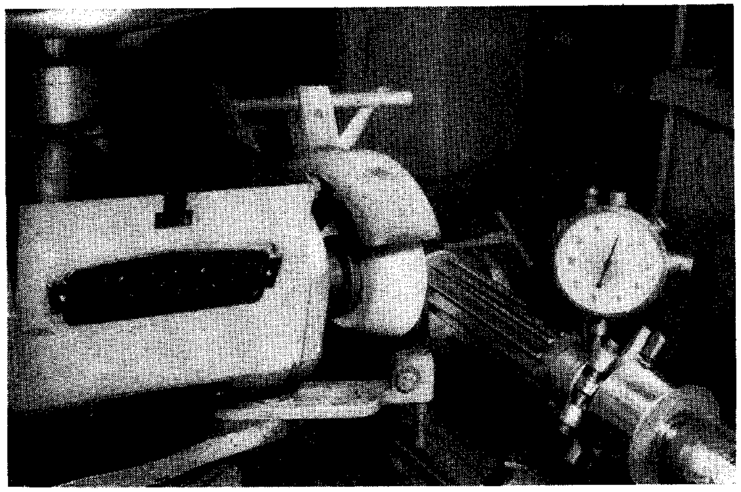
For steel, best results are generally obtained with a land from .005" to .008" wide. For cast iron, a slightly wider land,

about $\frac{1}{64}$", may be used. For nonferrous metals like brass and soft bronze, the land should be reduced to a "white line," no more than about .002" wide.

Hand Reamers

Except in the smaller sizes, the majority of hand reamers in use today are of the expansion or adjustable type. The usual procedure in sharpening such a reamer is to set it up oversize a sufficient amount, grind it cylindrically to the exact desired size and then back off the teeth so as to leave practically a sharp cutting edge, the land being no more than a few thousandths inch wide. A few light strokes along the cutting edges with an India oilstone will remove any slight burr produced in grinding.

If the reamer is provided with a front pilot and is ground between centers, the center supporting the expansion plug end

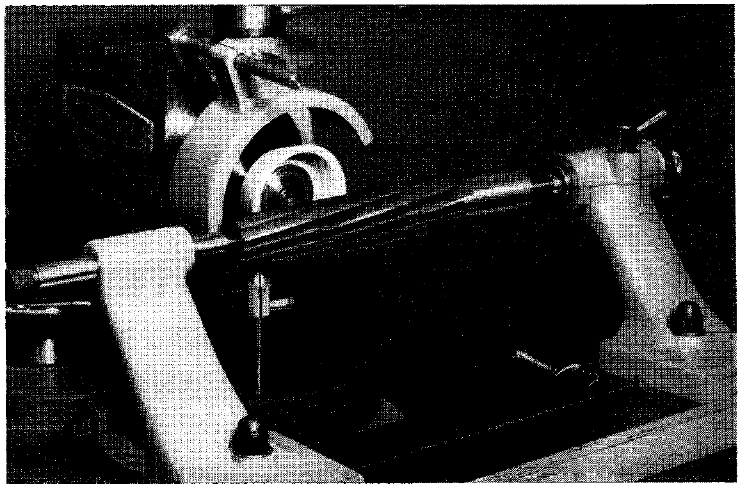


Sharpening an adjustable hand reamer. Note adjustable center should be adjustable so that the pilot surface can be centered with an indicator before grinding.

Hand reamers are always ground with a taper or lead at the front part of the blade to allow it to enter the hole freely and without chattering. The amount of lead depends on the amount of material to be removed and is generally about $\frac{1}{16}''$ per foot (obtained by adjusting the swivel table of the grinding machine) and approximately ½″ in length for reamers up to 2″ in diameter and ¾″ in length for larger sizes.

Taper Reamers

Taper reamers must be ground with great care in order to maintain the taper and the diameter absolutely correct. In the machine set-up shown below, the tooth rest is fastened to the wheel head and the finger is adjusted to support the



Sharpening a spiral taper reamer

tooth being ground. The swivel table has been adjusted to the required taper per foot, as indicated on the graduated scale at the end of the table.

The relief angle will depend on the material to be cut and the size of the reamer. On tilting wheel head type cutter grinders, such as the one illustrated here, the relief setting is made by simply tipping the wheel head to the angle desired. Trial cuts should be taken with a ground reamer and the reamer hole tested for truth with a standard plug before using the reamer.

In some tool rooms, taper reamers are sharpened by grinding cylindrically and then backing off the teeth, leaving a land a few thousandths inch wide, as in grinding straight reamers. This method insures uniform tooth height, which is important if the reamer is to cut without chattering and leave a smooth finish.