Back To Basics

Shaper Cutters — Design & Application—Part 2

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Editor's Note: This is part two of a feature begun in our last issue. In the Mar/Apr issue, Mr. Janninck discussed the shaping method, spur and helical cutters, herringbone cutters, cutter blank sizes, tooth shape change, tooth forms, and cutting internal gears.

Cutter Sharpening

Cutter sharpening is very important both during manufacturing and subsequently in resharpening after dulling. Not only does this process affect cutter "over cutting edge" quality and the quality of the part cut, but it can also affect the manner in which chip flow takes place on the cutter face if the surface finish is too rough or rippled.

The sharpening of spur cutters and those helicals under 8° helix angle that are made with a conical sharpening, are usually sharpened on a rotary table surface grinder using a centering plug, and with the table set at the sharpening angle. See Fig. 2-1. The sharpening angle has been standardized at 5°, so normally the table is set at 5°. Small downfeeds are used along with a good coolant flow to prevent material burn. No wavy pattern should appear.

The cutter manufacturer would recommend using two separate grinding operations, one a roughing pass with a coarser grit, and the second with a fine grit to get a fine, almost polished finish on the tooth face. Usually for expediency only, one operation is used.

The sharpening of helical cutters with the step-sharpening, as seen in Fig. 2-2, which is also called normal sharpening, requires more elaborate equipment. A surface grinder fixture which contains the geometric requirements is shown in Fig. 2-3. These fixtures have been made in several styles and are usually used in small shops. The fixture is usually made with a 5° angle. Fig. 2-4 shows a view of the sharpening plane on the cutter tooth face and the face sharpening angle.

For quantity sharpening of stepped face cutters, say on a high production gear line, specially constructed machines with automatic operation are used.

While the standard practice is to place the cutting face normal to the cutter helix, experience has proven a benefit in cutter utility by considering the off-normal sharpening. This is called a chip control sharpening, and the helical sharpening angle is usually 8° less than the cutter helix angle. See Fig. 2-5.

Cutter Lead Guides

For a spur cutter the reciprocation takes place in a straight line; thus, for all spur cutters a single spur guide is used in moving the cutter along a straight path.

For a helical cutter a helical guide of the same hand and lead as the cutter being used must be available. As a helical cutter is reciprocated it must pass the cutter teeth through a helical lead path. See Fig. 2-6 for a schematic view of the functioning of typical spur and helical lead guides.

For a vertical axis machine, the guide and shoe are usually located on the top end of the cutter ram, where they are accessable for changing. Lead guides are a required setup item.

Frequently the gear manufacturer wants to utilize lead guides that are available in-house, avoiding extra cost and possible delay in procurement. First, confirmation is made of the hand of guide and cutter. Then a comparison is made of the lead of guide and gear and number of teeth of cutter and gear according to this formula:

$$\frac{\text{LEAD OF GEAR}}{\text{GEAR TEETH}} = \frac{\text{LEAD OF GUIDE}}{\text{CUTTER TEETH}}$$

If the data meets equality in this equation, the guide can be used. Varying the cutter teeth or altering the gear data may find a solution.

Gear Clearance Grooves

When cutting a gear located adjacent to a shoulder, it is necessary to provide a groove for the cutter to pass into at the bottom of the stroke. Fig. 2-7 shows such a case for a spur cutter. Depending on the helix angle and the type of sharpening used, the groove width for helical gears will usually be wider. See Fig. 2-8.

Indicating Diameters

An accurately ground ring located on the shoulder diameter just behind the teeth of a disk or deep counterbore

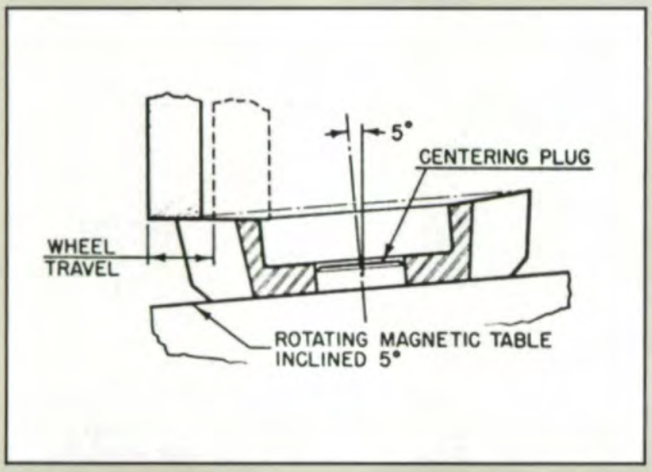

Fig. 2-1 – Circular sharpening of a cutter.

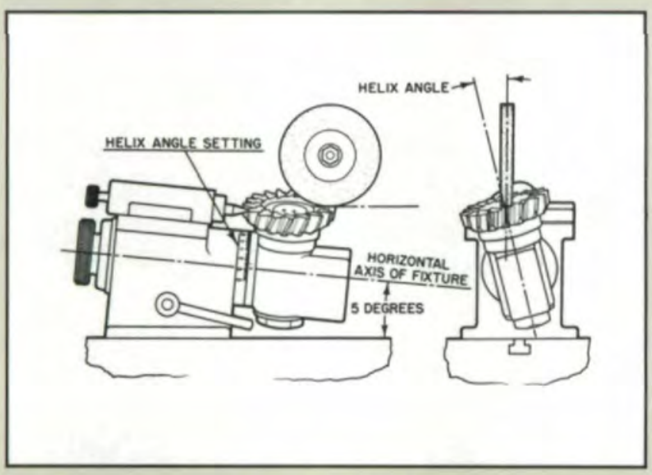

Fig. 2-2 – Helical cutter with step sharpening and its cut gear.

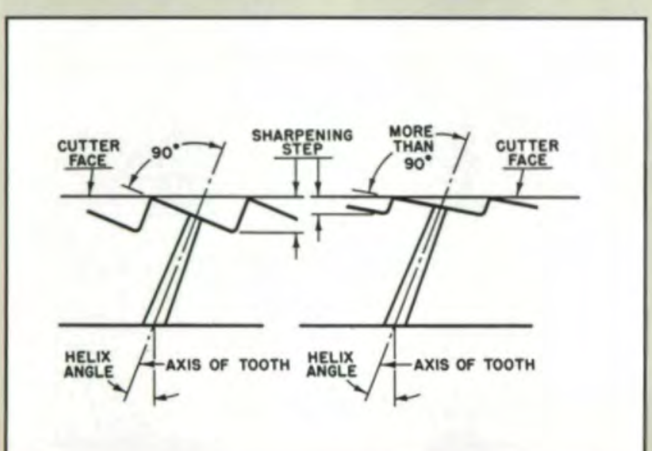

Fig. 2-3 – Helical cutter sharpening fixture.

Fig. 2-4 – Normal sharpening plane.

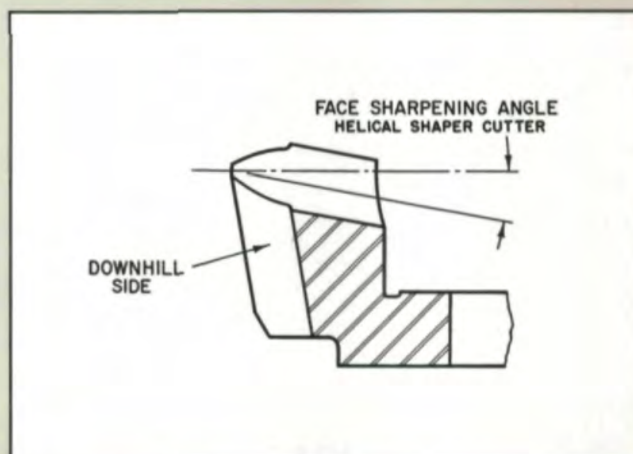

Fig. 2-5 – Normal and chip control sharpening.

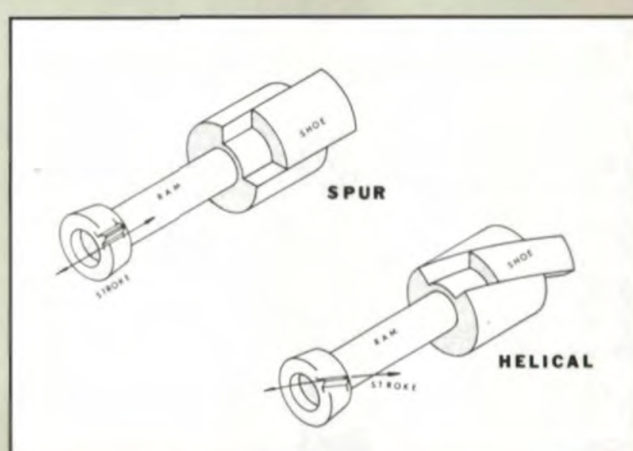

Fig. 2-6 – Diagramatic view of spur and helical lead guides.

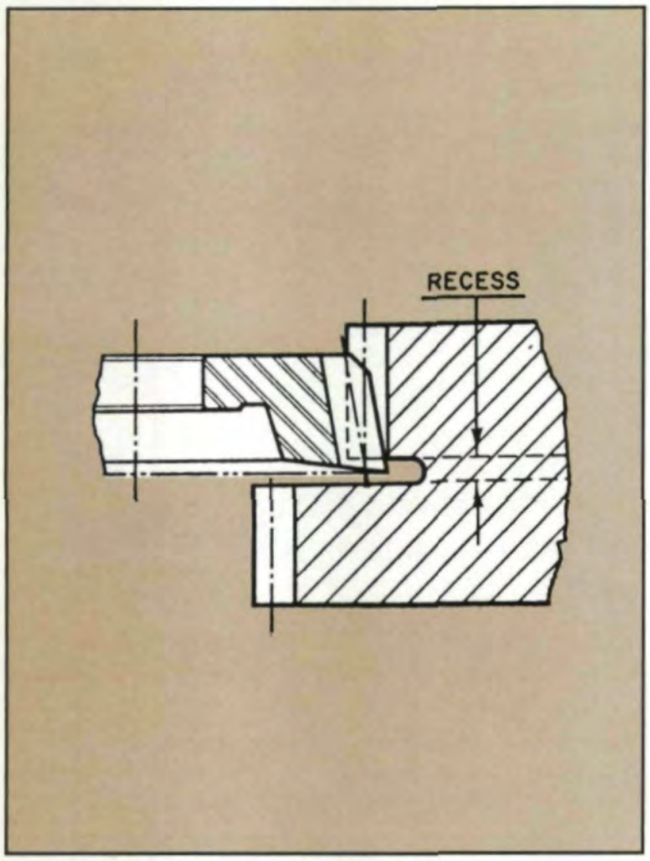

Fig. 2-7 – Clearance groove for a spur cutter.

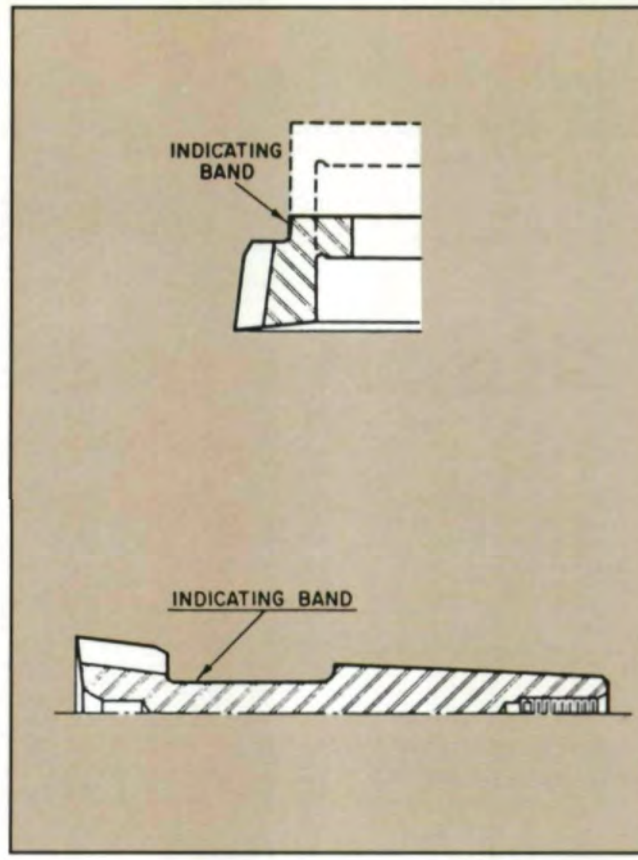

Fig. 2-9 – Cutter indicating rings.

Fig. 2-8 – Clearance groove for a helical cutter.

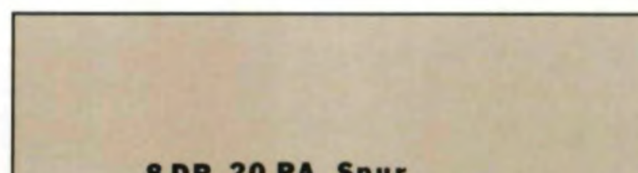

Fig. 2-10 – Shaper cutter accuracy capability.

shaper cutter, or on the diameter behind the teeth of a hub type or shank type cutter, is used as a truing ring for checking cutter runout while it is mounted in the gear shaping machine. See Fig. 2-9.

Cutter Tolerances

The first source for information on the tolerances for shaper cutters is the publication ANSI B94.21, "Gear Shaper Cutters." Only one level of accuracy is specified, which is called "Commercial Tolerance". MCTI, Metal Cutting Tool Institute, has similar standards which do include tolerances for "Commercial Ground" and, for certain cutter sizes only, tolerances for "Precision Ground".

Fig. 2-10 shows a comparison chart of what could be expected by cutting a gear using commercial tolerances, first, where only cutter tolerances are considered, and second, where some allowance is made for machine and machining influences. The best cutting ability is about AGMA Q-10 and, with allowances, about AGMA Q-8.

Tolerances are published for profile, spacing, and PD runout for the various types of cutter—disk, deep counterbore, shank, and herringbone. Tolerances are also given for bore, tooth thickness, flatness of cutter back, OD angle, sharpening angle, side relief angle, shank runout, shank diameter, indicating band runout, OD runout, and OD size. For herringbone cutters, matching tolerances on OD and width are given.

Cutter Base Circles

With the representation of the shaper

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Fig. 2-11 – Single flank generating grinder.

cutter as a gear, it is also inspected on an involute checking instrument. The base circle diameters are not the theoretical ones expected, but are corrected for the cutting clearances on the cutter. For a spur cutter the base diameters are the same on both flanks, right and left. With the additional geometry of the helix and normal sharpening on a helical cutter, base circles differ from side to side.

The base diameters of spur or helical cutters are constant throughout the life of the cutter.

Because of the need to maintain a cutting edge in the transverse plane, herringbone cutters are not corrected, and the base diameter is equal to the theoretical value and is the same on both flanks.

Cutter Generation

The traditional process used in making shaper cutters is by abrasive wheel grinding, which can provide both a good finish and accuracy. All processes use some form of involute generation, whether it be a single flank grind using the radial side of the grinding wheel, such as seen in Fig. 2-11, or using a dual flank grind with a reciprocating vee-shaped wheel, as is shown in the diagram in Fig. 2-12. Another method using a ribbed or threaded abrasive wheel running in timed relation to the cutter has been used for some unmodified fine diametral pitch tools.

The single flank method requires a *large wheel relative to the cutter width* and is positioned tangent to the cutter tooth flank. The wheel position is stationary, and the cutter is rotated and translated below the wheel to generate the involute. Each flank is ground separately, and the number of teeth is established by an indexing mechanism.

The dual flank grinder uses a vee-shaped grinding wheel dressed to generate the form required on the cutter. The cutter is rolled tangent to a generating circle and passed or translated through the reciprocating grinding wheel. Indexing takes place at the end of a generation cycle. The entire profile of the cutter, tip, root, and both flanks can be ground at one time with one space being completed between indexing cycles.

Fig. 2-12 – Dual flank generating grinder.

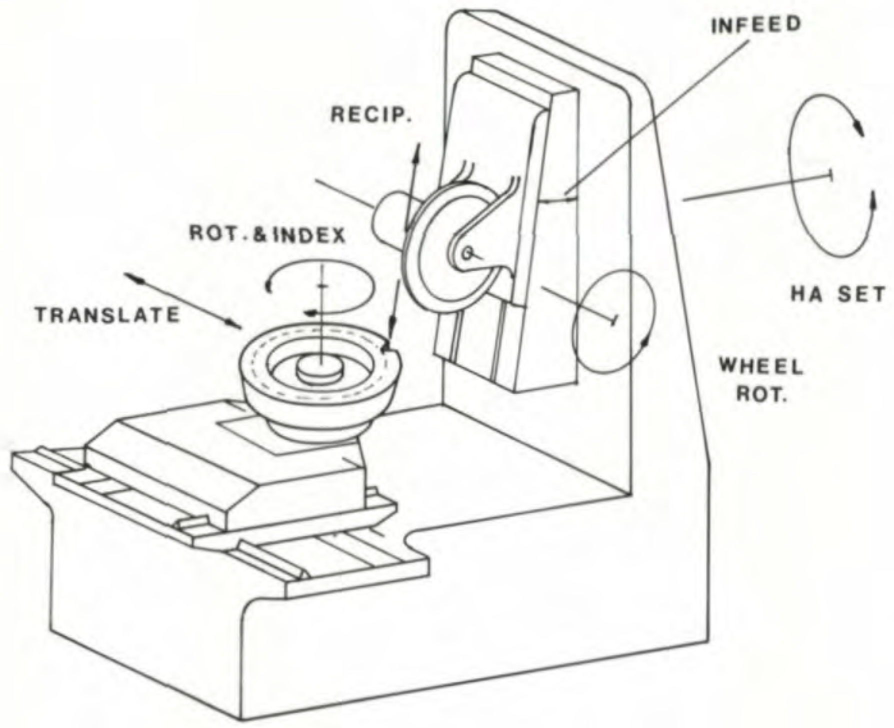
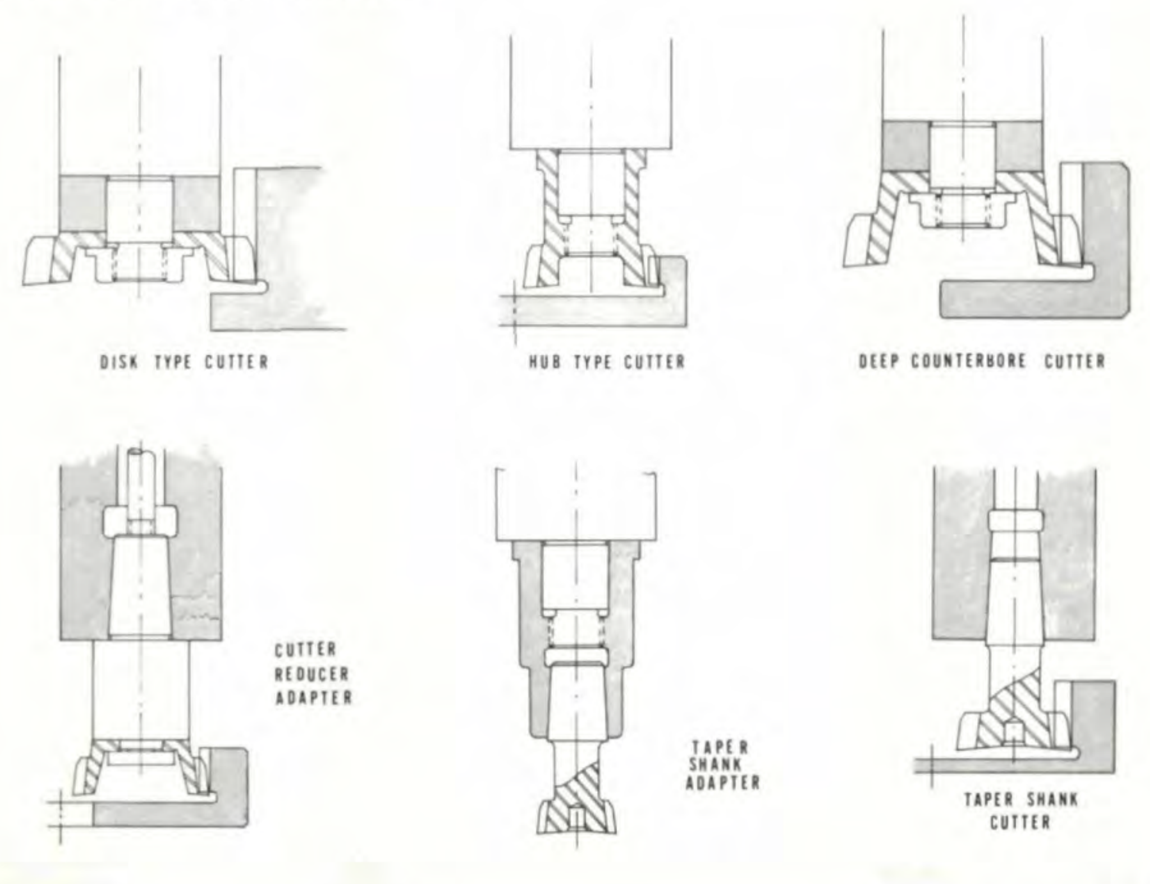


Fig. 2-13 – Machine mounting of various cutter types.



Cutter Clearance Angles

The side relief angle of a shaper cutter generally ranges between 1.5° and 2.5°, with the norm being 2.0°. This is a relatively low amount of clearance for a metal cutting tool, and any substantial increase in this angle can cause drastic changes in cutter geometry and design and would reduce useful cutter life.

The cutter outside angle is a function of cutter-gear geometry, amount of side relief, and pressure angle. It ranges approximately from 3.5° for 30PA to 5.5° for 20PA and 8.5° for 14.5PA. The geometrically true cutter outside angle is not usually a straight angle, but is really a curve that is compromised to a straight line. The cutter designer must be fully aware of the deviation amount in order to make proper allowances.

Cutter PD

The cutter PD is defined in the same way as an equivalent gear using the same formulae. With shaper cutters the PD is frequently referred to in a general way, such as a 3" or 4" PD cutter, meaning a nominal or approximate size.

Cutter Oversize and Undersize

In optimizing cutter life and utility it is normally expected that a cutter will be made somewhat oversize or larger on diameter than standard. Some gear geometries may require that a gear be made undersize or less than standard on diameter.

Design Optimization

In the process of designing a gear shaper cutter, several possible extremes are considered. Going toward a maximum oversize design will reduce cutter tip land toward a sharp. Setting a practical limit on the tip flat and maintaining proper part geometry will yield the maximum oversize cutter.

In consideration of the smallest possible diameter undersize for the cutter without damaging effects on the cutter or part, the targeted end life point on the cutter is determined. With allowance for other factors in the total tool layout, the final design will fall in between these limits. Such designs are usually computer aided and are planned solely for one part.

Fig. 2-14 – Involute profile inspection of a cutter.

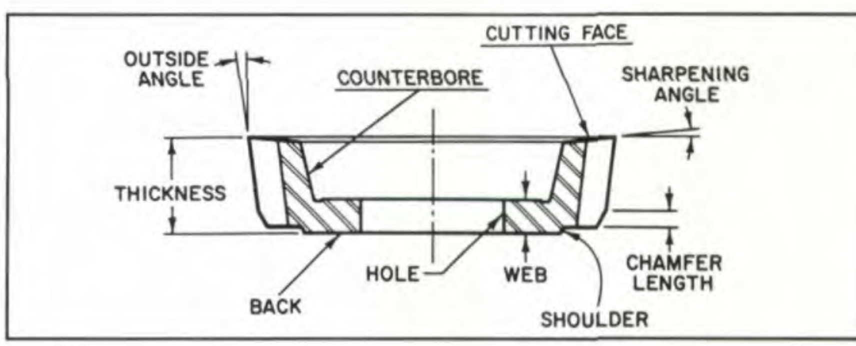


Fig. 2-15 – Cutter blank definitions.

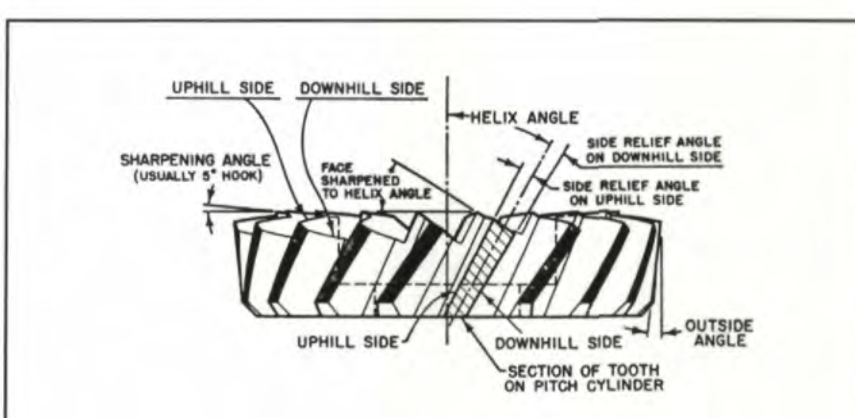


Fig. 2-16 – Helical cutter definitions.

Fig. 2-17 – Roller chain sprocket cutter.

Fig. 2-18 – Tandem cutter.

Fig. 2-19 – Cutter with teeth removed.

Fig. 2-20 – Groove and lip sharpening on herringbone cutter.

Keyways

Keyways are used on some shaper cutters, especially on helical cutters, where there is some chance that the cutter may slip rotationally under load. Herringbone cutters, always helical, use a keyway in the bore. Most other cutters use a slot in the mounting face. Another purpose of the keyway is for timing or alignment. Examples of keyways can be seen in some of the figures.

Cutter Mountings

Shaper cutters are made in various types to suit the special needs for application to the part or cutting machine. Fig. 2-13 illustrates various ways that these cutters can be mounted. While disk and deep counterbore cutters are fairly secure in their mountings, any long shank type cutter, including those used with taper or straight shank adapters, should be checked for possible excessive runout.

Cutter Inspection

Shaper cutters are inspected in a similar fashion to gears using some of the same involute, lead, and spacing instruments. Fig. 2-14 shows a view of a cutter during the involute profile check.

Nomenclature

Cutter nomenclature has been listed in several publications including the ANSI standard. Fig. 2-15 shows some of the terminology for a hole type cutter, and Fig. 2-16 illustrates some of the helical element definitions. Figs. 2-17 – 2-20 show cutters of various types and conditions.

Tool Materials

Most cutters are made of AISI M-2, M-3, and M-4 high-speed steels with some special applications of part material alloy content, part hardness, or material abrasiveness requiring the super materials, such as M-42, T-15, or Rex 76. Most of these materials are available in the particle metal process.

The titanium nitride coatings are also being used successfully on gear shaper cutters.

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