

The Gear Hobbing Process

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Gear hobbing is a generating process. The term *generating* refers to the fact that the gear tooth form cut is *not* the conjugate form of the cutting tool, the hob. During hobbing both the hob and the workpiece rotate in a continuous rotational relationship. During this rotation, the hob is typically fed axially with all the teeth being gradually formed as the tool traverses the work face (see Fig. 1a).

For a spur gear being cut with a single start hob, the workpiece will advance one tooth for each revolution of the cutter. When hobbing a twenty-tooth gear, the hob will rotate twenty times, while the workpiece will rotate once. The profile is formed by the equally spaced cutting edges around the hob, each taking suc-

cessive cuts on the workpiece, with the workpiece in a slightly different position for each cut (see Fig. 1b). Several cutting edges of the tool will be cutting at the same time.

The hob is basically a worm with gashes cut axially across it to produce these cutting edges. Each cutting tooth is also relieved radially to provide chip clearance behind the cutting edge. This also allows the hob face to be sharpened and still maintain the original tooth shape. The final profile of the tooth is created by a number of flats blending together. The number of flats corresponds to the number of cutting gashes which pass the workpiece tooth during a single rotation. Thus, the greater the number of gashes in the hob, the greater the number of flats along the

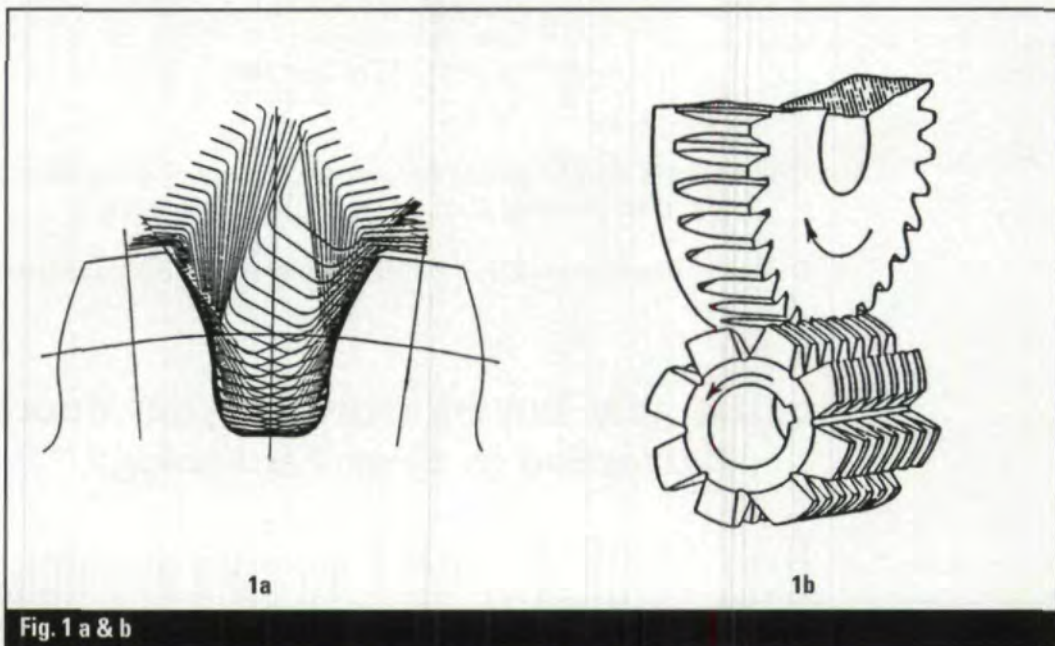


Fig. 1 a & b

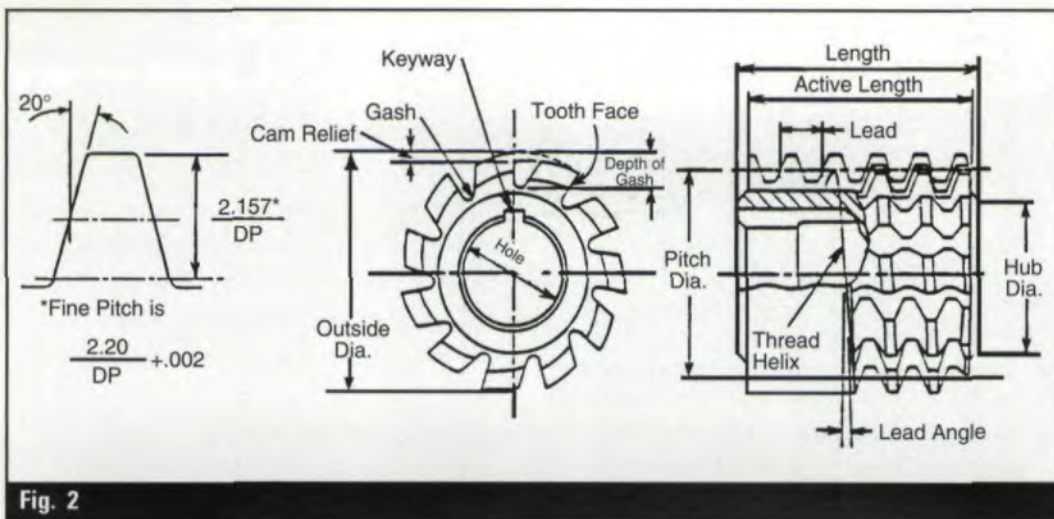


Fig. 2

profile which improves the "smoothness" of the tooth profile.

The Cutter

Hobbing is a generating process, and the hob will not cut the same shape as the cutting tool form. An unmodified involute gear tooth is produced by a hob with straight-sided cutting edges. Involute gear cutting is the largest application of hobbing (Fig. 2). In contrast, a straight-sided spline tooth is produced by a hob with curved cutting edges (see Fig. 3).

Cutter Modifications

It is possible to design the shape of a cutting tool to produce modified tooth forms. These are done for various reasons. The hob tooth root can be designed to cut the outside diameter of the gear tooth. With this "topping" hob, the tooth involute and the outside diameter of the blank will be hobbled in one operation (Fig. 4). This may eliminate finish turning of the gear blank, reducing machine operations.

The outside diameter of the gear will be concentric with the operating pitch diameter of the gear. This will provide a locating surface for subsequent operations and a method of measuring size.

Sharp corners between the tooth flank and outside diameter can be eliminated with a "semi-topping" or "tip chamfering" hob (see Fig. 5). With proper design such a hob may also correct the problem of gear tooth bending under load.

Gears which will be finished by a subsequent operation, such as skiving, shaving or grinding, may require clearance in the gear tooth fillet area for the finishing tool. This can be cut using a "protuberance" hob, which will

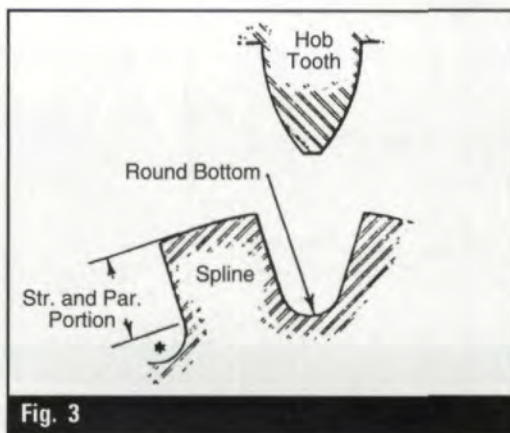


Fig. 3

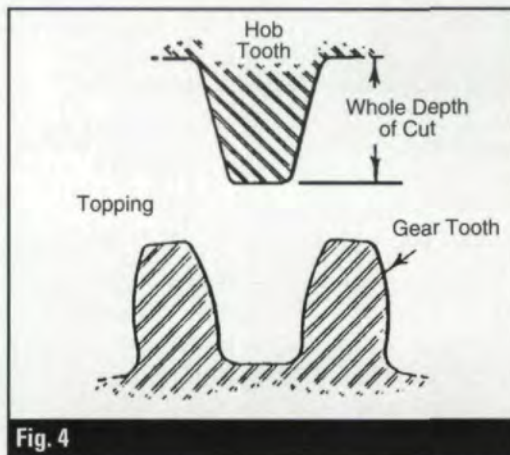


Fig. 4

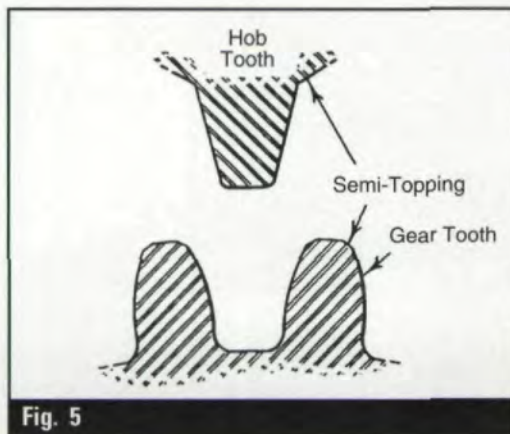


Fig. 5

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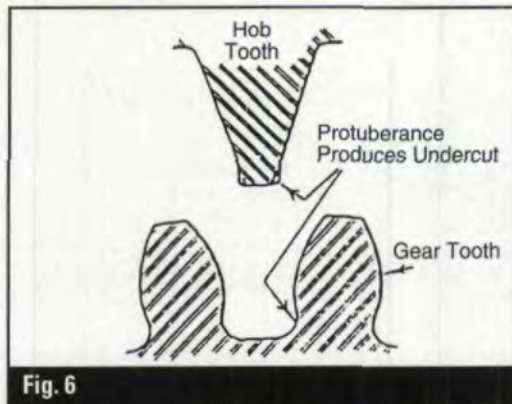


Fig. 6

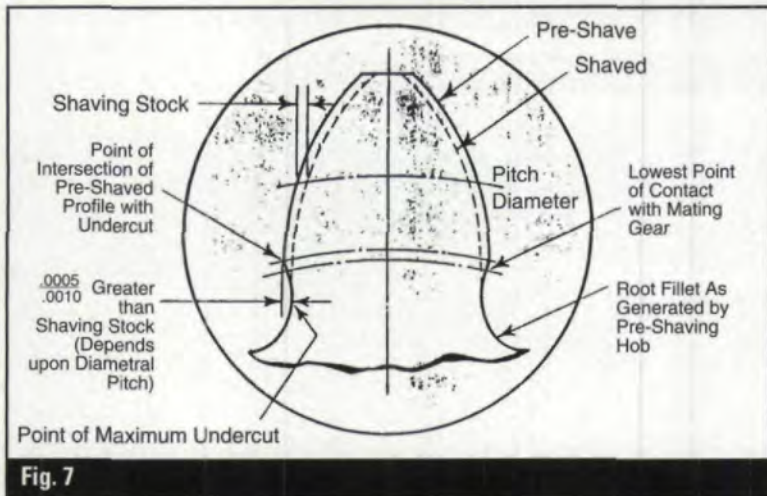


Fig. 7

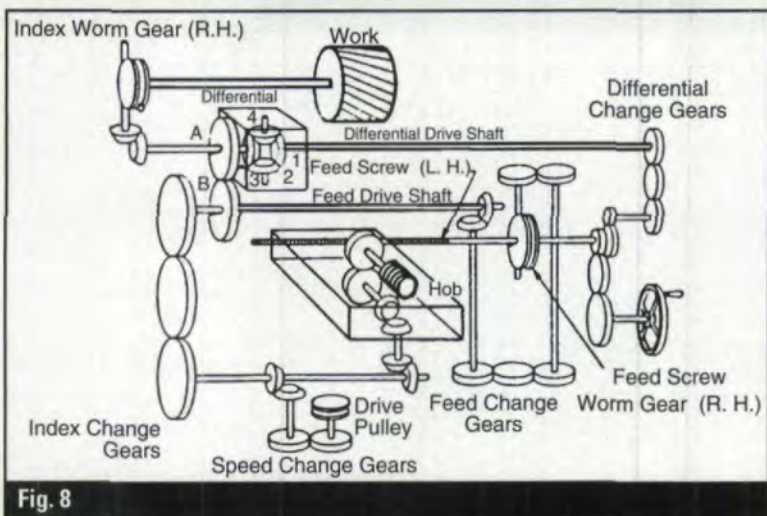


Fig. 8

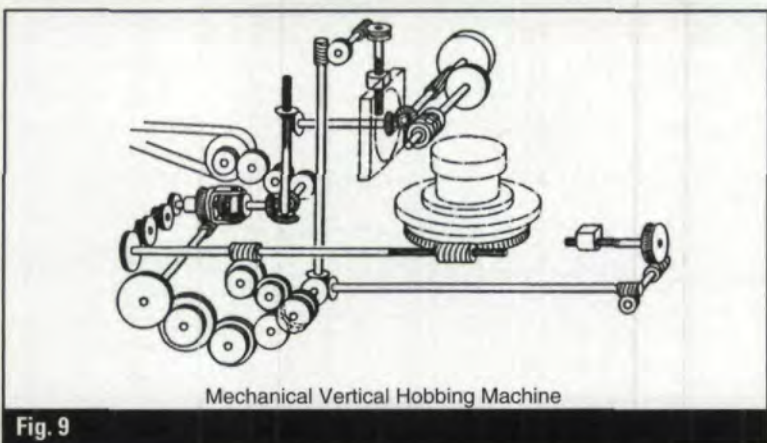


Fig. 9

produce undercut (see Fig. 6). The protuberance hob is designed to provide a uniform stock for the finishing tool and to provide a blend between the hobbed root area and the finished flank. Caution: On any modified cutter, we are changing the correct rack shape. Thus, the tool may cut only a certain range of gear teeth numbers correctly (Fig. 7).

The Gear Hobbing Machine

A gear hobbing machine consists of five common elements:

- A work spindle to rotate the work.
- A hob spindle to rotate the hob.
- A means of rotating the work spindle and hob spindle with a constant of ratio, depending on the number of teeth in the workpiece and the number of threads in the hob.
- A means of traversing the cutting tool across the face of the work in the direction of the work axis for spur and helical gears.
- A means of adjusting the center distance of the work and the hobs for different size workpieces. Figs. 8-10 show schematics for three typical hobbing machines.

Hobbing Feed

During hobbing, the cutting tool can be fed in a manner similar to a milling machine; both conventional and climb hobbing are used (see Fig. 11). A general rule of thumb is that climb hobbing yields better tool life, and conventional hobbing yields a better finish. In all cases, the cutting force should be directed against the work spindle, never against the tailstock.

The directions of feed on a hobbing machine correspond to the work axis. Thus, three feeds are possible — axial, radial and tangential (Figs. 12a, b, c).

It is also possible to combine more than one axis of feed sequentially or simultaneously during the machine cycle. A radial feed approach followed by axial feed across the face is very typical in fine pitch gear work or on a workpiece where an open axial approach is not possible (Fig. 13).

Axial and tangential feed are used simultaneously for several purposes on very large, coarse pitch, wide-faced gears. The tangential feed presents a sharp portion of the tool as the axial feed cuts across the gear face (Fig. 14).

Taper root splines are cut with simultaneous axial and tangential feed (Fig. 15).

A "jump" or "skip" cycle is used to cut mul-

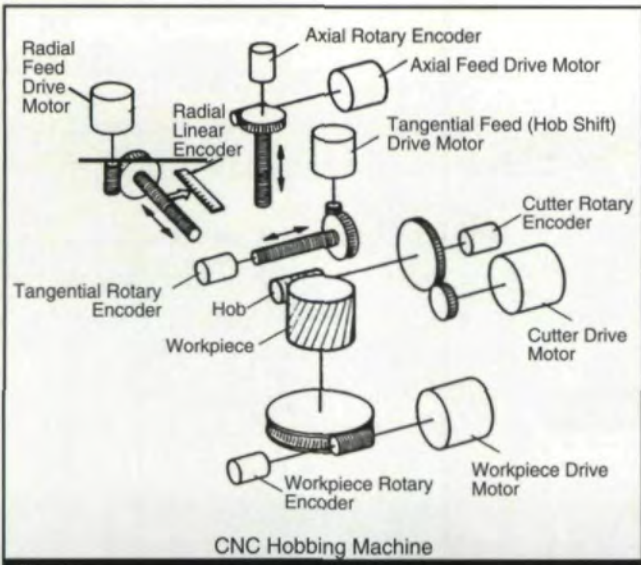


Fig. 10

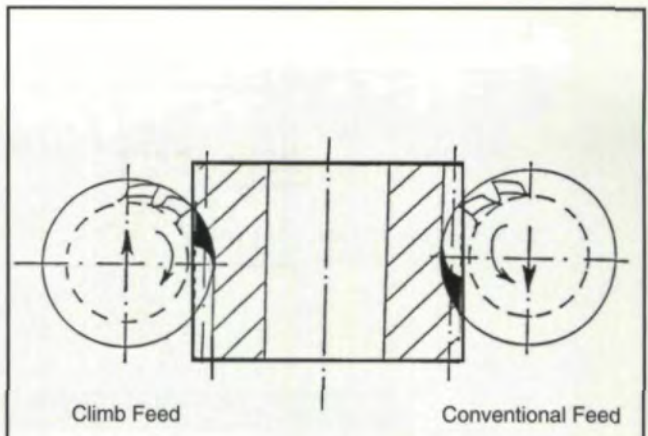


Fig. 11

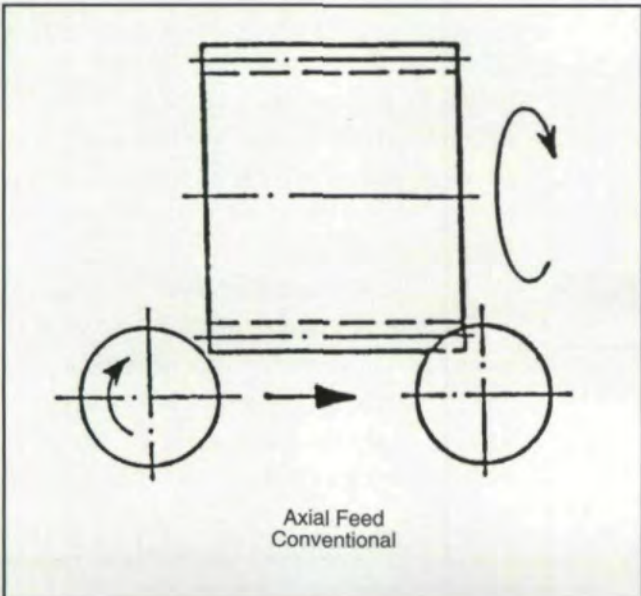


Fig. 12a

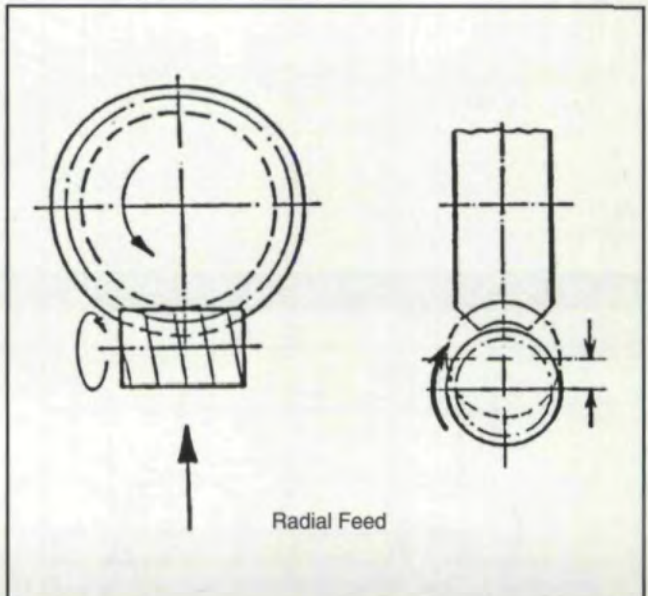


Fig. 12b

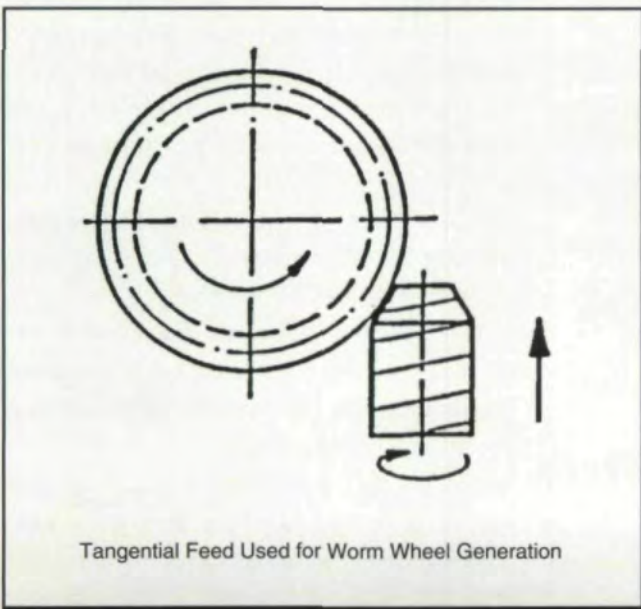


Fig. 12c

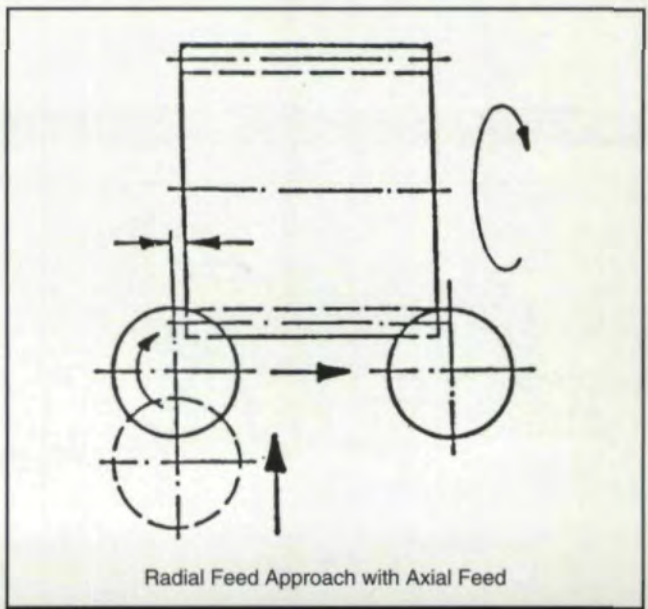


Fig. 13

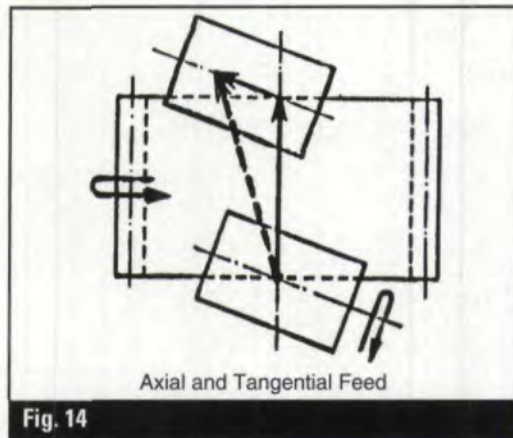


Fig. 14

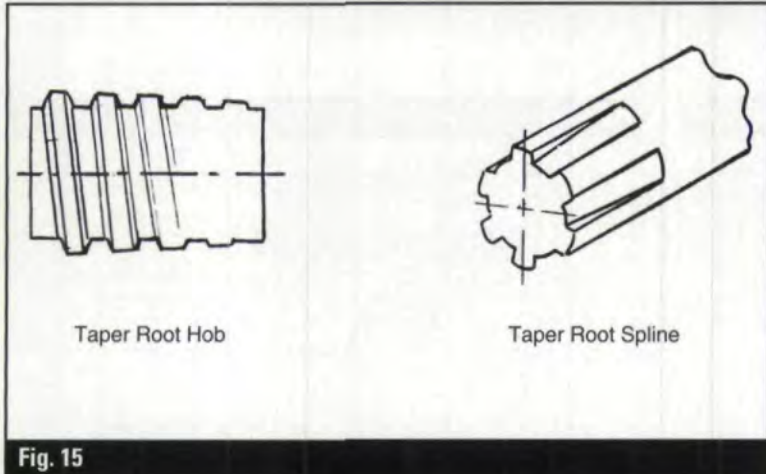


Fig. 15

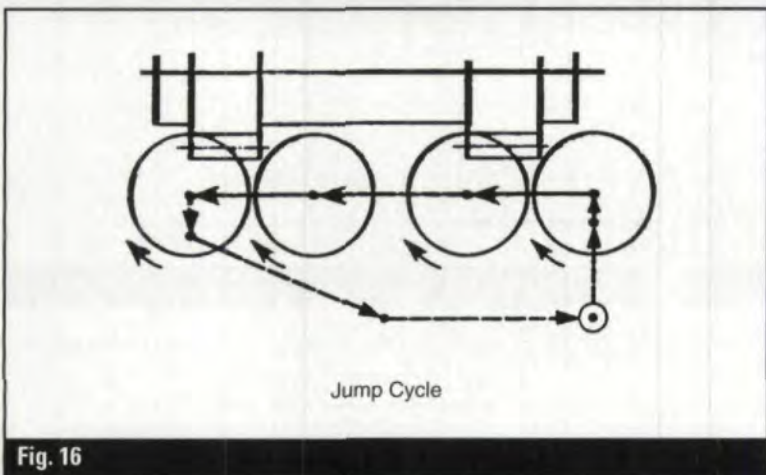


Fig. 16

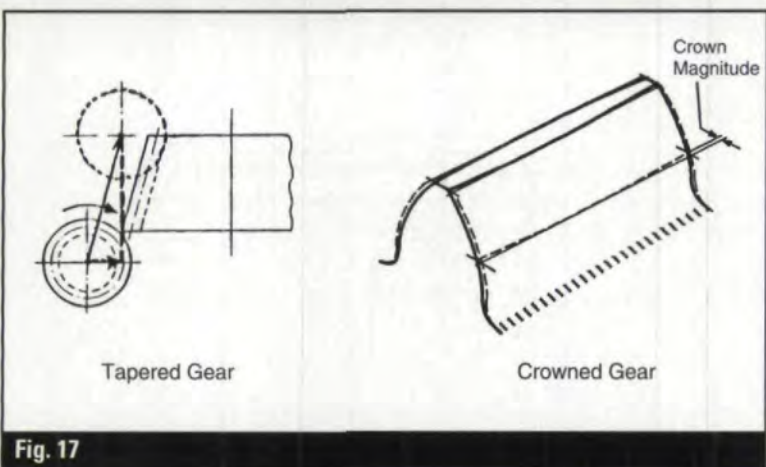


Fig. 17

multiple gear elements on a single part. This may be required for gear tooth alignment or simple cutting efficiency (See Fig. 16).

Tapered gears or crowned gears are produced with simultaneous radial and axial feed (Fig. 17).

At the beginning of the hobbing machine cycle, the cutter will not be generating the full depth of the gear tooth form. Only a small cut is made by each tooth in the hob gradually feeding into the part. This is known as the "approach" portion of the hobbing cycle. It is possible to utilize a different feed rate during this approach length with a reduction in cycle time (Fig. 18).

During the hobbing of some gears or splines, the cutter will not feed completely through the workpiece face. This is known as a "blind" cut. To complete all of the teeth evenly around the circumference of the gear, "dwell" is utilized. During dwell the hob and workpiece continue to rotate in a timed relationship for one or two more work revolutions, but without feed (Fig. 19).

Multiple Start Hobs

The hob is a series of racks positioned around the circumference of a cylindrical tool. Each successive rack is shifted axially to create a worm, typically a single thread. Thus, for each revolution of a single start hob, the gear must advance one tooth space (see Fig. 20). This is accomplished by the hobbing machine kinematic indexing system.

At this point, it is important to understand what causes the cutting marks on a hobbed gear. The marks axially across the face of the gear will correspond directly with the axial feed per work revolution of the tool. The marks positioned across the profile of the gear will correspond directly with the number of gashes or flutes on the hob (Fig. 21). Normally it is not possible to see the generating flats along the profile of the material.

It is possible to increase the speed of the hobbing operation by utilizing a hob with more than one thread. For example, if the hob has two threads, the gear must advance two tooth spaces for each revolution of that hob. This will double the speed of the work and double the production, all other factors being equal (Fig. 22). With four threads in the hob, four teeth on the part will index with every revolu-

tion of the cutter. However, there are factors that limit or prevent the use of multiple starts hobs for *all* cases.

The Hob

As more and more threads are designed into the tool, the lead of the thread will increase. Normally, a thread lead angle of 2-6° will be acceptable. Beyond six degrees, the left and right side of the cutting tooth will be loaded unequally, which will cause poor tool life. To compensate for this problem, the diameter of the tool can be increased slightly, but with a reduction in RPM to maintain the same SFM. Alternatively, the gash of the hob can be made helical to position the cutting tooth perpendicular to the cutting action.

To calculate the thread angle of a hob, use the following formula:

$$\tan \alpha = \frac{\text{Threads in Hob}}{\text{DP} \times \text{Hob Diameter}}$$

Example:

$$\tan \alpha = \frac{1}{20 \times 2}$$

$$\tan \alpha = .025$$

$$\alpha = 1^\circ 25' 56''$$

Another problem with multiple thread hobs is the number of effective gashes generating the profile. Again, all factors being equal, a two-start hob with twelve gashes will generate the gear profile with six of the gashes versus a single-start hob with twelve gashes.

The Hobbing Machine

As the number of threads in the tool increases, the work will index faster. This means that the work spindle of the hobbing machine must be able to rotate at higher speeds. On workpieces with high numbers of teeth, the machine speed is not a problem, but for gears with a low number of teeth, the hobbing machine must be designed correctly.

Several machine design solutions are used. For traditional worms and worm wheel work spindle drives, a multiple-start worm and worm wheel can be used. Four, eight and more thread worms are common. Another approach is to utilize a helical gear index system. Both systems work effectively in providing a mod-

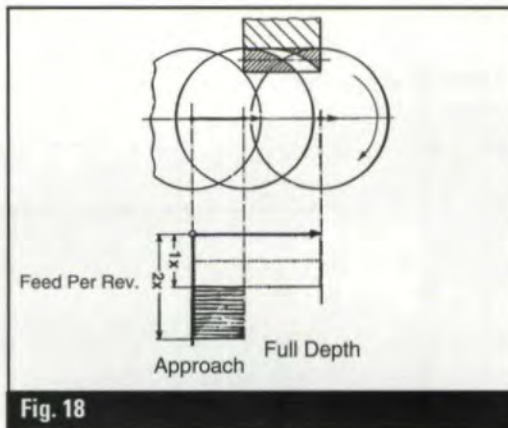


Fig. 18

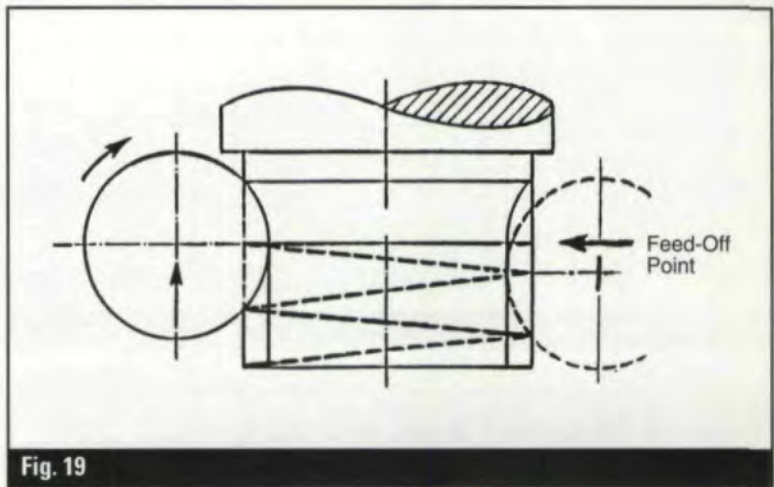


Fig. 19

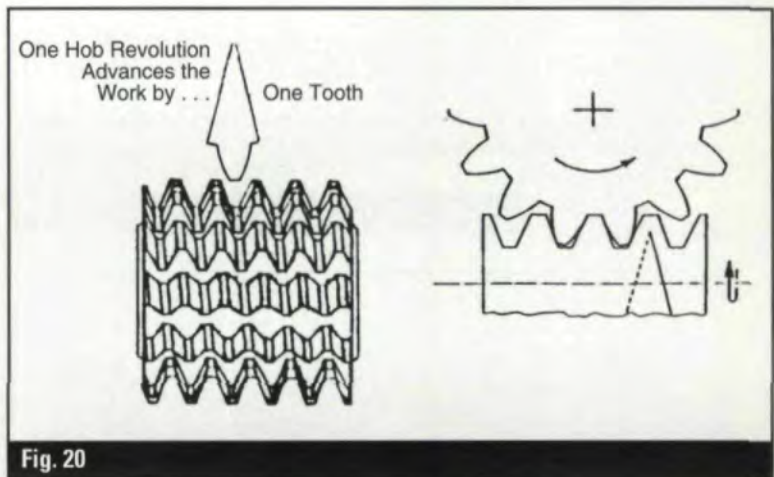


Fig. 20

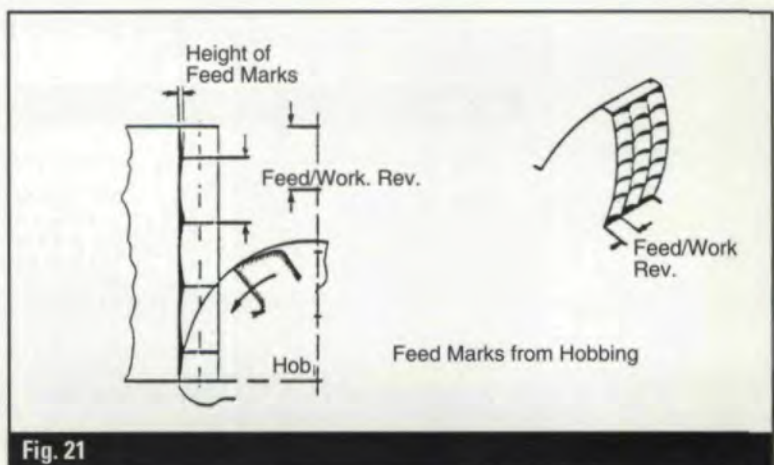


Fig. 21

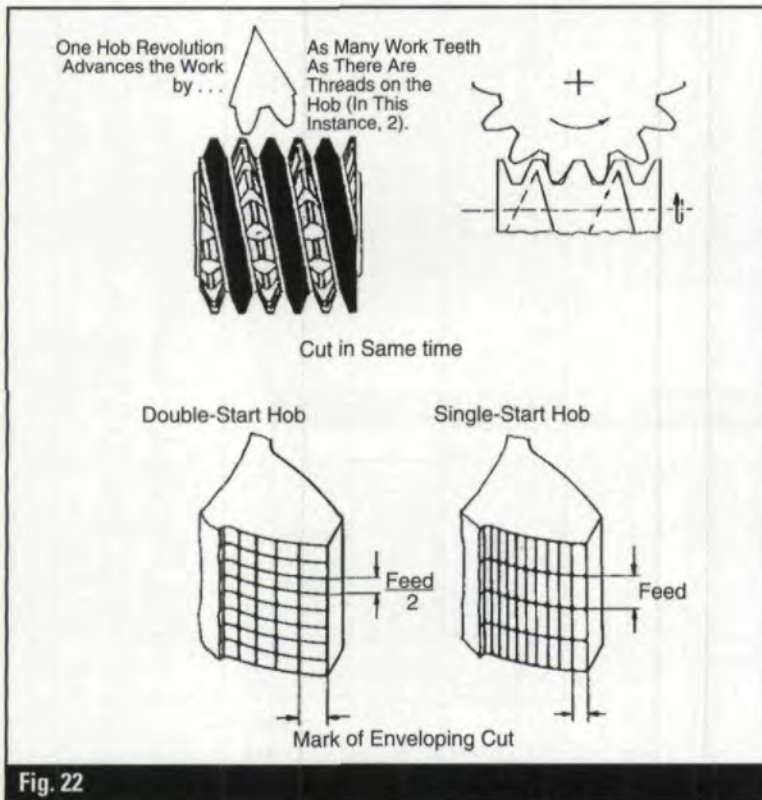


Fig. 22

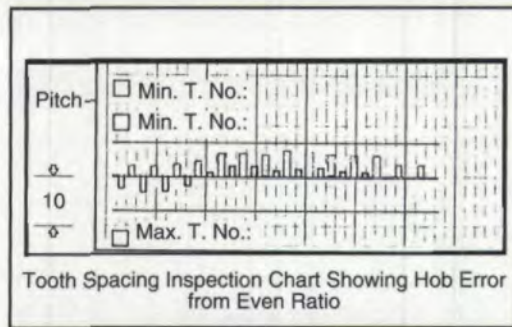


Fig. 23

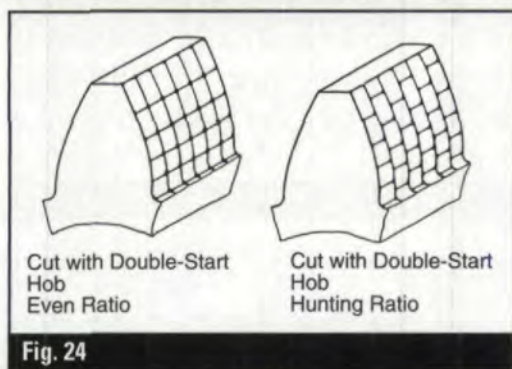


Fig. 24

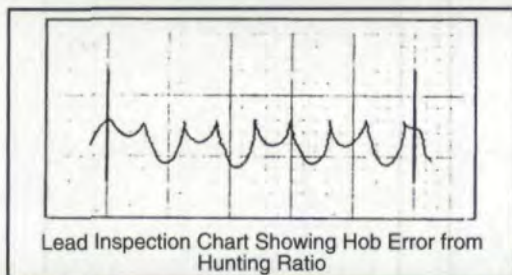


Fig. 25

ern high-speed hobbing machine.

Another consideration for the hobbing machine is the cutting capacity. As multiple-start hobs are used, the metal removal rate increases. If a subsequent finishing operation is used, such as shaving, rolling or grinding, it is practical to use much higher feed rates than used in finish hobbing. These feed rates can approach the maximum cutting capacity of a machine. Although the actual horsepower used in the hobbing operation is a small percentage of that used to drive the machine itself, the "effective" power of the machine must be considered. This effective power includes horsepower, rigidity, fixturing, maintenance, condition, etc.

Thread Spacing Errors

The multi-start hob will have manufacturing errors between the threads: in other words, the threads will *not* be in the correct position. This thread spacing error may or may not have an influence on the gear cut.

There are three possible conditions between the number of teeth in the part and the number of threads in the hob. First, an even ratio, such as a 2-start hob cutter and a 22-tooth gear (see Fig. 20). In this case, one thread will cut the even teeth, and one thread will cut the odd teeth. Thus, *all* of the thread-to-thread error will be seen in the tooth-to-tooth spacing, but not in the lead inspection (see Fig. 23).

The second condition occurs when certain threads of the hob will cut certain teeth, such as a 4-start hob cutting the same 22-tooth gear (Fig. 24a).

The final condition occurs when all threads cut all the teeth. This is the most ideal condition, as the thread-to-thread errors become distributed among all the gear teeth and "cancel" each other out. This is known as a hunting ratio (See Fig. 24b). This occurs when a 4-start hob cuts a 21-tooth gear. The thread-to-thread hob spacing errors are not seen in the tooth-to-tooth spacing, but will be seen in the lead inspection (Fig. 25).

It is possible to purchase cutting tools with improved thread-to-thread spacing. ■

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