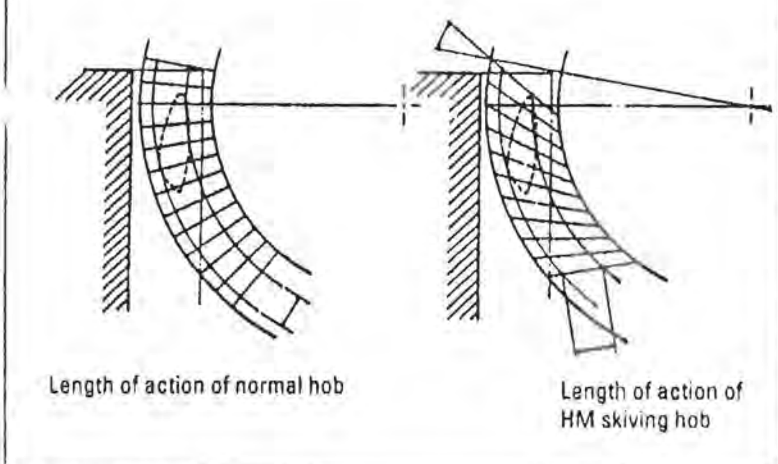

Fig. 10 - Hob skiving.

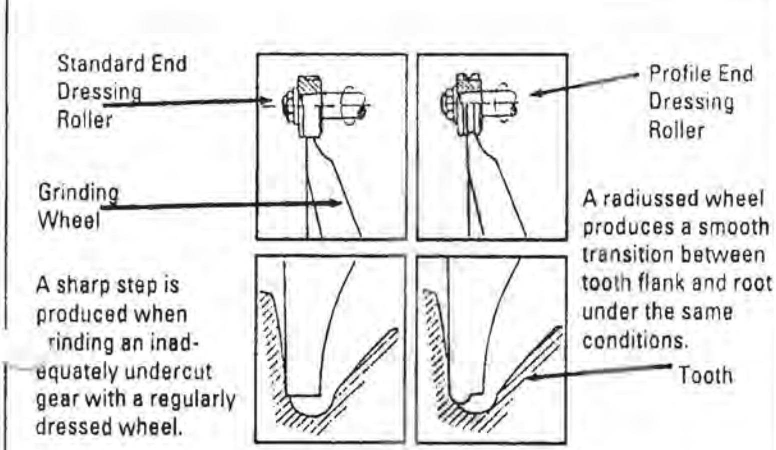

Fig. 11 - End dresser options for saucer wheel grinding machines.

The method of manufacture also effects the tooth surface finish. In the hobbing method, the number of gashes, or flutes, in a hob is a function of size, pitch, and other factors. Coarser pitch hobs normally have fewer gashes than finer pitch hobs. Consequently, finer pitch gears normally have a better tooth finish surface than coarser pitch gears.

Skiving or Hard Cutting

Skiving or hard cutting in hobbing or shaping is a term used to describe the operation in which hardened teeth are roughed or finished using a carbide tipped hob or CBN insert tool. Skiving in hobbing has limitations on quality based on many factors including machine, quality and sharpening of the tool, setup, gear geometry, etc. (See Figs. 10-11.)

Skiving hob sharpening. The carbide skiving hob is normally sharpened using a diamond wheel. Special setups are required at every sharpening to keep the pressure angle constant. A properly sharpened skiving hob is very critical for successful skiving. Improper sharpening can even produce hairline cracks in carbide inserts.

Protuberance and root clearance. Skiving hobs, as well as CBN tools, have been found inefficient in removing metal from roots because of premature chipping of tools. Therefore, proper protuberance and root clearance must be produced at soft teeth cutting prior to heat treatment.

Feeds and speeds. Feed and speed in skiving and hard cutting is important, not only for quality and time, but also for the successful execution of the process itself. Improper feed and speed can cause poor tool life, long machine time, poor quality, and many other problems. These problems can cancel all the advantages of the skiving or hard cutting. Tool suppliers should be contacted for recommended feed and speed values, which later can be optimized for each individual situation.

Skiving as a pregrind operation. Skive hobbing as a pregrind operation can be very helpful in many ways, as discussed in the section on Gear Tooth Grinding. Skiving can reduce the run time on critically loaded tooth grinding machines. In setups with limited grinding capability, skive hobbing can also be advantageous as rough finishing operations for CBN hard cutting.

CBN hard finishing of gears. CBN hard finishing is being used more and more on spiral bevel gears using rotary cutters, as well as on parallel axis gears using shaper type machines (rack type). This method provides gear teeth with the quality and surface finish of grinding without the possibility of metallurgical damage. This method also provides a means to finish larger gears which will not fit on a grinding machine. For example, gears which were originally designed as through-hardened, since no grinding capacity was available for finishing, can be case-hardened and hard-finished. Thus, the gear set rating is increased considerably without increasing the size of the set.

Gear Tooth Grinding

Gear grinding steps. Grinding steps in tooth fillets are very detrimental and have various causes. They act as stress risers and also reduce the critical case depth in tooth fillets. Any subsequent work performed to remove the steps raises the cost and can cause other problems. Here are some suggested approaches to eliminate or reduce the steps in tooth fillet.

- Always use a hob with proper protuberance, thickness, blend angle, fillet radius, etc.
- Use the correct amount of grinding allowance on tooth thickness at cutting.
- Grind the tooth flank to proper depth. Define and use the point of maximum undercut during grinding setup.
- Continuously train and educate personnel.
- Monitor and resolve problems by immediate attention.

Sometimes it will be quite difficult to avoid steps completely, because of excessive distortion at heat treatment, use of improper tools, excessive grinding allowance, etc. In such cases, use of a grinding wheel with tip radius can avoid sharp corners in grinding steps. The amount of radius can be selected on the basis of DPN, grinding machine, and all other factors. The same approach can be used in conical wheel grinding machines.

Gear grinding cracks. Gear grinding cracks usually indicate that there is a process control problem, either in heat treatment or gear grinding, or both. The correct amount of case carbon content is very critical, because an insufficient amount can cause low hardness problems; whereas, an excessive case carbon content can cause the presence of retained austenite. The grinding process generates pressure and heat, which causes transformation. Retained austenite transformation at grinding is considered a source of surface tempering or cracks or both.

Free carbides or carbide networks in case structure are another side effect of excessive case carbon content. Excessive hardness of the material (free carbides) can cause localized overheating. Overheating during the grinding results in surface tempering or cracks or both.

Heat treatment operations usually result in some film on the surface of heat treated parts. This scale must be removed before grinding, as it tends to load the grinding wheel. Surface oxidation in heat treatment produces a thin layer of decarburized and soft material on teeth flanks. This material loads up the grinding wheel, causing overheating, leading to surface tempering or cracks or both.

Excessive tooth distortions in an irregular pattern make it difficult for machine operators to locate the highest point on the gear tooth surface. If the grinding cut is not started at this point, excessive amounts of material will be removed during the cut from high points. Excessive cuts will generate overheating and can lead to cracking or surface tempering or both. This problem can be handled easily by the machine operator on a machine with threaded wheels and continuous indexing.

Gear grinding variables. The variables in gear grinding operations are the gear grinding machine, the grinding wheel, the coolant, in the case of wet grinding, and the grinding machine setup. Any problem with one or more variables can lead to various problems, including cracks on teeth. As discussed before, excessive heating at any point in the grinding operation can lead to surface tempering or grinding cracks or both. This overheating can be caused by a combination of factors, such as malfunction of the gear grinding machine, use of an improper grinding wheel, unsuitable coolant, improper positioning of coolant nozzle, or an excessive amount of cut or material removal.

Gear grinding cost. In a jobbing or low-batch production atmosphere, gear grinding time and, consequently, cost is an important matter. The time estimation is normally based on many factors in grinding, such as the number of teeth, DPB, helix angle, face, material, grinding allowance, quality, method, and machine. The final time estimate is then modified on the basis of past experience. Somehow the estimated time usually falls short of actual time. In the current competitive world, the gear grinding cost has to be maintained at a reasonable level. Below are some suggested approaches:

- Setup preparation cannot be overemphasized in a low-production atmosphere. It is good practice to have more than one item ready for the grinding machine. In case something goes wrong at the last minute with the first item in the line, the next in line can be started without excessive idle time.
- Heat treatment distortions and inadequate manufacturing process control will deliver gears with high inaccuracies to gear grinding. This will increase grinding time. Therefore, good control during the heat treatment and manufacturing processes will cut grinding times, reduce the number of scrapped parts, and enhance quality.
- Good preventive maintenance of gear grinding machines will keep downtime to a minimum.
- Training and education of personnel is quite critical and must not be overlooked.