Hob Tool Life Technology Update

By T.J. Maiuri

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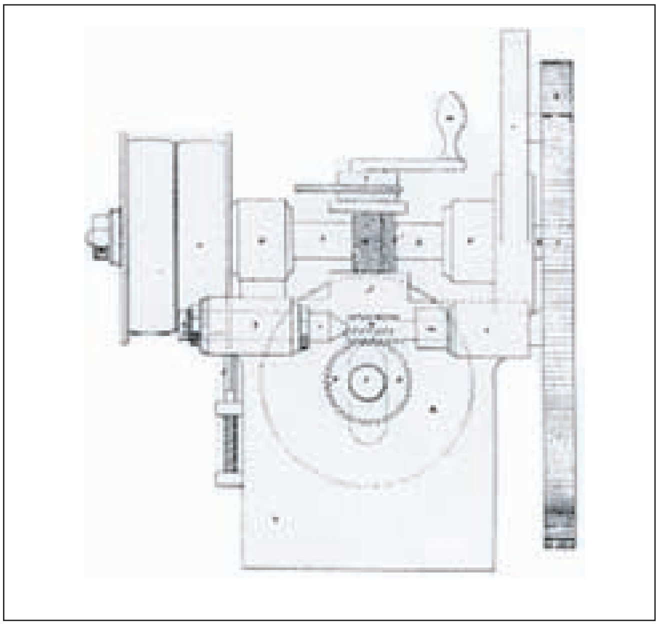

Figure 1—Whitworth's 1835 machine.

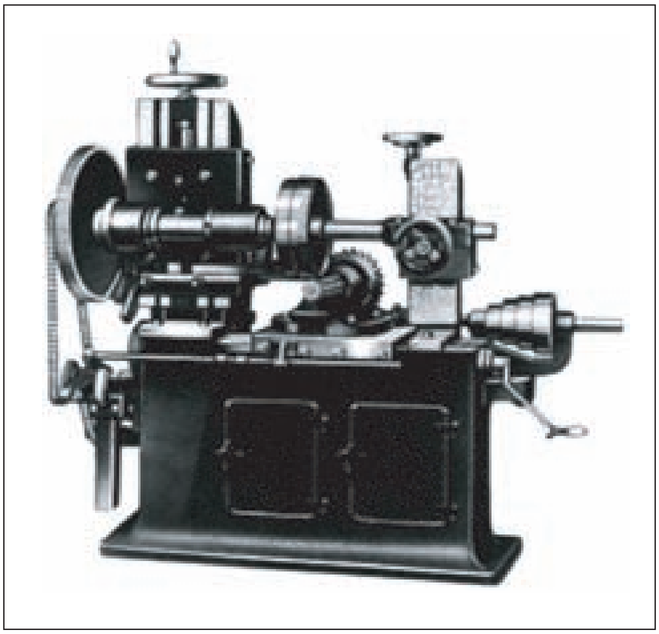

Figure 2—Robert Hermann Pfauter's prototype.

Management Summary

The method of cutting teeth on a cylindrical gear by the hobbing process has been in existence since the late 1800s. Advances have been made over the years in both the machines and the cutting tools used in the process. This paper will examine hob tool life and the many variables that affect it. The paper will cover the state-of-the-art cutting tool materials and coatings, hob tool design characteristics, process speeds and feeds, hob shifting strategies, wear characteristics, etc. The paper will also discuss the use of a common denominator method for evaluating hob tool life in terms of meters (or inches) per hob tooth as an alternative to tool life expressed in parts per sharpening.

Introduction

Up until the 19th century, almost all gears were handmade and the gears were cut with form cutters shaped to correspond to the spaces between the teeth. The first known gear cutting by machine was developed by Juanelo Torrianno (1501–1575). It was recorded that he was able to produce up to three gears per day on his hand-powered machine, using cutting tools that were nothing more than rotary files (Ref. 1). Much information about the history of gears can be found in the late Darle W. Dudley's book *The Evolution of The Gear Art*. The book was sponsored by the AGMA and published in 1969.

Figure 1 is taken from the English inventor Joseph Whitworth's patent of 1835, which clearly shows a hob cutting a gear. Whitworth claimed in the patent "the construction and arrangement of a mechanism by which I give a continuous rotary motion to the wheel or disc under operation, which motion is so proportioned to the speed of the rotary cutter that by every rotation of the cutter a segment of the wheel or disc shall be advanced equal to the distance of one tooth and space." The machine shown can be "bolted on to a work bench, or placed in any other convenient situation." (Ref. 2).

It is also interesting to note that in the 1871 patent of Philadelphia's Henry Belfield, the cutting tool is referred to

Table 1—High Speed Steel Materials

	C	Cr	W	Mo	V	Co	HRC
CPM M2	1.0	4.2	6.4	5.0	2.0	–	64
ASP 2023	1.3	4.2	6.4	5.0	3.1	–	64
CPM M4	1.4	4.3	5.8	4.5	3.6	–	64
CPM REX 54	1.45	4.3	5.8	4.5	3.6	5.3	65
CPM REX 45	1.3	4.1	6.3	5.0	3.1	8.3	66
ASP 2030	1.3	4.0	5.0	6.5	3.0	8.0	66
CPM T15	1.6	4.0	12.3	–	5.0	5.0	66
CPM REX 76	1.5	3.8	10.0	5.3	3.1	9.0	67
CPM REX 86	2.0	4.0	10.0	5.0	5.0	9.0	68
ASP 2060	2.3	4.0	6.5	7.0	6.5	9.0	68
CPM REX 121	3.3	3.8	10.0	5.3	9.0	9.0	70
M35V [Conventional]	1.2	4.1	6.0	5.0	3.0	5.0	66

as a "hub," not as a hob (Ref. 2). George B. Grant was issued a patent for a spur gear hobbing machine in 1889.

The first machine capable of cutting both spur and helical gears was invented by Robert Hermann Pfauter of Germany, in 1897 (Fig. 2). It included a horizontal workspindle on vertical ways, a hob swivel, a hob carriage fed along horizontal ways on the bed of the machine, and an upright outboard support of the work arbor. The hob feed was accomplished manually with a crank on the end of a feed screw (Ref. 2).

Today, most hobbing machines are full six-axis, CNC-controlled machines—capable of very high cutter and work table speeds. Many machines utilize direct drive hob and work spindles, which present an interesting scenario in which we now produce gears with machines that do not have gears in them.

The Hobbing Process

In brief, to paraphrase what Joseph Whitworth said in his patent of 1835, hobbing is a continuous indexing process in which the cutting tool and the workpiece rotate in a constant relationship to each other while the hob tool is fed into the work. For generating helical gears, the rotation of the work is either slightly retarded or slightly advanced in relation to the rotation of the hob. As the hob is fed across the face of the work once, all the teeth in the work are completely formed. The hob can be fed axially, radially, diagonally or tangentially, depending upon the application and the machine options available.

The hobbing process can be visualized as a worm and worm wheel running together—the hob is represented by the worm and the workpiece by the worm wheel. The hob has a worm thread that has been fluted to provide cutting edges, with each tooth relieved to form clearance behind the cutting edges. It must be made from a material suitable for cutting the workpiece material.

High-speed steel (HSS) cutting tool materials. Early cutting tool materials (from the 1900s to 1940s) consisted of high-speed steels designated as 1841, which consisted of 18% tungsten, 4% chromium and 1% vanadium (Ref. 3). Today we have many materials to choose from. Table 1 lists high-speed steel materials in use today, their chemical composition and Rockwell C hardness (Ref. 4).

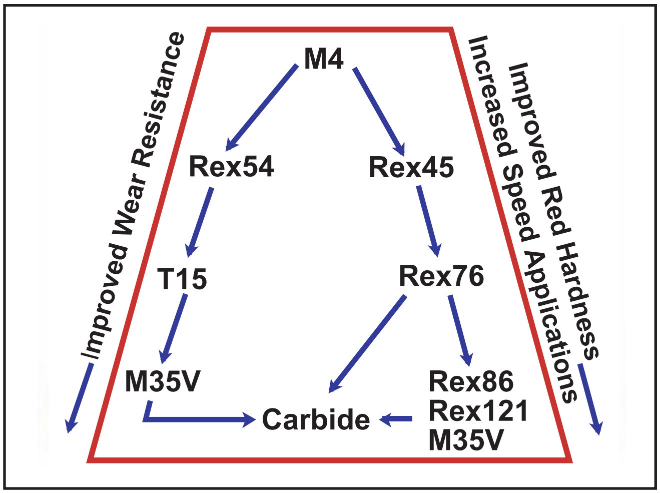

Figure 3—Material upgrade selection.

In the movement to cut gears without the use of coolant, carbide was initially selected as the hob tool material. Because of the expense of the carbide, the manufacturing costs and the special handling required, high-speed steel "bridge" materials were identified and have replaced the carbide in many applications. It is interesting to note this is not the case in bevel gear dry cutting production, where carbide remains the choice material for stick blades used in bevel cutter systems (Ref. 4). See below for more information on carbide material.

Figure 3 is a material selection upgrade guide based on what the desired output is: improving the red hardness (the property for retaining hardness at elevated temperatures) of the material, increasing the hob speed and/or increasing

continued

the wear resistance of the material. Rex 86, Rex 121 and M35V are grouped together on the chart, and the choice of material within the group should be based on a cost-per-piece analysis. Because of the high alloy content of REX 121, the hob sharpening technique is critical to avoid damaging the substrate material. Availability of a specific material can be a factor in your choice.

Carbide grades. Even though HSS "bridge" materials have replaced many early applications, carbide is used for applications such as steering pinions and armature shaft pinions (Fig. 4)—generally, small-diameter fine-pitch applications. Carbide is also used in hard finishing applications where gears are finish hobbed after heat treatment.

Basically, there are two classifications of carbide grades: "P" and "K". It is important to understand that the grades refer to the recommended working conditions and not the exact composition of the material.

Cemented carbides are a range of composite materials that consist of hard carbide particles bonded together by a metallic binder. The proportion of carbide phase is generally between 70–90% of the total weight of the composite.

ISO "K" grades of carbide are a simple two-phase composition consisting of tungsten carbide (WC) and cobalt (Co). A typical composition of a "K" grade carbide is 90% WC and 10% Co by weight. "K" grades have good edge stability and abrasion resistance, with a grain size range of 0.5 µm–0.9 µm.


Figure 4—Carbide shank hob.

ISO "P" grades of carbide are three-phase alloyed compositions consisting of tungsten carbide (WC), cobalt (Co) and cubic carbides. The cubic carbide binders can be titanium carbide (TiC), tantalum carbide (TaC) and niobium carbide (NbC). A typical composition of a "P" grade carbide is 73.5% WC, 8.5% TiC, 8% TaC and 10% Co by weight. The cubic carbides are softer and have larger grain size: 2 µm to 4 µm is normal for these alloy materials.

Most carbide applications in use today are ISO "K" grade. Note that traditional titanium base coatings cannot be stripped from ISO "P" grade carbides (Table 2).

The following figures show some of the relative material properties of carbide and steel.

The density of carbides (Fig. 5) is nearly twice that of steel. This means that a carbide hob with the same geometric characteristics as a high-speed steel (HSS) hob is much heavier.

Carbide is also much harder (Fig. 6) than steel, and is not as tough (Fig. 7). Think of toughness as the ability to resist fracture. This means that if you drop an HSS hob you may just put a "ding" on a couple of teeth, but if you drop a carbide hob it may shatter into pieces. Because of these properties, you must take certain precautions with the carbide hobs that you normally would not take with the conventional HSS hobs.

The linear expansion of carbide (Fig. 8) is less than half that of steel. This can be a significant characteristic due to the fact that if you are using a shell-type carbide hob with a steel hob arbor, the hob arbor will expand at a greater rate than the carbide hob, and you must account for this thermal expansion difference in the clearance between the hob bore and the steel arbor; otherwise, you may shatter the hob (Ref. 5).

Cermet. Test cutting with cermet hobs has also been conducted. The word cermet is derived from the terms ceramic and metal. A cermet is a hard material based on titanium carbide or titanium carbonitride cemented with a metal binder (Ref. 6). Cermet materials allow for higher cutting speeds over HSS tools, and even carbide tools. At this point, however, cutting with cermet tools has not proven to be cost-effective.

Table 2—Coating Re-conditioning Guidelines

Guideline	TiNite® TiN	CarboNite® TiCN	AlNite® TiAlN-S	TiAlN-X	AlCroNite® AlCrN
Strippable from HSS	Yes	Yes	Yes	Yes	Yes
Strippable from K-grade carbide	Yes	Yes	Yes	Yes	Yes
Strippable from P-grade carbide	No	No	No	No	Yes
Recoatable over itself	Yes	Not recommended	Yes	Yes	No
Number of recoatings	3 - 7	--	2 - 4	2 - 4	- -

Coatings

Tool coatings came to the market in the 1980s. The most popular at the time was titanium nitride (TiN). This coating served well for high-speed steel applications used with a coolant, and is still in use today.

Titanium aluminum nitride (TiAlN) was developed in the mid-1980s, and gained popularity in the 1990s, as a coating used in cutting hard materials and high heat applications; it has been a very popular coating for dry cutting applications.

Aluminum chromium nitride [AlCrN] coating was introduced in 2006 and is today the coating of choice for best results in dry hobbing applications.

The coatings used in gear production today are primarily AlNite (Balzers Balinit FUTURA NANO), TiAlN–X (Balzers Balinit X.TREME), and AlCroNite (Balzers Balinit ALCRONA). The performance of AlNite and TiAlN–X are about the same, although some customers prefer one over the other, and TiAlN–X is used primarily on carbide substrate material tools. AlCroNite (Balzers Balinit ALCRONA) has shown advantages for a number of applications over the other coatings.

Trials with Balinit X.CEED (a high-deposition temperature, high-aluminum single-layer coating), Balinit Hardlube (a duplex coating consisting of a wear-resistant TiAlN base layer and a high lubricity–low-friction coefficient—WC/C top layer) did not show any significant advantage over other coatings.

Nanocomposite coatings such as nACo by Platit are available. The nACo coating comprises AlTiN nano-sized particles embedded in an amorphous (non crystalline) matrix of silicon nitride (Si3N4), yielding a high oxidation resistance (Ref. 7).

The following is a brief description of coatings used in production today:

- **TiNite** (Balzers Balinit A)—TiNite is a TiN (titanium nitride) coating and is a general purpose coating for all wet oil or water soluble applications. It is not recommended for dry cutting applications.
- **CarboNite** (Balzers Balinit B)—Carbo-Nite is a TiCN (titanium carbonitride) coating recommended for wet cutting only on materials that are abrasive in nature, such as cast iron or other hard-to-machine materials that require high abrasion resistance.
- **AlNite** (Balzers Balinit FUTURA NANO)—AlNite is a single-layer TiAlN coating with a nominal 50:50 ratio of titanium to aluminum. It has high thermal stability and can be used for cutting all steels, cast iron and stainless steel, and may be used wet or dry.
- **TiAlN–X** (Balzers Balinit X.TREME)—X.TREME is a single-layer coating of TiAlN. It is specialized for carbide mills for hardened

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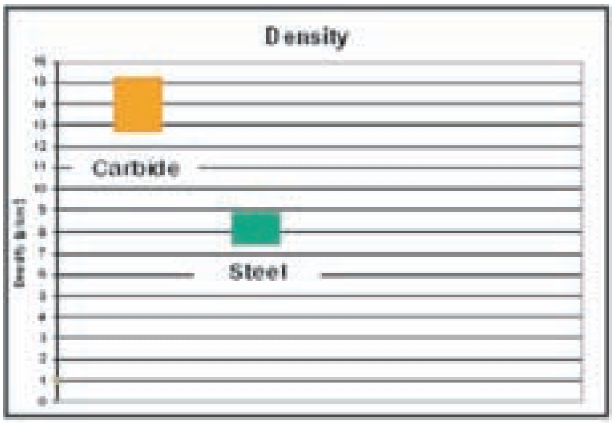

Figure 5—Density.

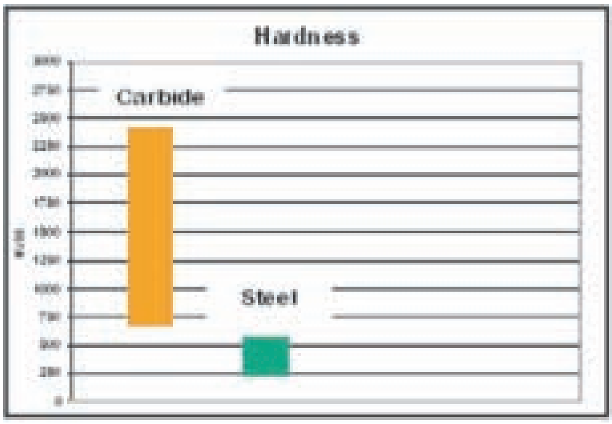

Figure 6—Hardness.

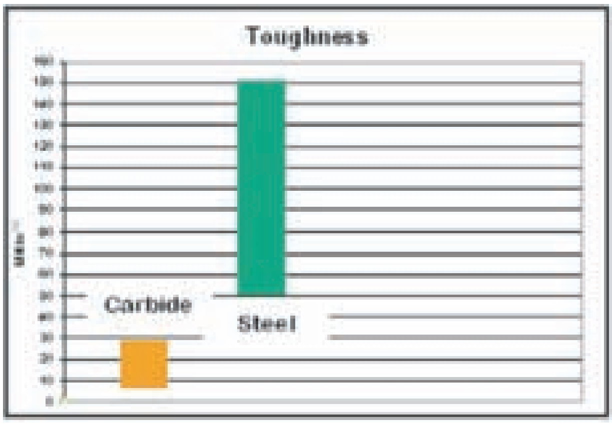

Figure 7—Toughness.

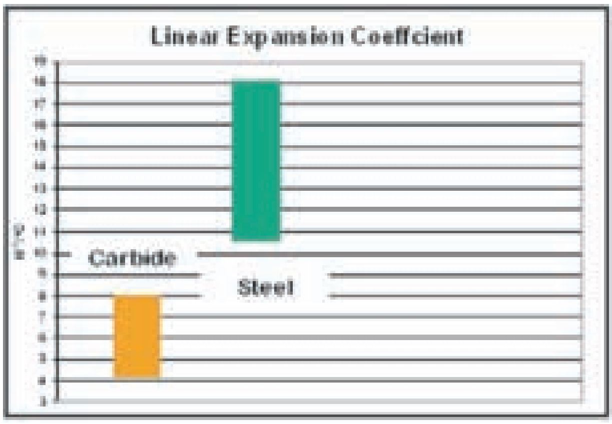

Figure 8—Linear expansion.

steel workpieces (>50 HRC). It may also be used wet or dry, and is a very popular coating today for bevel gear carbide stick blade applications.

- **AlCroNite** (Balzers Balinit ALCRONA)—ALCRONA is a high-performance, titanium-free coating (AlCrN) of the G6 generation (Ref. 8). It has exemplary wear resistance under both conventional conditions and severe mechanical stresses.

Table 3 (Ref. 8) lists some of the properties of coatings in use today.

The pie chart in Figure 9 gives an indication of how the trend in coatings has changed over the last decade. The chart represents coatings applied to all cutting tools, including bevel stick blades. You can see the increase in use of the TiAlN coatings, and now the trend to the AlCrN coating.

Tool Reconditioning Guidelines

Once the hob tool is used, it must be sharpened to remove the wear. The sharpening process will remove the coating on the face of the tool. To obtain better tool life, it is good practice to recoat the tool after sharpening. However, consideration must be given to whether the coating must be stripped off the tool before recoating, or if it can be coated over itself. Stripping the coating from a hob consists of a chemical process where the coating is removed with a peroxide base solution.

Table 2 offers guidelines for stripping and recoating of various coatings in use today.

Hob edge preparation. Tool life improvements can be made by preparing the edge of the hob tooth (Ref. 9). The process for treating the edge on HSS materials consists of removing the burr in a dry blast with an abrasive material. This process is followed by a wet blast operation to remove any residual, dry abrasive to enhance the surface for the coating application.

Treating the cutting edge of carbide tools consists of a honing process with a diamond brush. Generally, an edge radius of about 0.0004" to 0.0008" (10 to 20 µm) is desired.

Table 3—Coating Properties

	TiNite® TiN	CarboNite® TiCN	AlNite® TiAlN	AlNite®-X TiAlN-X	AlCroNite™ AlCrN
	Balzers BALINIT® A	Balzers BALINIT® B	Balzers BALINIT® Futura Nano	Balzers BALINIT® X.TREME	Balzers BALINIT® ALCRONA
Hardness (HV 0.05)	2300	3000	3300	3500	3200
Coefficient of friction	0.4	0.4	0.30 – 0.35	0.4	0.35
Max. service temp.	600°C 1112°F	400°C 752°F	900°C 1652°F	800°C 1472°F	1100°C 2012°F
Coating color	Gold	Blue-grey	Violet-grey	Violet-grey	Blue-grey
Coating structure	Monolayer	Multilayer	Nano	Monolayer	Monolayer

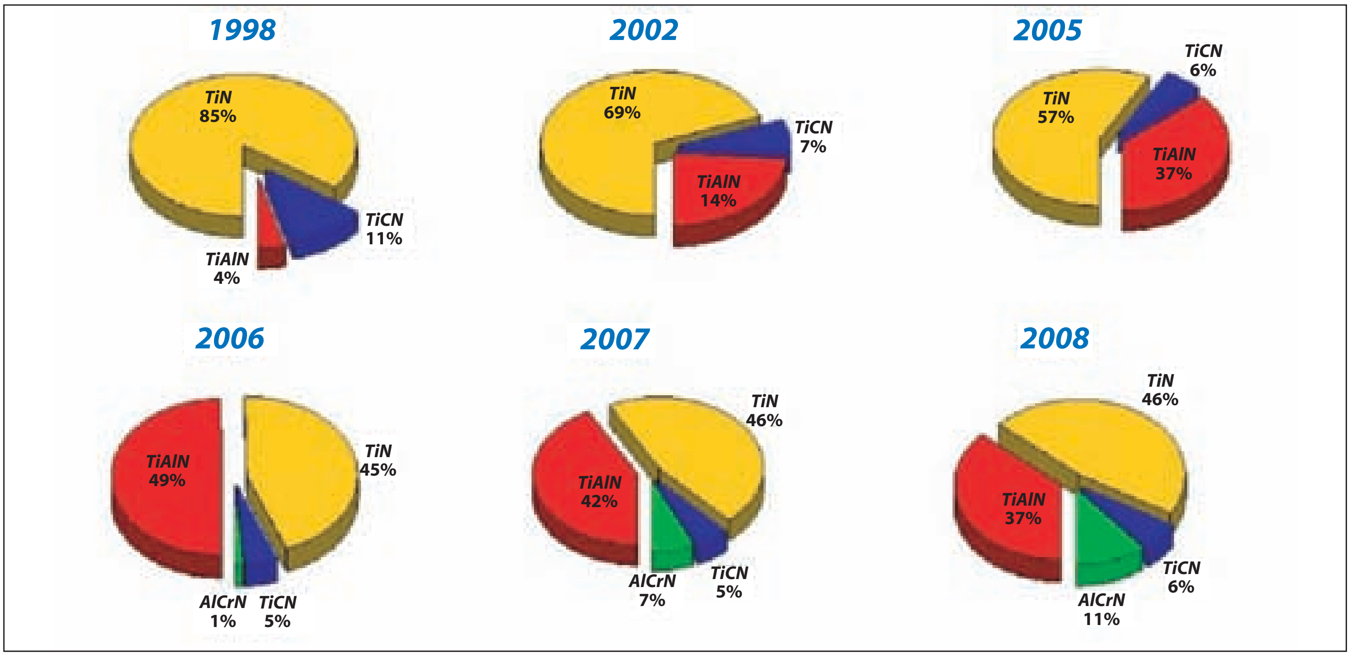

Figure 9—Coating trends.

Wear basics. Figure 10 identifies the basic types of hob wear. Tip and flank wear are normal, and eventually the wear will break through the coating and abrade the substrate material of the hob. Cratering on the face of the hob can also occur, and the tool can fail if the crater becomes too large and extends to the cutting edge of the tool. See the appendix at the end of this paper for actual photos of the different types of wear (Ref. 10).

Edge chipping on the flanks and top of the tool can occur if the tool material is too hard or brittle for the application. Edge chipping can also occur if the gear material is too hard or there is a lack of rigidity and/or vibration during the cutting process.

Another type of problem that can occur with tools is called built-up edge (BUE). BUE is a deposit of workpiece material that adheres to the face of the cutting tool. Sometimes the deposit of material can break off, taking the tool material with it. BUE is a common problem when machining ductile materials such as soft steels, aluminum and copper alloys (Ref. 11). Low cutting clearances on the tool and insufficient coolant flow or type of coolant can also cause BUE.

Hob failures can occur for other reasons besides normal wear. Chip packing can occur when the volume of material being removed is high and there is not enough room or clearance in the gash between the rows of teeth. Chip packing can often result in shelling the hob, where the hob teeth break off the hob body in the cutting zone of the hob. Grinding cracks from the sharpening operation can also lead to hob failures. Microchipping of the tool can be another mode of failure. The appendix contains photos of hobs depicting the problems described above (Ref. 11).

Indications of excessive hob wear. There are a number of indicators during the hobbing process that can be a direct result of excessive hob wear. The following are some of these indicators:

- Increase in machine power requirements
- Increase in machine vibration
- Excessive noise or chatter during the cut
- Excessive heat is generated in the cutting process; gear and/or hob tool temperatures increase
- Gear surface finish deteriorates
- Gear dimensions move out of tolerance
- Burrs that are normal get larger

If any of these indicators are observed, remove the hob from the machine and examine the tool for wear.

Hob Design Recommendations

There are a number of considerations that can be incorporated in the hob design that will help to improve tool life. In general, it is recommended to use shank type hobs, not so much for improved tool life, but for other reasons. The shank design offers several advantages. First, the hob will be mounted directly in the hob spindle, eliminating the need for premounting. Theoretically, the shank design allows the best possible hob runout on the machine. Secondly, if you are using a carbide hob, you do not have to worry about problems from the different rates of thermal expansion of the carbide and steel, which would require more clearance between the hob bore and the hob arbor diameter.

Many hob designs incorporate a positive rake angle on the face (generally 5°) to allow for better chip ejection during the hobbing operation. However, there are applications in production without the positive rake. No rake on the front face makes it easier to sharpen the hob, and the small positive rake may not be a significant factor in the overall tool life. It is very important to have a good surface finish on the hob face—5 μinch Ra or less is recommended. There should be enough clearance in the gash between the rows of teeth to lessen the effect of any chip packing. Sometimes an increased secondary cam angle can help, as well as removing the fins that may exist in the root of the gash from sharpening the hob. Hobs with longer usable face lengths are beneficial for hob shifting (more on hob shifting later). As explained earlier, edge preparation is important.

Special Considerations for Carbide Hobs

When using a carbide hob, special precautions should be taken because of their properties (and their cost—about three times the cost of a HSS hob). Because they are fragile, you should take steps to protect them in handling and transportation, etc. Also, a diamond wheel is required to sharpen the hob and you must consider special coolants for the sharpening operation to avoid any possibility of cobalt leaching.

Tool Life Variables and Meters per Hob Tooth

Below are some of the many factors that will affect the hob tool life.

- Hob tool material, its hardness specification and coating
- Workpiece material, hardness and microstructure (all affect machinability)
- Hob speeds and feeds
- Coolant type and application
- Hob shifting procedure
- Hob clamping arrangement
- Wear criteria

When asked, "What kind of tool life are you getting?" the most common response is in terms of "pieces-per-sharpening." There is a better way to think of tool life, and that is to express it in terms of a "life factor," with units of "meters-per-hob-

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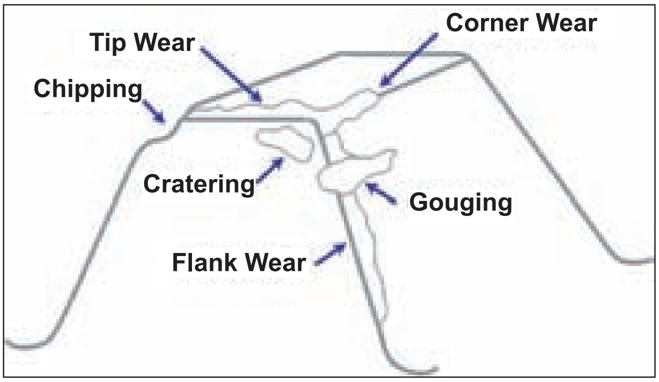


Figure 10—Types of hob tool wear.

tooth" or "inches-per-hob-tooth," instead of "pieces-per-sharpening." Here is one reason why: if the response to the tool life question is "500 pieces-per-sharpening" on an application, how do you know if that is a good number? It may be good if the hob length were 3 inches (76.2 mm) long, but would it be good if the hob were 8 inches (203.2 mm) long?

If a "life factor" in "meters/tooth" (or inches/tooth) is used, then it does not matter how long the hob is. The number of parts-per-sharpening can be calculated from the meters per hob tooth based on the hob length. Also, using a "life factor" allows us to compare tool life for different applications.

The calculation for a "life factor" is a simple one. First calculate the linear meters (or inches) of gear teeth and then calculate the number of usable hob teeth between the hob shift limits for the given application or cutting trial.

Once these simple calculations are made, the life factor for a known parts/sharpening can be determined, or the parts/sharpening for a known life factor can be determined.

The formula for linear meters (inches) of gear teeth is:

$$\text{LIN} = \text{N (NPPC)} \left(\frac{\text{FW}}{\cos(\text{HA})}\right) \qquad (1)$$

The formula for the usable number of hob teeth is:

$$\text{USEN} = \text{FLUTES} \left(\frac{\text{USELEN}}{\text{NCP}}\right) \qquad (2)$$

Where

LIN	Linear meters (inches)
N	Number of gear teeth
NPPC	Parts per cycle (number of parts in the stack)
FW	Face width (meters or inches)
cos (HA)	Cosine function of the gear helix angle
USEN	Usable number of hob teeth within the hob shift limits
USELEN	Usable length of the hob (length along the hob axis between the hob shift limits)
NCP	Normal circular pitch of the hob
FLUTES	Number of hob flutes or gashes

Having calculated the linear meters (inches) and the usable number of hob teeth between the shift limits, the life factor can be calculated as follows:

$$\text{LF} = \text{LIN} \frac{\text{(PARTS)}}{\text{USEN (NPPC)}} \qquad (3)$$

or the parts-per-sharpening can be calculated:

$$\text{PARTS} = \text{LF (USEN)} \left(\frac{\text{NPPC}}{\text{LIN}}\right) \qquad (4)$$

Where

LF	Life factor
PARTS	Parts-per-sharpening

It is important to note that the life factor method does not take into account the volume of material being removed, the rate of material removal (speeds and feeds), the machinability of the gear material or the hob material and hob coating. It is assumed that the application being evaluated is running at reasonable speeds and feeds, and the material is a typical gear material and hardness and the tool utilized has a good base material and coating. Despite these assumptions, the life factor method works very well.

When asked to estimate the parts-per-sharpening for a new application, make the calculation as described above using 3 meters per hob tooth. This is a very good starting point that can most often be met initially, and can be exceeded with development of the shifting strategy, speeds and feeds, etc.

The life factor is also very useful in setting up hob shifting strategies. See the section on "Hob Shifting Methods."

To give an idea of what type of life factor numbers to expect, 3 meters per hob tooth is a good starting point for all applications. Generally speaking, 4 to 5 meters/tooth is an achievable estimate, taking into consideration the tool life variables mentioned earlier and the application. For example, an automotive supplier in production is achieving 6 meters per hob tooth on planetary pinions, 5 meters per hob tooth on sun gears, 4 meters per hob tooth on transfer gears and 3 meters per hob tooth on final drive gears. For course pitch gears 3 NDP (8.47 Mod) or coarser, you can expect life factors of 1 to 2 meters per hob tooth.

Of course, the tool life can be increased or decreased by changing any of the parameters mentioned in the bullet items above.

Tool Wear Criteria

It is important to establish what the tool wear criteria is, and sharpen the hob when the wear limit is reached. Wear on a tool may accelerate rapidly after a certain point is reached. For carbide tools, a 0.10 mm (0.004") maximum wear limit is recommended, although there are applications using a 0.15 to 0.20 mm (0.006–0.008") wear criteria in the field. For HSS tools, a 0.30 mm (0.012") maximum wear limit is recommended; however, this also is exceeded in the field. Note that, when reporting tool life results, you should specify what your wear criteria are. For example, you can expect better tool life results (more parts/sharpening or higher life factor) if the wear criteria used were 0.15 mm (0.006") as opposed to a 0.10 mm (0.004") criteria.

Also, tool wear criteria can be based upon other parameters, not just the measured amount of wear on the hob tool. For example, the deterioration of the cut part quality, surface finish

Table 4—Hob Speeds and Hob Chip Thickness

	HSS	Carbide
Hob speed	100–180 SMPM [325–590 SFPM]	250–300 SMPM [820–985 SFPM]
Hob chip thickness	0.20 - 0.30 mm [0.008" - 0.012"]	0.15 mm [0.006"]

on the teeth being cut, heat of the workpiece after hobbing or hob spindle power draw during the cut can also be criteria for a tool change.

Hob Speeds and Feeds

Table 4 is a general guide comparing hob speeds and feeds for both HSS and carbide hobs. The chart assumes speeds and feeds for 8 normal diametral pitch (3.175 Module) gears or finer. For coarser pitch applications—harder materials and more difficult to machine—the speeds and feeds should be reduced.

Note that the table indicates hob chip thickness recommendations as opposed to specifying actual feed rates in inches/rev or mm/rev. The hob chip thickness is calculated using the formula developed by Hoffmeister that is based on the hob, gear geometry and hob feed rate. Knowing the desired hob chip thickness, the hob feed rate can then be calculated for the application. For some applications the feed rate may also be limited by the amount of allowable scallop depth.

Also note that for carbide material the hob can be run faster than that of HSS hobs; however, the maximum hob chip thickness, which determines the hob feed rate, is half that of HSS applications. This means you cannot run the carbide hobs at the same feed rates as HSS—so you gain on the speed, lose on the feed. The same speeds and feeds can be used for both wet and dry cutting, given the proper tool and coating for the application.

Hob Shifting Methods

Hob shifting methods are extremely important, fig. 11 in the hobbing process, whether it be for wet or dry applications (Fig. 11). Initially with HSS wet applications, a small incremental amount of hob shift was used after each cycle. The amount of hob shift will vary, but it is generally 0.001" (0.025 mm) to 0.050" (1.27 mm), depending on the normal diametral pitch (module), etc. Many companies have their own algorithm for calculating the starting amount of hob shift when using small, incremental shifts. The shifting strategy for small, increment shifts is set up such that after one pass over the usable length of the hob, the tool would be ready for sharpening.

With the introduction of dry hobbing, it was recommended to use larger shift increments approximately equal to the normal circular pitch of the gear or axial circular pitch of the hob, and to use multiple passes over the usable hob length. A small offset amount at the beginning of each pass is also recommended. The theory is to shift out of the "hot zone" or contact area of the hob and gear as soon as you can. The contact area on the hob consists of a roughing and finishing zone that is dependent on the geometry of the hob and gear.

As mentioned earlier, using a life factor is also very helpful in setting up your initial hob shifting strategy. For example, if the strategy is to use a large shift increment with multiple passes, start with the assumption the shift amount will be one circular pitch (or something near one circular pitch). Whatever the value chosen, the number of parts-per-pass can be calculated for the shift limits by dividing the shift amount into the usable shift distance between the shift limits. If 3 meters per hob tooth is assumed to start with (or whatever the life factor is to be used), the number of parts-per-sharpening can be calculated, and therefore the number of hob passes necessary to obtain the number of parts-per-sharpening. The amount of offset for each pass can be calculated by dividing the number of passes into the amount of hob shift.

If the hob shift strategy is to use one pass with a small, incremental amount of shift, calculate the number of parts-per-sharpening based on the life factor and divide the distance between the hob shift limits into that number, and that determines the shift amount.

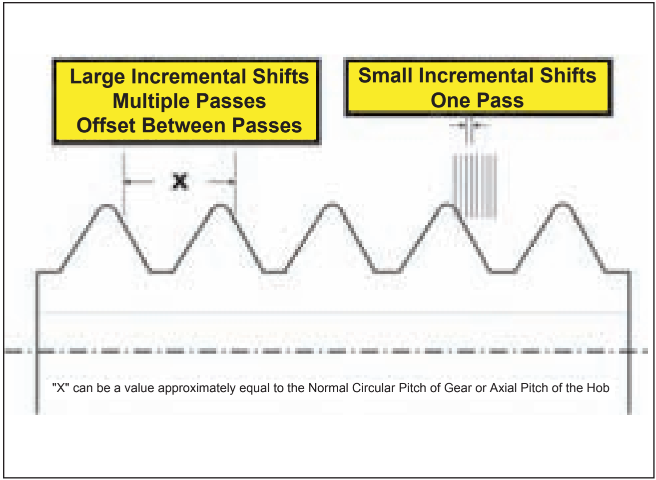
Wet and Dry Hobbing

The benefits of using a coolant are well known. Coolants are used to cool and lubricate the cutting tool, as well as maintain work and workholding equipment temperatures. Coolant also aids in the chip removal during hobbing. Dry hobbing is very popular today because it eliminates the need for coolant, therefore eliminating coolant costs, disposal fees, etc. Note that dry hobbing does require the application of air to the hob tool and to the workholding equipment to aid in chip evacuation. The cost of air must be considered in the economics of the dry hobbing process. Other benefits to dry hobbing are the reduction in health hazards from the coolant, cleaner hobbed parts and a much cleaner working environment.

In the initial movement to dry hobbing, carbide tools were selected. As stated earlier, most applications today have switched to using HSS materials for the base material when dry hobbing with one of the several coatings available.

As for the end result, you will not see any difference in quality (lead, profile, pitch, size, etc.) between parts hobbed wet or dry. What you will most likely see is better tool life with coolant than you will when hobbing dry. Much has been written about the benefits of dry hobbing, including statements about obtaining better tool life. In most cases, the improved tool life came from the fact that, when making the switch to dry hobbing, the base material of the hob and the coating were

continued



"X" can be a value approximately equal to the Normal Circular Pitch of Gear or Axial Pitch of the Hob

Figure 11—Hob shifting strategies.

upgraded. If the same upgraded hob tool material and coating were used in the wet application, most likely the resultant tool life would be better with the coolant application over the dry application.

Summary

There are many factors that can contribute to tool life. Start with a good base material and coating, and good hob design. Use reasonable speeds and feeds and think in terms of meters-per- hob-tooth (inches-per-hob-tooth), not in pieces-per-sharpening. Take a closer look at your current application and determine what the life factor is.

We can expect that new materials and coatings will be developed that will inherently yield better tool life, and or/ allow use of more aggressive speeds and feeds. Enhancements in the machine tools that cut the gears will also be introduced. As the new materials and coatings and machine tools are rolled out into the marketplace, they will be evaluated and recommendations will be made just as in the past.

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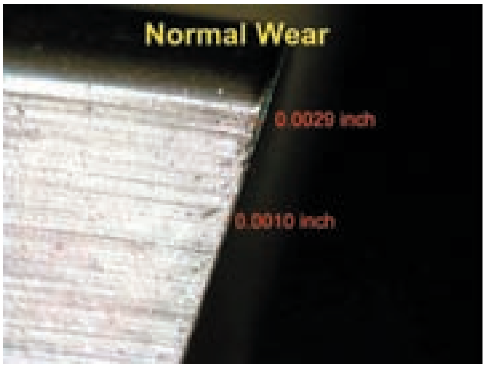
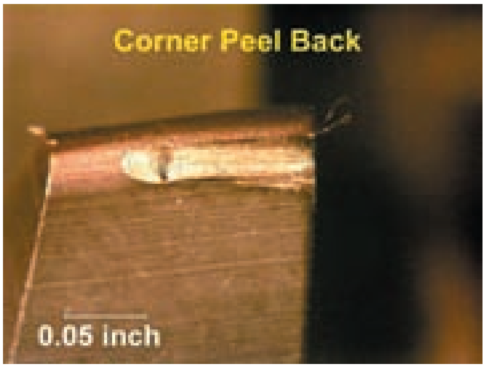
Appendix—Hob Wear Photographs

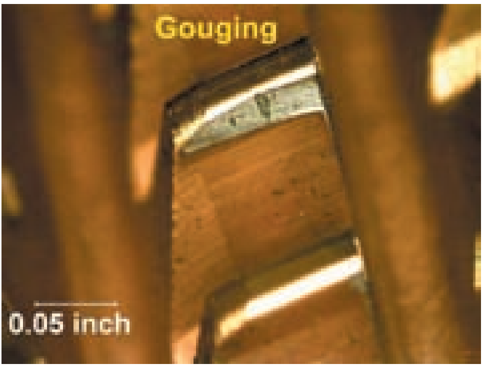

Normal Wear


Normal Flank Wear


Corner Peel Back


Tip Wear and Flank Wear


Face Cratering


Gouging

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11. Appendix photos courtesy of Gleason Cutting Tools.

T.J. "Buzz" Maiuri *began his career at The Gleason Works in Rochester, NY as an engineering apprentice in 1966, and has been with Gleason ever since. He graduated from the Rochester Institute of Technology with a Bachelor of Science degree in mechanical engineering in 1974. He has held various positions in The Gleason Works organization over his 42-plus years of service, most recently as manager of application engineering and currently as product manager. Maiuri has authored technical papers, articles and recently a webinar on various gear-related subjects, and has participated in many gear seminars (SME, AGMA, etc.) speaking on various gear-related subjects. He has served on the AGMA TDEC (Technical Division Executive Committee) since 2001.*

Appendix—Hob Wear Photographs