New Innovations in Hobbing — Part II

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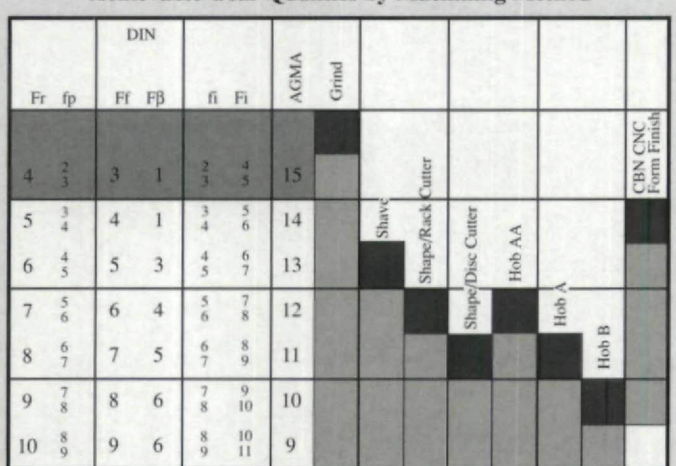
Introduction

The first part of this article, which ran in the September/October 1994 issue, explained the fundamentals of gear hobbing and some of the latest techniques, including methods of hob performance analysis and new tool configurations, being used to solve specific application problems. In this issue, the author continues his exploration of hobbing by describing the effects of progress on requirements in accuracy, as well as the latest in materials, coatings and dry hobbing.

Achievable Gear Qualities by Machining Method



DIN Fr	DIN fp	DIN Ff	DIN Fβ	DIN fi	DIN Fi	AGMA
4	2/3	3	1	2/3	4/5	15
5	3/4	4	1	3/4	5/6	14
6	4/5	5	3	4/5	6/7	13
7	5/6	6	4	5/6	7/8	12
8	6/7	7	5	6/7	8/9	11
9	7/8	8	6	7/8	9/10	10
10	8/9	9	6	8/9	10/11	9
11	9/10	10	7	9/10	11/12	8
12	10/11	11	8	10/11	12	7

Fr = Runout
fp = Pitch variation
Ff = Profile
Fβ = Lead
fi = Tooth-to-tooth composite
Fi = Total composite

Possible only under special conditions

SOURCE COMPARISONS: DIN 3962 (1974) and AGMA 390.03
NOTE: SEE THE ACTUAL STANDARDS FOR EXACT COMPARISONS

Fig. 1

Accuracy Improvements

While considerable progress has been made toward solving application problems, part requirements are becoming more and more demanding, to a point where the quality level expected from the tool has to be raised. It has long been understood that there is a very direct relationship between the accuracy of the hob and the quality of the part being produced. It has been common to see the quality requirement of the tool raised from Class B to Class A or even Class AA. There are even applications for which the requirement actually exceeds the industry standards to a point of developing tolerances that are Class AAA.

For an idea of the "normal" quality levels that are achievable with different manufacturing processes, refer to Fig. 1.

The two elements in the hob that directly affect the quality of the gear being produced are the lead in one pitch and the profile. In a single-thread hob, if the errors in these elements are added together, the result will be equivalent to the involute error possible in the part.

Historically, the method to measure this error is a conventional lead check and profile check (Fig. 2). With this method, it is possible to find the worst spot in the lead and add it to the profile error and be relatively confident that this will represent the worst-case involute error.

The use of CNC inspection equipment makes it possible to take this measurement directly. The line-of-action check (Fig. 3) enables the evaluator to review the combination of the lead and profile in one step. The method involves making the same movement axially as checking the lead, but in addition, the probe is moved radially to simulate the contact pattern realized when hobbing the gear. One drawback to the present method of line-of-action check is that it represents only one generating zone of the hob.

With multiple-thread hobs, a similar approach to evaluating the accuracy can be used with the addition of one more element, referred to as thread-to-thread error. In these cases, the sum of the lead error in one pitch, the profile error and the thread-to-thread error will give the involute error that can be expected. This additional element limited the use of multiple-thread hobs to roughing and pre-finishing operations, but today hob manufacturers can produce very accurate multiple-thread hobs.

With the introduction of the latest CNC technology to the grinding and inspection of hobs, tolerances that were virtually impossible to hold now are maintained routinely. In some cases, the thread-to-thread error has been held within .0001–.0002". As mentioned earlier, the requirements of today's tools have in some cases even surpassed the industry standards. Here Class AAA tolerances that are equal to 60% of Class AA have been developed. Of course, it must be understood that in these cases, the sharpening tolerances, hub faces, hub diameter, bore, etc., all must be modified to support the tight tolerances on lead and profile.

Materials

When the idea of improving the productivity of an application is discussed, one area that normally receives considerable attention is the substrate material of the tool. The intent of this article is not to give a complete description of the different grades of steel, but instead to raise the level of awareness about the multiple possibilities for a solution to a specific problem. The successful introduction of particle metallurgy some years ago has given the application engineer materials with characteristics of wear resistance, toughness and red-hardness levels (Fig. 4) considerably better than the original high-speed steels.

The general direction of the industry in recent years has been to upgrade the steel for a given application, normally by increasing its alloy content. The advantages of this approach can be realized in a number of different areas. The first one is the improved life factor, which results in increased lineal inches cut per sharpening when compared to the initial base grade. A table showing relative life

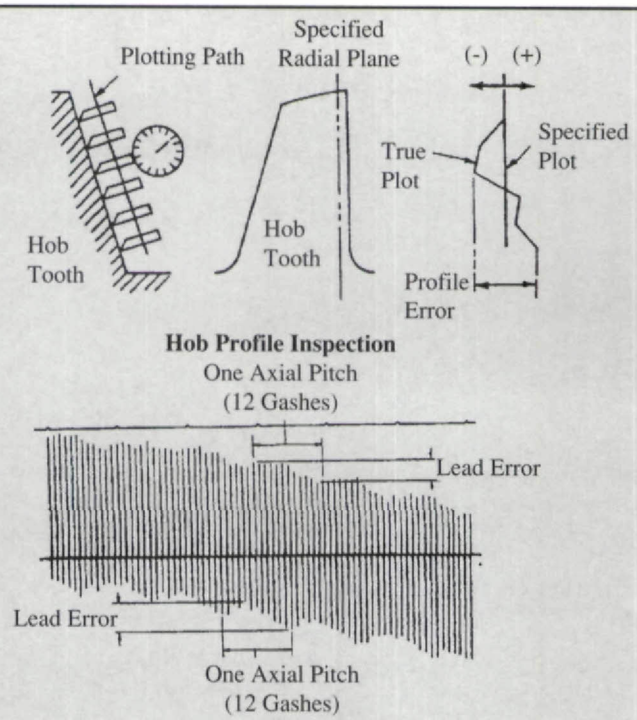


Fig. 2 **Hob Lead Chart**

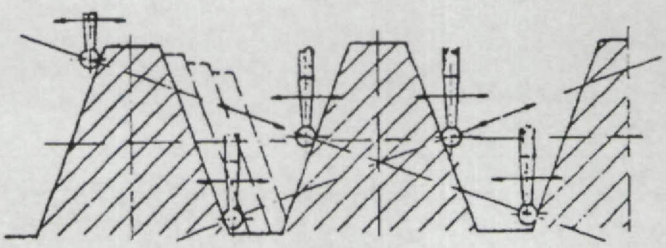


Fig. 3 **Line-of-Action Check**

High-Speed Steel Comparagraph

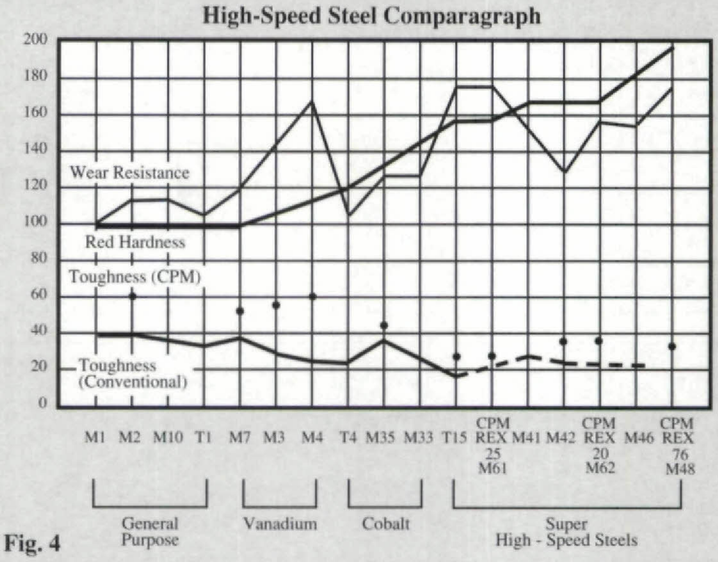


Fig. 4

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(Percent Relative Life)

M3	**M4**	**M35**	**M42**	**REX20**
100	115	110	110	110
REX45	**REX76**	**T15**	**ASP23**	**ASP30**
110	120	120	100	110

Fig. 5

(Percent Relative Feed)

M3	**M4**	**M35**	**M42**	**REX20**
100	105	100	115	115
REX45	**REX76**	**T15**	**ASP23**	**ASP30**
115	115	115	100	100

Fig. 6

(Percent Relative Speed)

M3	**M4**	**M35**	**M42**	**REX20**
100	100	120	125	125
REX45	**REX76**	**T15**	**ASP23**	**ASP30**
120	200	200	100	120

Fig. 7

(Percent Relative Price)

M3	**M4**	**M35**	**M42**	**REX20**
100	100	115	125	125
REX45	**REX 76**	**T15**	**ASP23**	**ASP30**
125	175	165	100	125

Fig. 8

factors as compared with M3 steel for different high-speed steels is shown in Fig. 5. The figures in this table and the two that follow depend on how aggressively the original tool is being applied. Actual results may vary, but generally this will give the manufacturer a good place to start.

In addition to the increase in tool life, the gain achieved in productivity improvements is another area that deserves attention.

In a typical hobbing application, approximately 85% of the total manufacturing cost is machining cost. This machining cost is directly related to feeds and speeds in any given application. Some typical figures for relative feeds and speeds are shown in Figs. 6 and 7.

When compared with the total manufacturing cost per metal-cutting operation, the price of the tool is minor. It is not uncommon for the purchase cost of a tool to amount to only about 5% of the total cost per part. With this in mind, it follows that simply buying the cheapest tool is not an effective way of reducing cost. If the purchase price of the tool is combined with the cost of resharpening and recoating, we find that the tool cost is approximately 15% of the total. Relative price increases compared with M3 steel are shown in Fig. 8. This table takes into account both the increase due to material cost and the additional machining cost encountered by the tool manufacturer.

One area that has shown significant advances in the past few years is the ability to tailor the hardening of high-speed steel to the performance of a specific application. This allows the tool manufacturer yet another opportunity to address wear or failure concerns. The approach that has been taken consists of hardening the tool to a higher or lower hardness than what might be considered "normal." In fact, we have seen occasions where even one point higher or lower in hardness can make the difference between catastrophic failure and success.

Next in the series of material improvements is the field of carbide tools. There has been a great deal of effort to apply carbide in situations where high-speed steel hobs normally would be used. The main reason for this is to take advantage of the high production rates that are possible with carbide. The gear hobbing industry has realized that in many cases, the relatively high tool cost of a carbide hob can more than be offset by the reduction of machining cost.

The availability of some newer grades of carbide have solved some of the earlier problems of applying carbide tools. The cutting process of hobbing is a very severe interrupted cut that demands certain characteristics to assure success. Intensive research in the past few years has led to the development of micrograin carbide, which addresses the problems associated with this process.

One factor that must be taken into consideration when applying carbide is the speed at which the hob is being run. In many cases, the machinery needs to be capable of speeds two to three times faster than those used with high-speed steel in order to take full advantage of what carbide has to offer. There is even a possibility of failure if these speeds are not possible. Running these speeds, of course, reduces the machining cost significantly while at the same time yielding extended life as compared with high-speed steel.

A comparison of the quality of parts that were cut with a high-speed steel hob and parts cut with a carbide hob, each at the optimal conditions, shows a great advantage in favor of the carbide hob (Fig. 9). The reason is the lower force components resulting from the conventional process, the lower number of threads, a lower axial feed and the higher cutting speeds.

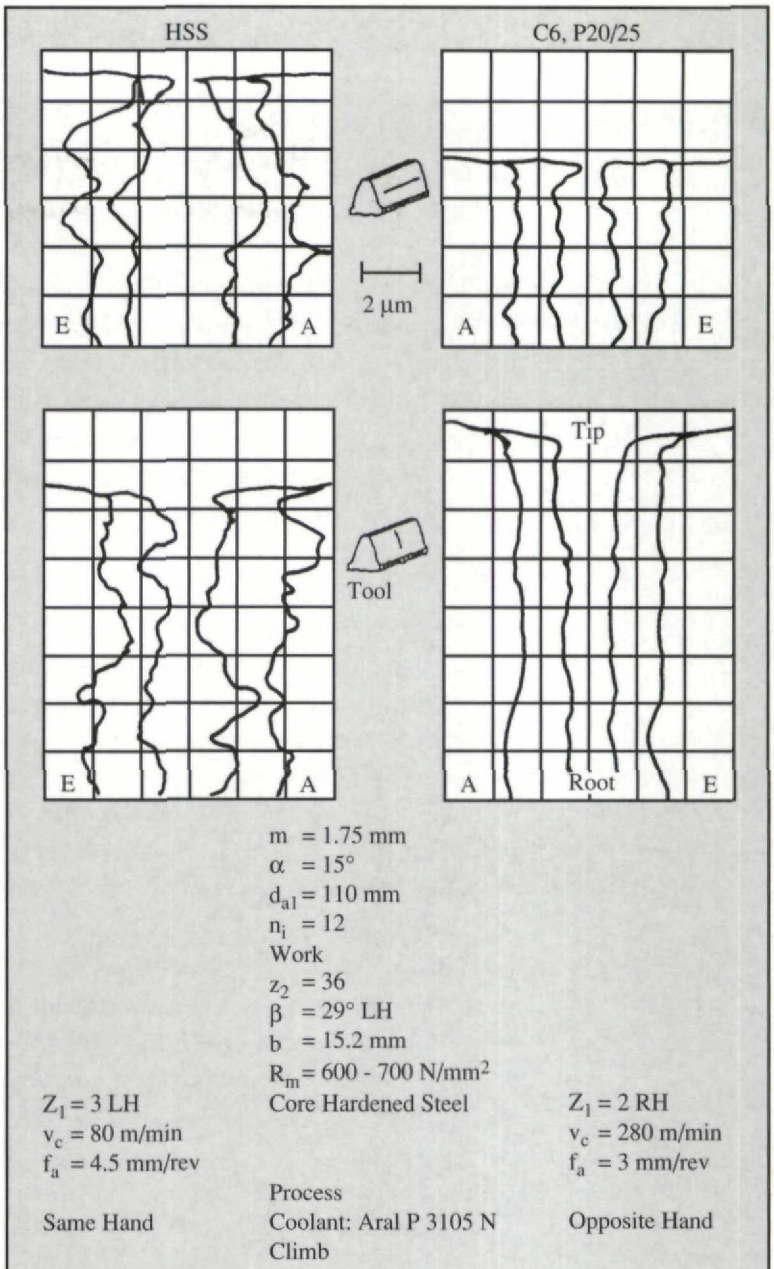

Fig. 9

Coatings

Since the early 1980s, titanium nitride coatings have been very successful at improving the process of hobbing. This coating proved to be extremely adaptable to most applications and gained acceptance relatively quickly within the gear cutting industry. It is assumed the reader is familiar with the advantages of coatings in general, so a detailed explanation of economic justification is not offered with this article.

In recent years, there has been considerable work to improve on what titanium nitride had done within this industry. The number of hard coatings that are available has increased dramatically. Today, there are as many as a dozen different coatings and multilayer coatings available to choose from. Some of these include

- TiCN—Titanium Carbonitride
- TiAlN—Titanium Aluminum Nitride
- CrN—Chromium Nitride
- CrC—Chromium Carbide

All of these coatings have certain advantages. Titanium nitride is very versatile, while some of the newer coatings are more application-specific. For example, TiCN has shown promise in areas that are very abrasive (cast iron), where TiN may not be performing at an acceptable level. TiCN, on the other hand, is somewhat sensitive to temperature, so in cases where high speeds are attempted, this coating may not show the same improvements. It seems that in cases where temperature is an issue, TiAlN may be a better selection. There has been some work recently applying TiAlN to high-speed steel in dry hobbing attempts for just that reason.

It now becomes even more important for the end user to work very closely with the tool manufacturer to coordinate the design, material, application and coating to obtain the best possible solution to a specific process. It is still generally accepted that a starting point for the addition of coatings is TiN. It may not be the final solution, but the user can begin with a relatively high level of comfort as to the success of the coating.

Dry Hobbing

One last area to explore is the recent work being done in dry hobbing of gears. This subject has a number of areas being developed, but the common goal is to successfully hob gears without using coolants. The advantages of hobbing without coolant are numerous, including cost reduction in

- Cleaning/washing parts
- Filtration
- Chip disposal (clean)
- Coolant requirement
- Coolant additives

These factors, as well as the environmental issue of disposal, have driven the efforts to progress with this new technology. There are a number of different approaches to how this can be accomplished. The actual solution, as with the new coatings, may prove to be dependent on the application. The basic methods to develop this technology can be grouped as

- High-speed steel hobs
- Carbide hobs
- Cermet hobs

High-speed steel hobs have been applied with TiAlN coatings with initial success. The material removal rate of this application is comparable to carbide hobbing at high speed and low feed. The tool life was even better than a TiN-coated tool with oil coolant.

Carbide tools have been applied as both coated (TiN) and uncoated. Considerable care must be used to select the best grade of carbide for each application. The ability of carbide to withstand high temperatures while providing very high wear resistance has significantly affected the success of the approach.

Cermet materials are multi-component cutting materials generally based on titanium carbide (TiC), with nickel (Ni) as a binder matrix. They were primarily developed to provide thermal stability, edge-holding ability and toughness. In many cases, coating this type of tool can also improve its performance. There are certain advantages as well as risks involved with applying this material in the hobbing applications.

The advantages include:

- Three to six times the life of carbide
- Higher cutting speeds

The possible risks include:

- Process fine tuning—slight deviations from the optimal setup can result in catastrophic failure.
- Limited toughness characteristics compared to carbide. This currently limits the maximum feed rates.
- Grinding difficulty and cost. These facts result in tool prices in the range of two to three times the price of a carbide tool. This material is more susceptible to grinding cracks.

Conclusion

It should be apparent to the reader that there have been significant improvements in gear cutting technology. The goal, as stated in the opening comments, should always be to improve the process in all respects. The advances in new technology will continue in the years to come, and it must be the responsibility of everyone to exploit the advancements. Simply to continue with the process as it was developed years ago is not good enough in today's market. To fully utilize the latest in these developments, it becomes even more important to get the tool manufacturer involved in the early stages of this optimization cycle. It should also be evident that the final solution for success can be considerably different depending on the results expected, even within the same application. One point to keep in mind, however: all processes have room for improvement. ■

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