Carbide Hobs

Robert P. Phillips
Pfauter-Maag Cutting Tools, Ltd., Loves Park, IL

Introduction
The following article is a collection of data intended to give the reader a general overview of information related to a relatively new subject within the gear cutting industry. Although carbide hobbing itself is not necessarily new, some of the methods and types of application are. While the subject content of this article may be quite broad, it should not be considered all-inclusive. The actual results obtained and the speeds, feeds, and tool life used in carbide hobbing applications can vary significantly.

History of Carbide Cutting Tools
The use of carbide has been accepted in the metal cutting tool industry for many years. Generally, when we talk about carbide cutting tools, we direct our attention to carbide inserts used mainly for machining centers and lathes. Carbide lends itself particularly to these types of tools for several reasons. One is that the insert itself has a relatively simple geometry (compared to a hob, for example). This geometry makes maintaining dimensional control of the tool somewhat easier during manufacturing process.

These types of tools take advantage of the benefits of carbide and at the same time tolerate some of its disadvantages. In most applications, the tool was used in high-speed, uninterrupted cuts that required the high heat qualities of the carbide material, yet was not hindered by the brittleness and lack of ability to withstand shock loads encountered during interrupted cuts. The stability of carbide at elevated temperatures also allowed insert manufacturers to take advantage of the properties of CVD titanium carbide and other CVD coatings to enhance the tool performance.

Early Carbide Hobbing
The benefits realized in the successful application of carbide in the insert industry made the ability to apply the same technology to the hobbing industry look quite attractive. Initially, the use of carbide here was somewhat limited to those applications with special needs that could not be met by the use of more conventional materials, such as high-speed steel.

Examples of these types of applications include hobbing gear materials, such as plastics, phenolics, or cast iron. These materials have a tendency to be very abrasive and can be very difficult to hob using high-speed steels. The high abrasion resistance of carbide in these cases offset the early manufacturing problems to be discussed in greater detail later.

Another example of the early use of carbide in the hobbing process is in hard finishing or skiving hobs. (See Fig. 1.) Here, the tool was used to finish hob gears after hardening. In many such cases, the part to be hobbed reached hardnesses in the range of 60Rc. High-speed steel simply would not hold up because of high part hardness.

Hobbing Steel From Solid
More recently, a great deal of effort has been applied to using carbide in cases where normally high-speed steel hobs would be used. The main reason for this is the desire 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 be more than offset by the reduction of machining costs. We are now using carbide in applications such as soft hobbing gears from the solid.

Transferring the technology learned from many successful years of carbide insert applications to the hobbing industry was very desirable. However, a number of problems needed to be overcome before carbide hobbing could be considered a viable alternative to high-speed steel hobbing.

One of the first obstacles was the inability of the older hobbing machines to provide the right conditions to take advantage of all that carbide hobs had to offer. Two key factors had to be addressed. The first was the rigidity of the machine being used. Because of its extreme hardness, carbide has an inherent tendency to chip, so every attempt had to be made to minimize looseness, vibration, and chatter. In many cases the older machines were not capable of withstanding the conditions created when attempting to use carbide hobs.

The second item that was critical to the success of carbide hobbing was the hob head speed capabilities. To take full advantage of carbide materials, hob speeds that had never before been realistically possible (because of the high-speed steel hobs being used) would have to now be made available. In many cases, hob speeds in the area of 900 sfm would have to be accommodated.

The hobbing machines were not the only early obstacles to applying carbide to the hobbing industry. One of the major problems that needed to be addressed was the ability of carbide to withstand the severe cutting conditions that are present during the hobbing process. The carbide would have to be tough enough to allow the cutting edges (individual hob teeth) to continuously enter and exit the cut during the generating process. The impact and shock resistance of the carbide would have to be increased if it were to be used successfully. Fortunately, over the last few years, a great deal of progress has been made with new grades of carbide, as well as grain size control, so that now numerous selections of grades for a given application are available.

Carbide Hob Manufacturing

Besides the machine and the material itself, the problem of manufacturing the carbide tool still remained. In most cases, the hob manufacturer were not toolled for or experienced in manufacturing tools made out of carbide. One attempt to overcome this was the "bladed" or "tipped" design. (See Fig. 2.) With this design, a steel hob was manufactured, the teeth were removed by gashing, and carbide blades were inserted and finished by grinding the teeth in the carbide from solid. This allowed the manufacturer to use many of the same processes used on standard high-speed steel hobs.

This method, however, did present some problems. By using a composite design, the manufacturer had to develop an effective means of holding the carbide blade in the steel body. Early on the most widely used method was brazing. This method was successful, but did have drawbacks because of the heat required to braze. The high heat made it too difficult to accurately locate the carbide tip in its proper position. In some cases, the heat also caused the carbide to crack because of the difference in thermal expansion properties between the steel body and the carbide blade. The introduction of new adhesives in recent years allows the blade to be held effectively without the need for high heat. Positioning of the blades can now be done very accurately, and cracking has been virtually eliminated. Using this method does require a more accurate interface between the blade and body and, in most cases, requires ground surfaces to assure proper adherence.

To help minimize the amount of form grinding required to produce the teeth in the blade, one of two different approaches can be used. The first is to use preformed tips supplied with the teeth formed in each blade by the carbide manufacturer. The second is to use wire EDM to cut the teeth in each blade. (See Fig. 3.) The use of blades with teeth make accurate location of the blades in

Robert P. Phillips
is Vice President of Engineering and Quality Assurance at Pfauter-Maag Cutting Tools, Ltd. His background is in tool design engineering, and he is responsible for the departments of Tool Design Engineering, Research and Development, Manufacturing Engineering, and SPC Implementation.
the body even more critical, so here, normally the adhesive bond technique is used.

The ability of carbide manufacturers to accurately produce preformed blanks has solved another carbide hob manufacturing problem. Through different methods, ranging from preform pressing to CNC machining before sintering, manufacturers are now able to deliver much more complex blanks than in the past. It is now possible to receive preformed hob blanks that have the bore, hubs, and gashes roughed into them. (See Fig. 4.) The hob manufacturer is then required to complete the grinding operations to the hole, hubs, sharpening, and tooth form to finish the hob.

Solid carbide blanks have an advantage over the composite design in that it is possible to enhance the performance of the tool with coatings without the threat of contaminating the furnace with the braze or adhesive bond material.

Design

Certain common practices should be followed to assure an acceptable design for carbide hobs. An example of one of these considerations is the avoidance of sharp corners. An internal sharp corner will result in a stress riser that could cause cracks to propagate. An external sharp corner creates a structurally less sound edge that could lead to premature failure due to chipping.

With high-speed steel hobs, it is possible to grind with an assortment of different types of grinding wheels (aluminum oxide, silicon carbide, Borazon®, etc.). When grinding with carbide, the choice is limited to diamond. Although work is currently being done to develop a dressable, vitrified diamond wheel, the majority of carbide form grinding is done with either plated diamond or resin bond diamond grinding wheels. The inability to readily form the diamond wheels has, in the past, limited the profile modifications that are permissible on the tooth flanks.

Maintenance

When discussing the proper maintenance of carbide hobs, a number of areas must be addressed. The first one - often overlooked - is the special care that must be taken when handling carbide hobs. Although precautions must be taken when handling any cutting tool, carbide is somewhat more brittle than high-speed steel and more susceptible to chipping and breakage. When dealing with carbide hobs, special cases for transporting and storage should be investigated.

Tooling is another area that should be examined. Some tooling that may be considered standard when using high-speed steel hobs, simply must be avoided when using carbide materials. One example is any kind of "press type" arbor. Obviously, given some of the material characteristics of carbide, any excessive force used with this type of arbor could lead to cracking sooner than with steel hobs.

The only maintenance with which the final user of a carbide hob must be concerned is the proper sharpening of the cutting face of the hob.
when the tool is worn. In practice, the same process is used to sharpen a carbide hob as a steel hob. The differences are the type of grinding wheel used, the feeds and speeds, and possibly the coolant used. Diamond grinding wheels should be used when sharpening carbide hobs. We have had success using both plated diamond and resin bonded diamond grinding wheels. The actual wheel specification can vary according to the machine being used, and the surface finish and amount of stock removal required. The wheels we have found successful are:

- Plated - Universal Super Abrasive (Elgin Diamond) 180 Grit
- Resin Bond - Universal Super Abrasive (Elgin Diamond) 180 Grit 100 concentration

Both wheels are capable of producing surface finishes of 16μ or better (resin as low as as 6-8mm) if applied correctly.

Grinding wheel speeds will vary according to the type of wheel being used, but, typically, to provide the proper cutting conditions, the speed will be in the range of 6500/6700 sfm. The table feed rate should stay in the area of four inches per minute. The stock removal rate is very critical when sharpening carbide hobs. The rate of removal is much less than with steel hobs. Normally .001 stock removal per pass of the grinding wheel should not be exceeded. Stock removal rates much higher than this can lead to heat generation, causing sharpening cracks. Note that using magnaflux to detect cracks in carbide tools (as might be done with steel hobs) is not recommended. A more readily accepted method for crack detection in carbide is a chemical means, such as Zyglo.

One final topic to cover in the proper maintenance of carbide hobs is the coolants being used, not only in the sharpening operation, but also in the hobbing application. Cutting oils should be evaluated to assure that no elements in the chemical make-up of the oil may be detrimental to the carbide material itself. Certain sulfur and chlorine additives can tend to leach the carbide binders, leaving an extremely brittle cutting edge that will lead to premature failure of the tool.

**Carbide Properties**

Of the many different types of carbide materials available today, the one based on tungsten carbide and cobalt has the widest industrial use. In the case of machining steel, the chips are much different from those produced in the early carbide hob applications discussed previously. The chip in this case can be relatively long and stringy. The properties of the newer grades of carbide for these applications have been tailored to meet the needs present here.

The strength and hardness of a cobalt-bonded tungsten carbide section depends primarily on the uniformity and the thickness achieved in the cobalt film surrounding the carbide particles. This is controllable by adjusting the proportion of cobalt to tungsten carbide and, to a lesser degree, by varying the particle size of the tungsten carbide. Smaller amounts of cobalt will result in the structure assuming properties more like tungsten carbide itself; namely, higher hardness and increasing tendency toward brittleness and lower strength. The effect of cobalt on hardness and strength is represented in Figs. 5 and 6.

Aside from its tremendous compressive strength and hardness, the best known characteristic of carbide
is its abrasion resistance. (See Fig. 7.) However, a direct relationship exists between these two characteristics and the transverse rupture strength. This is a measure of shock resistance. (See Fig. 8.)

**Carbide Grades**

Each carbide vendor has a wide selection of carbide grades available for a given application. The primary bases for selection of a specific grade of carbide are the material being cut and the type of cutting application being performed. A chart showing a number of different carbide vendors and their specific grade designations is shown in Fig. 9. In many cases, within a specific grade, there may be variations as far as grain structure and size to help tailor the performance to an application. The carbide vendor should be included in discussions regarding grade selection.

**Application Results**

As stated in the introduction, the actual results obtained in specific applications of carbide hobbing can vary greatly. The following examples are included for reference only, but can help give an indication as to the possible benefits obtainable with the proper application of carbide hobs.

![Fig. 7 - Relative resistance to abrasion. (Carmet grades.)](image_url)

![Fig. 8 - Transverse rupture strength vs. hardness. (Carmet grades.)](image_url)
### Machining Data

**Hob Data:**
- **# threads**: 1
- **Material**: Steel (M3+TiN) vs Carbide

**Machining Data:**
- **Steel**: Speed RPM: 500, Speed SFM: 163, Feed rate: .030, Shift Amount: .009, # pieces per shift: 1
- **Carbide**: Speed RPM: 2500, Speed SFM: 820, Feed rate: .035, Shift Amount: .009, # pieces per shift: 2

---

### Steel Hob vs. Carbide Hob Comparison

**Example 1**

**Part Data:**
- **Number of teeth**: 11
- **Pitch**: 30
- **Outside diameter**: 0.46

**Hob Data:**
- **Outside diameter**: 1.25
### Total Cost Per Part Analysis

#### I. Tool cost per part

<table>
<thead>
<tr>
<th>Cost of tool</th>
<th>Steel</th>
<th>Carbide</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. of pieces per sharpening</td>
<td>140</td>
<td>280</td>
</tr>
<tr>
<td>Amt. of stock removed per</td>
<td></td>
<td></td>
</tr>
<tr>
<td>sharpening</td>
<td></td>
<td></td>
</tr>
<tr>
<td>No. of sharpenings per hob</td>
<td>9</td>
<td>18</td>
</tr>
<tr>
<td>Total pieces per tool</td>
<td>1260</td>
<td>5040</td>
</tr>
</tbody>
</table>

**Total cost per piece**: $0.23 $0.26

#### II. Hobbing cost per part

<table>
<thead>
<tr>
<th>Feed</th>
<th>.030</th>
<th>.035</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hob travel - inches</td>
<td>.530</td>
<td>.530</td>
</tr>
<tr>
<td>No. of teeth in part</td>
<td>11</td>
<td>11</td>
</tr>
<tr>
<td>No. of threads in hob</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Hob speed - rpm</td>
<td>500</td>
<td>2500</td>
</tr>
<tr>
<td>Helix angle - degrees</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

**Hobbing time per piece (min.)**: .390 .067

**Shop labor rate per hour**: $50 $50

**Hobbing cost per piece**: $0.325 $0.056

#### III. Total cost per part

**Tool cost + Hobbing cost**: $0.555 $0.316

### Steel Hob Vs. Carbide Hob Comparison

#### Example 2

**Part Data:**
- Number of teeth: 42
- Pitch: 17.8
- Outside diameter: 2.585

**Hob Data:**
- # threads: 4
- Material: Steel (M3+TiN) vs. Carbide

**Machining data:**
- Speed RPM: 285 1000
- Speed SFM: 205 720
- Feed rate: .060 .200
- Shift amount: .0036 .0009
- # pieces per shift: 1 1
### TOTAL COST PER ANALYSIS

<table>
<thead>
<tr>
<th></th>
<th>Steel</th>
<th>Carbide</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>I. Tool cost per part</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cost of tool</td>
<td>$1190</td>
<td>$3680</td>
</tr>
<tr>
<td>No. of pieces per sharpening</td>
<td>1500</td>
<td>6000</td>
</tr>
<tr>
<td>Amt. of stock removal per sharpening</td>
<td>.015</td>
<td>.008</td>
</tr>
<tr>
<td>No. of sharpenings per hob</td>
<td>16</td>
<td>30</td>
</tr>
<tr>
<td>Total pieces per tool</td>
<td>24000</td>
<td>180000</td>
</tr>
<tr>
<td>Tool cost per piece</td>
<td>$0.05</td>
<td>$0.02</td>
</tr>
</tbody>
</table>

|                      |        |         |
|**II. Hobbing cost per part** |        |         |
| Feed                 | .060   | .200    |
| Hob travel - inches  | 1.00   | 1.00    |
| Number of teeth in part | 42   | 42     |
| Number of threads in hob | 4    | 1      |
| Hob speed - RPM      | 285    | 1000    |
| Helix angle - degrees | 21   | 21     |
| Hobbing time per piece (min.) | .657 | .225 |
| Shop labor rate per hour | $50  | $50    |
| Hobbing cost per piece | $.548 | $.188  |

|                      |        |         |
|**III. Total cost per part** |        |         |
| Tool cost + hobbing cost | $598  | $208    |

**Acknowledgement:** This article was presented at the Society of Manufacturing Engineers Gear Clinic in Nashville, TN, Oct., 1990. Reprinted with permission.