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.

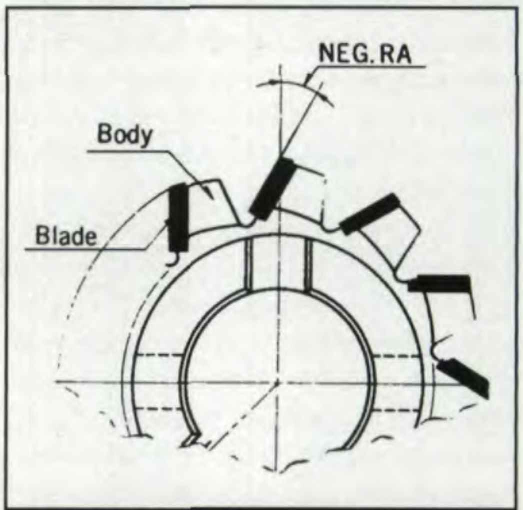

Fig. 1 - Skiving hob.

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.

Transfering 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 manufacturers were not tooled 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

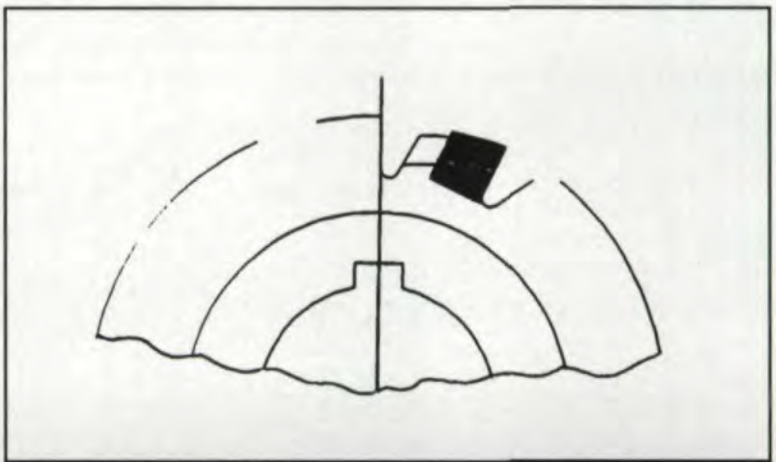

Fig. 2 - Carbide "tipped" hob.

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.

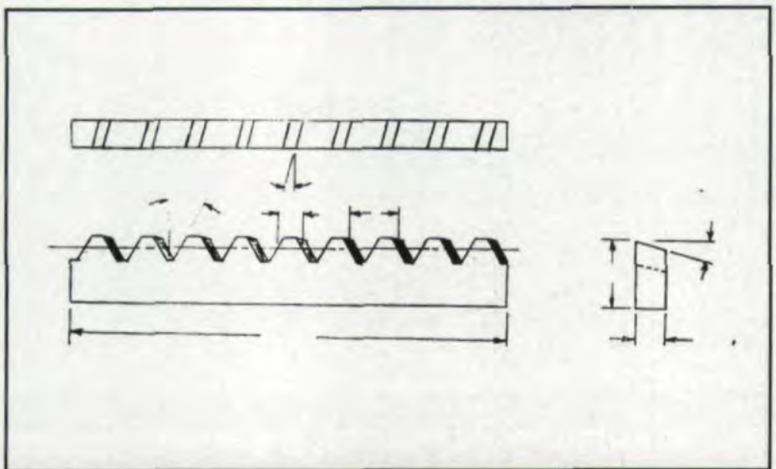

Fig. 3 - Pre-formed carbide tips.

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

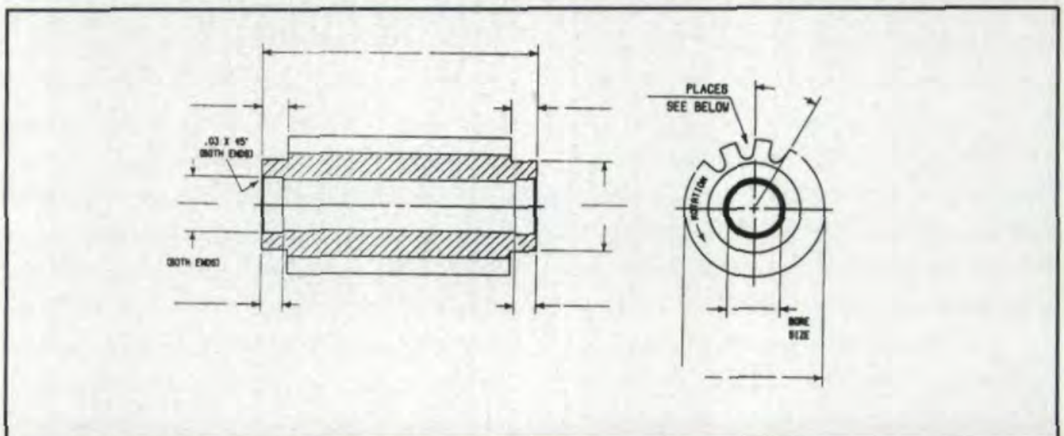

Fig. 4 - Solid carbide hob blank as manufactured by carbide vendor.

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

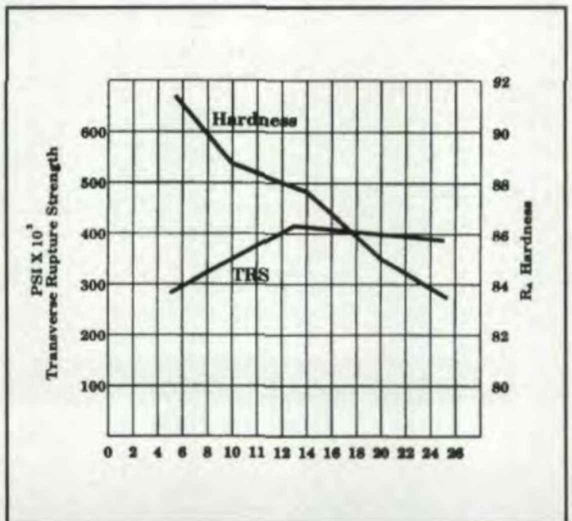

Fig. 5 - Hardness and strength vs. cobalt content.

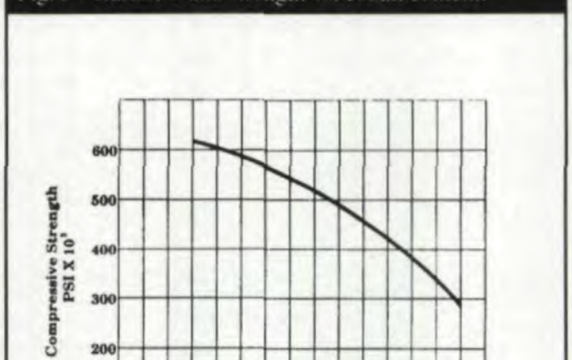

Fig. 6 - Effect of cobalt on compressive strength.

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.

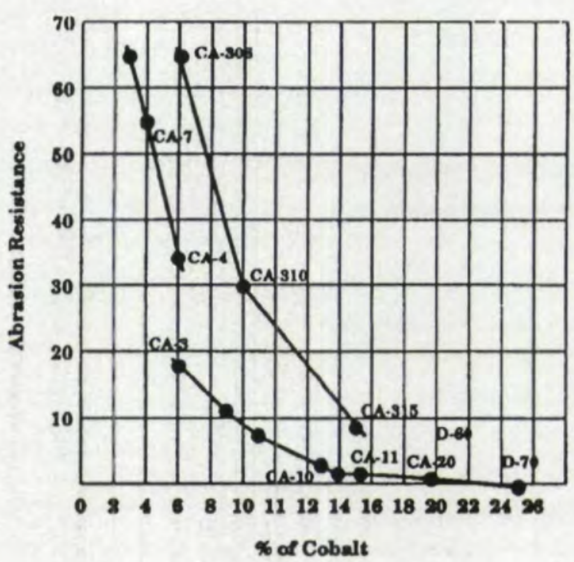

Fig. 7 - Relative resistance to abrasion. (Carmet grades.)

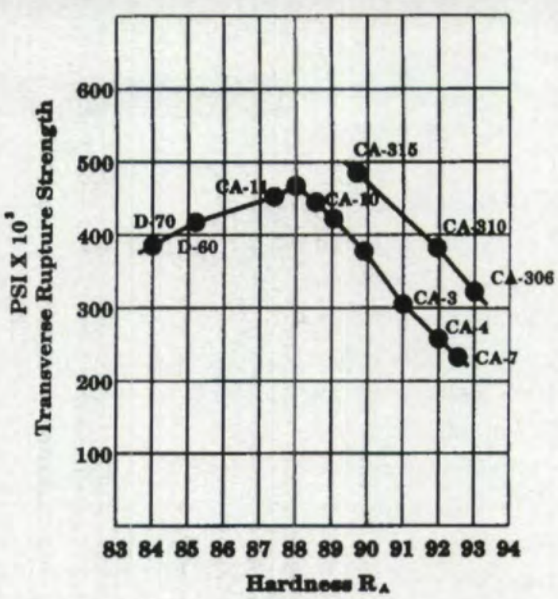

Fig. 8 - Transverse rupture strength vs. hardness. (Carmet grades.)

		C Code	ISO Code	Working Conditions	ADAMAS	Carboloy	Firth Sterling	Kennametal	Newcomer	Sandvik	Valenite	VR-Wesson	Wendt Sonis
CHIP REMOVAL APPLICATIONS	CAST IRON, NON-FERROUS METALS AND NON-METALLIC MATERIALS	C-1	K30	Roughing Cuts	B	**523 44A 883	**HN +4 HN + H17 H8	**KC 250 K8735 K1	N10	H10F	**VN8 **VIN **V88 VC1 VC28	**650 **653 **660 2A68 RAMET 1 VR 54	**CQ22T **U222 **722 CQ2
CHIP REMOVAL APPLICATIONS	CAST IRON, NON-FERROUS METALS AND NON-METALLIC MATERIALS	C-2	K20	General Purpose	#ADAMAX 6000 †ROXIDE †264 †241 A PWX AM	†570 (560) **523 875 883	**HN+ †CC46 H6	†KC910 (KC 950) **KC210 K8735 K6	**NT25 **NT2 N25 N22	**GC1025 **GC315 †GC015 †GC320 †GC310 (GC415) HIP H10F H13A H20 HM HML IRB	**VN8 **VIN **V88 †V01 †V05 VC2 VC28	**630 **633 **650 **660 (680) 2A5 VR54 VR 82	**CQ22T †918 **U222 **Q27 CQ2 CQ23
CHIP REMOVAL APPLICATIONS	CAST IRON, NON-FERROUS METALS AND NON-METALLIC MATERIALS	C-3	K10	Light Finishing	#ADAMAX 3000 †ROXIDE †241 PWX	†570 (560) **523 895 883	**HN+ †CC46 H21 HA HTA	†KC910 (KC950) **KC250 K68	**NT 25 N30 N20	**GC1025 **GC315 †GC015 †GC320 †GC310 (GC415) HIP H10 HM IRB	**VN8 **V88 †V01 †V05 VC2	**630 **633 (680) (690) 2A7 VR52 VR82	**CQ23T **U222 **723 CQ23
CHIP REMOVAL APPLICATIONS	CAST IRON, NON-FERROUS METALS AND NON-METALLIC MATERIALS	C-4	K05	Precision Boring and Finish Turning	†241 GU-2	†545 895	†CC46	†KC910 (KC950) **KC210 K11 K8	**NT25 N20	**GC1025 **GC315 †GC015 †GC310 †GC315 HIP	**V88 †V01 †V05 VC3	(680) (690) 2A7 VR52 *VR65 *VR97 *VR100	**CQ23T **037 CQ3
CHIP REMOVAL APPLICATIONS	STEELS AND ALLOY STEELS	C-5	P40	Rough and Interrupted Cutting at Slow Speeds	434	**515 **518 **538 **550 370 390	**TC+4 **HN+4 TO4	**KC850 KM K420 K21 K2S	**NT5 N55 N52	**GC135 **GC235 (GC435) S6 S30T S35 SM30 SMA	**VIN VC56	**643 **650 **653 †655 VR77 VR79 WS	**CY17T **717 CY17
CHIP REMOVAL APPLICATIONS	STEELS AND ALLOY STEELS	C-5	P30	Rough and Interrupted Cutting at Moderate Speeds	*T50 **764 **CNC †264 499 THERMILL #ADAMAX 6000	†570 (560) **550 **538 **536 **518 **515 375 370	**TC+4 **TC+ **HN+4 **HN+ NTA T12 T14	**KC850 (KC950) **KC810 K2885 K2884 K21 K420 K2S	**NN55 †NA02 N50	**GC1035 **GC135 GC225 **GC120 †GC015 (GC415) (GC435) S4 S30T S35 SM SM30 SMA	**VN8 **V88 **VIN †V01 †V05 VC56 VC35M VC5	**650 **653 (655) †680 **660 **663 VR75 VR77	**CY15T **U225 **715 **716 **717 **755 CY16
CHIP REMOVAL APPLICATIONS	STEELS AND ALLOY STEELS	C-6	P-20	General Purpose	*T60 **CNC **764 †ROXIDE †264 499 THERMILL	†570 (560) **550 **536 **515 375 370	**TC+ **HN+ †CC46 TXH T22	**KC850 (KC950) **KC810 K2885 K2884 K29 K4H	**NN55 **NN6 †NA02 N60	**GC1025 **GC120 **GC225 †GC015 (GC415) S2 S30T SM SM30 SMA	**VN8 **VN5 **V88 †V01 †V05 VC5 VC35M	**660 **663 (655) (680) VR 73	**CY15T †918 **U225 **U227 **714 **715 **716 **755 CY14 CY16
CHIP REMOVAL APPLICATIONS	STEELS AND ALLOY STEELS	C-7	P10	Finish Cuts	#ADAMAX 3000 **CNC †ROXIDE 548 *T80	†570 (560) †545 350	**TC+ **HN+ †CC46 T24 T25	†KC910 (KC950) K45 K5H	**NN55 **NN6 †NA02 N70	**GC1025 **GC120 **GC225 (GC415) †GC015 SIP SIOT	**VN8 **VN5 **V88 †V01 †V05 VC165 *VC67 VC7	**660 **663 (680) (690) *VR65 VR73	**CY15T **U227 **714 **715 CY14 CY31
CHIP REMOVAL APPLICATIONS	STEELS AND ALLOY STEELS	C-8	P05	Precision Turning and Boring	*T80 **CNC MIRROCUT MIRROMILL	†570 †545	†CC46 *SD3	†KC910 (KC950) K7H	N95 N80	†GC015 (GC415) SIP SIOT	**V88 *VC67 *VC83 †V01 †V05 VC7	(680) (690) *VR65 *VR97 *VR100	**CY31T **U227 **714 **731 *T18
WEAR APPLICATIONS		C-9	–	Wear Surface No Shock	PWX A	895 883	HA	K68 K96 K6	N20	CS05 CS10 CS20	VC9	2A5 2A68	CQ12
WEAR APPLICATIONS		C-10	–	Wear Surface Light Shock	B	44A 779	H	K95	N10	CS20 CG35	VC10	2A68 2A6	CQ12
WEAR APPLICATIONS		C-11	–	Wear Surface Heavy Shock	BB	55A 55B	HC	K94 K92 3109	–	CG35 CG40 CG60	VC11	2A3 2A1	CQ14
IMPACT APPLICATIONS		C-12	–	Impact-Light	BB	779 115 55A	DC1 DC2	K94 3109	–	CT45 CT50	VC12	2A3 VR13	U50 CQ14
IMPACT APPLICATIONS		C-13	–	Impact-Medium	HD15	55A 55B	DCX	K92	–	CT60	VC13	VR14 VR15	CQ13

NOTES: *Grades containing more than 50% titanium carbide.
**Coated Grades
#Cermet Grades
†Al_2O_3 Coatings.
Multiple Coated Grades including Al_2O_3( )

The above chart is not a grade comparsion chart. The information listed herein is approximate, and instructions regarding the specific use and application of any competitive grade should be obtained direct from the manufacturer.

Fig. 9 - Grade selections.

Steel Hob vs. Carbide Hob Comparison

Example 1

Part Data:

Number of teeth	11	Helix angle	0
Pitch	30	Face width	0.53
Outside diameter	0.46	Hardness Rc	35

Hob Data:

# threads	1	Outside diameter	1.25

Material Steel (M3+TiN) vs Carbide

Machining Data:

	Steel	Carbide
Speed RPM	500	2500
Speed SFM	163	820
Feed rate	.030	.035
Shift Amount	.009	.009
# pieces per shift	1	2

Total Cost Per Part Analysis

	Steel	Carbide
I. Tool cost per part		
Cost of tool	$300	$1300
No. of pieces per sharpening	140	280
Amt. of stock removed per sharpening	.010	.005
No. of sharpenings per hob	9	18
Total pieces per tool	1260	5040
Total cost per piece	$0.23	$0.26
II. Hobbing cost per part		
Feed	.030	.035
Hob travel - inches	.530	.530
No. of teeth in part	11	11
No. of threads in hob	1	1
Hob speed - rpm	500	2500
Helix angle - degrees	0	0
Hobbing time per piece (min.)	.390	.067
Shop labor rate per hour	$50	$50
Hobbing cost per piece	$.325	$.056
III. Total cost per part		
Tool cost + Hobbing cost	$.555	$.316

Steel Hob Vs. Carbide Hob Comparison

Example 2

Part Data:

Number of teeth	42	Helix angle	21
Pitch	17.8	Face width	1.00
Outside diameter	2.585	Hardness Bhn	180

Hob Data:

# threads	Steel-4 Carbide-1	Outside diameter 2.75
Material	Steel (M3+TiN) vs. Carbide	

Machining data:

	Steel	Carbide
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

	Steel	Carbide
I. Tool cost per part		
Cost of tool	$1190	$3680
No. of pieces per sharpening	1500	6000
Amt. of stock removal per sharpening	.015	.008
No. of sharpenings per hob	16	30
Total pieces per tool	24000	180000
Tool cost per piece	$0.05	$0.02
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.*