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New Developments in Gear Hobbing

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[The statements and opinions contained herein are those of the author and should not be construed as an official action or opinion of the American Gear Manufacturers Association.]

Abstract

Several innovations have been introduced to the gear manufacturing industry in the last years. In the case of gear hobbing, the dry cutting technology and the ability to do it with powder-metallurgical HSS-materials might be two of the most impressive ones. But the technology is still moving forward.

The aim of this article is to present recent developments in the field of gear hobbing, as there are innovations regarding tool materials, process technology and process integration.

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Introduction

During the last years, a couple of new developments have been introduced regarding gear hobbing. The innovations in the substrate materials and coating systems have led to an increase of productivity by higher cutting speeds and longer tool life. But of course, higher performance leads to higher prices for the tools, so the impact on the tool investment as well as the resulting costs per piece have to be examined.

Another perspective to improve productivity is to shorten the process chain. Here, the process integration via chamfering and deburring on the hobbing machine is discussed. Besides conventional chamfering methods like the Gratomat®-principle or the rotary deburring, a new process using specially designed chamfering cutters will be presented.

Finally, the chance for cost savings by process substitution is discussed focusing on examples for

finish hobbing. To overcome shaving as the traditional soft-finishing method, new tool concepts are presented which aim to increase the process performance regarding tool life and workpiece quality. Especially the chance to eliminate or control the natural twist of finish hobbing might open up the way for new applications.

Modern tool design

Although also the machine tools have been improved a lot in the last decades, the major impact on the hobbing technology was related to the tool development. If we look on the improvements in the past there, the focus was on the one hand on the substrate materials and on the other hand on the coating systems (figure 1). Both developments together lead to much higher cutting speeds and/or longer tool life. Even processes like dry hobbing became reality.

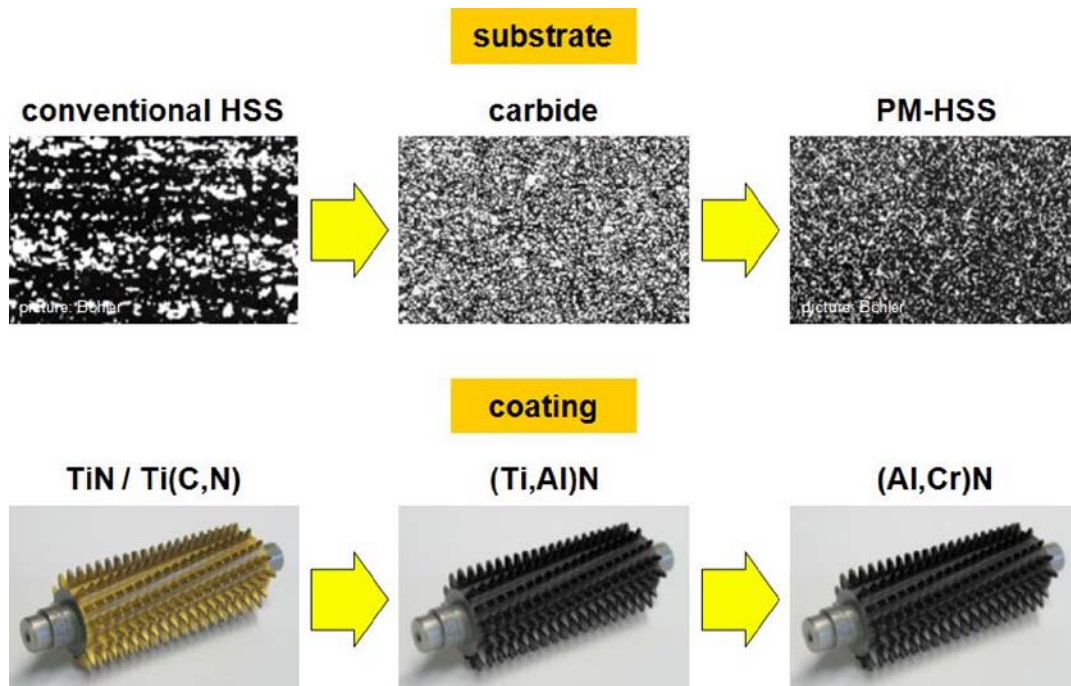


Figure 1. Tool improvements in the past

Coming from the conventional HSS substrates (e.g., EMo5Co5 or M35) with TiN-coating, the use of carbide hobs seemed to be necessary to realize dry hobbing applications. But after a phase of enthusiasm, problems with the process reliability regarding the tool life of the reconditioned carbide hobs (e.g., due to cobalt leaching during stripping) stopped the trend. Then the introduction of the more heat-resistant TiAlN-coatings in combination with higher alloyed and more homogeneous PM-HSS substrates brought the dry cutting back on track. Nowadays, dry-cutting with PM-HSS as well as carbide is state-of-the-art. And since the AlCrN-based coatings have been introduced successfully in the gear hobbing market a couple of years ago, speeds and feed could be increased even more in many applications.

Besides their more homogeneous structure, the main advantage of the powder metallurgical HSS substrates is the ability to contain greater amounts of alloys. As shown in figure 2, the remaining content of iron was reduced from about 70% for a standard substrate (e.g., ASP2030, S590 or Rex45) to a minimum of 55–60% for the so-called

“bridge materials” (e.g., ASP2080, S290 or Rex 121). Those extremely alloyed substrates are more similar to carbide material than PM-HSS, which gives on the one hand the advantage of higher wear resistance but on the other hand the disadvantage of much worse resharping. Therefore, medium alloyed substrates like ASP2052, S390 or Rex 76 are a good compromise for high performance hobbing applications.

Regarding the different coating systems, figure 3 shows a comparison of the most important characteristics.[1] While the higher hardness of the TiCN-coating compared to the TiN-coating showed potential to improve the tool performance in wet cutting, the low red hardness (maximum service temperature) of both coatings was not really sufficient for dry hobbing applications. Here the TiAlN- and especially the new AlCrN-coatings have proven their performance ability. With maximum service temperatures of 900 – 1100°C in combination with their thermal isolating effect to the substrate material, a new level of dry cutting could be reached.

Supplier	Product Name	Clarification	Achievable Hardness [HRC]	%C	%Cr	%Mo	%W	%Co	%V	Remaining %Fe
Erasteel	ASP2023	HS 6-5-3	66	1,28	4,1	5	6,4	-	3,1	80
	ASP2030	HS 6-5-3-8	67	1,28	4,2	5	6,4	8,5	3,1	72
	ASP2052	HS 10-2-5-8	67	1,60	4,8	2	10,5	8,0	5,0	68
	ASP2060	HS 6-7-6-10	69	2,30	4,2	7	6,5	10,5	6,5	63
	ASP2080	HS 11-5-6-16	71	2,45	4,0	5	11,0	16,0	6,3	55
Crucible	CPM REX T15	HS 12-0-5-5	67	1,60	4,00	-	12,00	5,0	4,90	73
	CPM REX 20	HS 6-11-2	68	1,30	3,75	10,50	6,25	-	2,00	76
	CPM REX 45	HS 6-5-3-8	68	1,30	4,00	5,00	6,25	8,0	3,00	72
	CPM REX 54	HS 6-5-4-5	66	1,48	4,00	5,00	5,50	5,0	3,75	75
	CPM REX 76	HS 10-5-3-9	69	1,50	3,75	5,25	9,75	8,5	3,10	68
Bohler	S790	HS 6-5-3	66	1,30	4,2	5,0	6,3	-	3,0	80
	S690	HS 6-5-4	66	1,33	4,3	4,9	5,9	-	4,1	79
	S590	HS 6-5-3-8	67	1,30	4,2	5,0	6,3	8,4	3,0	72
	S390	HS 10-2-5-8	69	1,60	4,8	2,0	10,5	8,0	5,0	68
	S290	HS 14-2-5-11	68	2,00	3,8	2,5	14,3	11,0	5,1	61

standard material
 high-performance material
 "bridge" material

Tungsten and Vanadium increase the abrasive wear resistance.

Cobalt increases the crater wear resistance.

Figure 2. PM-HSS materials

Product name	Coating material	Microhardness HV ^a	Friction coefficient against steel (dry) ^a	Internal stress (GPa) ^a	Max. service temperature (°C) ^a	Coating color	Coating structure
BALINIT®A	TiN	2300	0,4	-2,5	600	gold-yellow	Monolayer
BALINIT®ALCRONA	AlCrN	3200 !	0,35	-3	1100 !	blue-grey	Monolayer
BALINIT®B	TiCN	3000	0,4	-4,0	400	blue-grey	multilayer, gradient
BALINIT®C	WC/C	1000 / 2000	0,10 - 0,20	-1,0	300	black-grey	lamellar
BALINIT®D	CrN	1750	0,5	-1,5 / -2,0	700	silver-grey	Monolayer
BALINIT®DIAMOND	polycrystalline diamond	8000 - 10000	0,15 - 0,20		600	light-grey	Monolayer
BALINIT®FUTURA NANO	TiAlN	3300 !	0,30 - 0,35	-1,3 / -1,5 !	900 !	violet-grey	Nano structured
BALINIT®FUTURA TOP	TiAlN	3300 !	0,25 !	-1,3 / -1,5 !	900 !	violet-grey	Nano structured
BALINIT®G	TiCN + TiN	3000	0,4	-4,0	400	gold-yellow	multilayer, gradient
BALINIT®HARDLUBE	TiAlN + WC/C	3000	0,15 - 0,20 !	-1,7 / -2,0	800	dark-grey	multilayer, lamellar
BALINIT®TRITON	DLC (a-C:H)	2500	0,1 - 0,2		350	black-grey	Monolayer
BALINIT®X.CEED	TiAlN	3300 !	0,4	-3,0 / -3,5	900 !	blue-grey	Monolayer
BALINIT®X.TREME	TiAlN	3500 !	0,4	-4,0	800	violet-grey	Monolayer

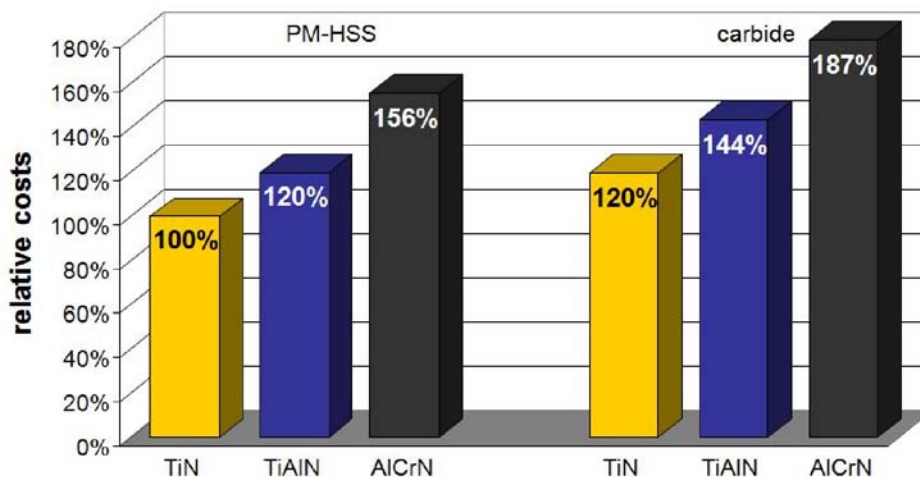
source: Balzers

! : positive influence on dry hobbing

Figure 3. Properties of modern coating systems

As usual, higher performance means higher pricing (figure 4). As a rule of thumb, on PM-HSS hobs a TiAlN-coating costs about 20% more than a TiN-Coating. An AlCrN-coating will cost additional 30%

compared to a TiAlN-coating, so in total about 55% more than a TiN-coating. For carbide hobs, the coating prices are typically about 20% higher than for PM-HSS-tools.



The price of the coatings increases with their improved physical properties. Whether the higher investment pays off is dependent upon the application.

Figure 4. Costs for different coatings

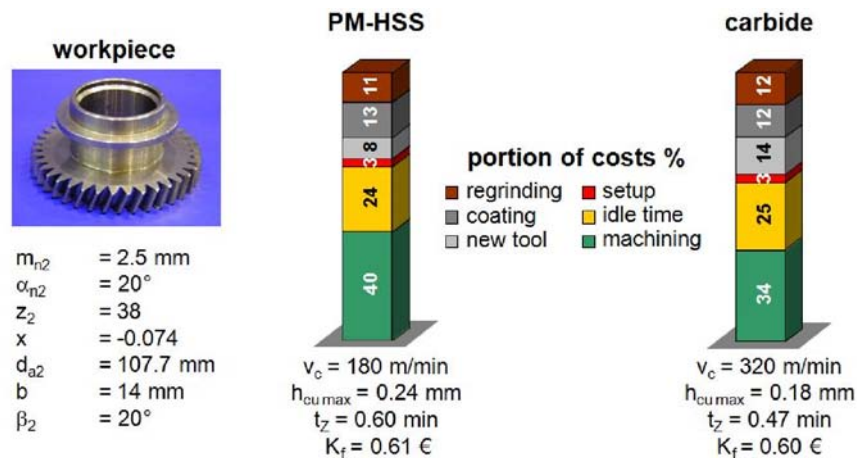
Due to the usually lower tool costs, PM-HSS is actually the preferred substrate material for hobs especially in the smaller modules (e.g., automotive and truck industry). Characteristic for PM-HSS is its reliable wear behavior in a widespread range of applications. Carbide offers advantages especially in the area of finishing and cutting of high-strength workpiece materials ($R_m > 900 \text{ N/mm}^2$) due to its high wear resistance. For low to medium strength material ($R_m = 500\text{--}700 \text{ N/mm}^2$), typical cutting data are given in figure 5. PM-HSS normally allows higher chip thickness (higher feed rate), carbide offers higher cutting speeds.

The final decision for the best choice of substrate should be based on a detailed analysis of the costs per piece (figure 6). As assumed, the use of PM-HSS leads to lower tool costs (here: 16%). Carbide tools offer lower machining times (here: 22%) and thus lower machining costs. In the presented example, both advantages are almost leveling out each other concerning the costs per piece. This underlines that the decision regarding the right substrate should be made each time separately. If no significant advantages for carbide, PM-HSS is actually favored in most applications due to the more reliable performance and the lower investment costs.



PM-HSS	carbide
main advantage: low tool costs	main advantage: low wear at high cutting speeds
cutting data: $v_c \approx 160 - 230 \text{ m/min}$ $h_{cu} \approx 0,18 - 0,24 \text{ mm}$	cutting data: $v_c \approx 280 - 450 \text{ m/min}$ $h_{cu} \approx 0,14 - 0,18 \text{ mm}$

Figure 5. PM-HSS vs. carbide



The higher the cutting data, the more the idle time gains importance.
The tool investment has a small impact, so higher-quality substrates and coatings pay off.

Figure 6. Cost calculation example