

Power-Dry-Cutting of Bevel Gears

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American Gear Manufacturers Association



TECHNICAL PAPER

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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

High speed machining using carbide has been known for some decades for milling and turning operations. The intermittent character of the gear cutting process has delayed the use of carbide tools in gear manufacturing. Carbide was found at first to be too brittle for interrupted cutting actions. In the meantime, however, a number of different carbide grades were developed. The first successful studies in carbide hobbing of cylindrical gears were completed in the mid 80's, but still did not lead to a breakthrough in the use of carbide cutting tools for gear production. Since the carbide was quite expensive and the tool life was too short, a TiN coated high speed steel hob was more economical than an uncoated carbide hob.

Improvements in carbide grades and sintering processes in combination with new coating methods and the use of CNC machines has lead to a significant new trend in the way cylindrical gears are produced. This trend combines high speed hobbing using coated carbide tools, without coolant. Provided that process parameters are set optimally, extremely short cutting times can be achieved with long tool life and high part accuracy. Process development in bevel gear cutting also benefits from the carbide and coating developments.

After successful investigations of the high speed carbide cutting process with coolant, the next logical step was to follow the general trend and proceed with a process development of a bevel gear dry cutting method. It was found that nearly all geometrical and technological parameter of the carbide wet cutting method could be applied also to bevel gear dry cutting. The surface cutting speed of the newly introduced method is 1000 ft./min. which is four times the value of conventional cutting. The cutting process is conventional cutting in the continuous face hobbing method and plunge cutting in the single index face milling case.

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Power-Dry-Cutting of Bevel Gears

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1. Introduction

High-speed machining using carbide had been known for some decades for milling and turning operations. The intermittent character of the gear cutting process has delayed the use of carbide tools in gear manufacturing. Carbide was found at first to be too brittle for interrupted cutting actions. In the meantime, however, a number of different carbide grades were developed. The first successful studies in carbide hobbing of cylindrical gears were completed in the mid-80's, but still did not lead to a breakthrough in the use of carbide cutting tools for gear production. Since the carbide was quite expensive and the tool life was too short, a TiN coated high-speed hob was more economical than an uncoated carbide hob.

It is now known that the coating is a key factor in the use of carbide tools. The coating lowers the friction between the chip and blade front face, and it protects the porous surface of the carbide. Heat and friction cause chemical reactions between the chip and the carbide binder material and "washes out" the carbide grains on the cutting front face. This causes a cratering wear pattern. The combination of fine grain carbide with the well-known TiAlN coating is sufficient for skiving operations, and leads to reasonable tool life [1].

Improvements in carbide grades and sintering processes in combination with new coating methods and the use of

CNC machines has lead to a significant new trend in the way cylindrical gears are produced. This trend combines high-speed hobbing using coated carbide tools, without coolant. Provided that process parameters are set optimally, extremely short cutting times can be achieved with long tool life and high part accuracy. Process development in bevel gear cutting also benefits from the carbide and coating developments.

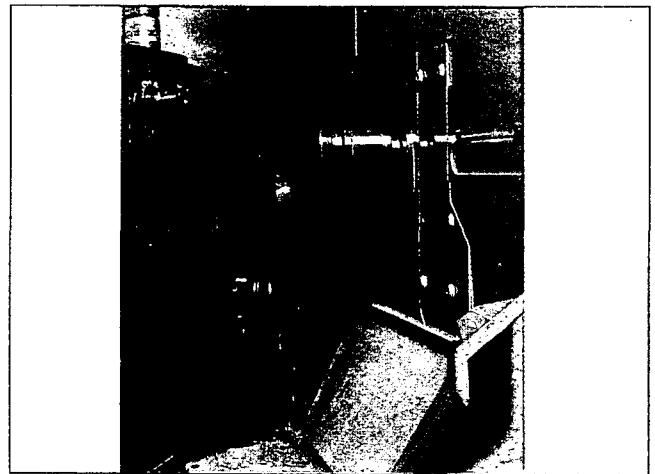


Figure 1: View into the work area of a cutting machine during single index Power-Cutting with coolant

The results in carbide cutting, with and without coolant, are the product of substantial research work. Besides dramatically reduced cutting times of about 75%, improved surface finish and gear geometry quality are realized in comparison to conventional production with high-speed steel. This is largely due to the high stiffness and good dynamic behavior of the Free-Form machines used for the cutting studies. **Figure 1** shows the wet

Power-Cutting of a face milled ring gear; the photo gives an impression of the high-cutting speed. The Gleason Power-Cutting process, as opposed to the carbide rough cutting, is a finishing process, which is suitable for later short time lapping or grinding. AGMA Class Q12 and Q13 gear quality was achieved in all development studies.



Figure 2: Dry cutting with chip removal enclosure

2. Bevel Gear-Dry-Cutting

After successful investigations of the high-speed carbide cutting process with coolant [2], the next logical step was to follow the general trend and proceed with a process development of a bevel gear dry cutting method. It was found that nearly all geometrical and technological parameters of the carbide wet cutting method could be applied also to bevel gear dry cutting. The surface cutting speed of the newly introduced method is 1000 ft./min. – which is four times the value of conventional cutting. The cutting process is conventional cutting in the continuous face hobbing method and plunge cutting in the single index face milling case. The generating of pinions can be a combination of conventional and climb cutting. Cutting feed rates identical to conventionally applied rates were found to be optimal as a result of the investigations.

Since the index speed of the single-index face milling cycle is the same for both Power-Dry-Cutting and conventional cutting methods, cycle time reduction of 70% is possible in the case of Power-Dry-Cutting face milling. In the continuous-index face hobbing case, the indexing speed is proportional to the cutter RPM, which reduces the cutting times up to 80%. This, and other advantages, shows the enormous economic potential of the Power-Dry-Cutting, especially if it is applied to the continuous-indexing face hobbing process.

Figure 2 shows the Power-Dry-Cutting continuous-index face hobbing process of high-speed cutting a ring gear. The thin oil film for rust protection on the blank surface does not cause any visible smoke development. The illustrated gear is a face hobbed ring gear with 45 teeth and a module of 5.9 mm. The complete cutting time was 1.5 min. (as opposed to 5 min. conventional).

The carbide stick blades were TiAlN coated. The maximal tool life corresponds to two times that of high-speed steel tools. It is expected to achieve even higher tool life in the future.

Figure 3 shows chips from ring gears, which were cut in the course of the parameter studies. The feed rate used to generate the chips was 0.005 in./blade. The highest temperatures of the chips in Figure 3 were around the tempering temperature. Only parts of the chips turned blue. The chips in Figure 3 were created during the end of the plunging cycle; they are wide and u-shaped and were generated simultaneously from the cutting edge, the blade tip and the clearance side of the blade. The wider chip was cut in a Formate face milling operation; the smaller chip comes from Formate face hobbing. As a plunging feed function, a single ramp is applied that decreases the feed rate with increasing depth of the cut. The chip thickness, at the beginning of the plunging, is thinner than comparable HSS cutting to generate the