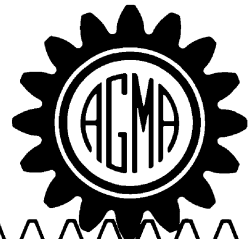


Contemporary Gear Hobbing – Tools and Process Strategies

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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

Gear manufacturing without coolant lubrication is getting more and more important. Modern hobbing machines are designed to cope with dry hobbing. In the last years carbide hobs were prevailing in high-speed hobbing due to their excellent thermal stability. Today this high performance rate is confronted with rather high tool costs and a critical tool handling. Powder metallurgical HSS combined with extremely wear resistant coatings on the base of (Ti,Al)N offer now interesting alternatives for dry hobbing. It is evident that existing conventional hob geometries can be optimized respecting limiting factors like maximum chip thickness and maximum depth of scallops. The existing machine concepts with direct driven tool and workpiece axis have sufficient reserves for increasing feeds and speeds in applications of the future. An analysis of contemporary used hob geometries shows that modifications in no. of gashes and no. of starts can increase the efficiency of the hobbing process. That means that a larger number of gashes increases the number of teeth in the shifting zone. Due to this the hob can be used for a longer time. Regarding to the question of increasing cutting speeds the texture analysis of a gear that was hobbled at a cutting speed of 1000 m/min shows that there is no influence of the cutting speed on the structure.

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American Gear Manufacturers Association
1500 King Street, Suite 201
Alexandria, Virginia, 22314

October, 2002

ISBN: 1-55589-806-8

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Dry cutting versus wet cutting

If in the hobbing process coolant is used or not, is primarily a question of the required workpiece quality and in a second step a question of the manufacturing environment. When an other manufacturing operation before heat treatment is performed by using coolant, a washing operation is necessary.

Today, more than eight years after the first presentation of a hobbing machine for up to date dry cutting, the process is verified by various applications. There are advantages and disadvantages regarding to an ecological process without coolant (**figure 1**).

Due to higher temperatures during the chip flow cutting forces are reduced. This indicates a higher constant workpiece quality. But this may cause surface defects due to critical chip flow effects.

The tool life by using coolant depends on the applied technology and the resulting chip thicknesses. At low cutting speeds smallest chip thicknesses can be cut. With increased cutting speed also the cutting temperature is increased. Based on this fact the tensile strength of the workpiece material is decreasing. At lowest tensile strength rates the forging grade is decreasing so that the workpiece material may flow between cutting edge and the pre-cut workpiece surface. The results are optical damages on the workpiece surface.

	Wet Hobbing	Dry Hobbing
Tool Life	+ low tool wear at moderate cutting speeds due to lubrication effects + no minimal chip thickness	+ higher cutting speeds with “modern” tool systems (HSS-PM, carbide, coatings) - Pressure angle > 10°
Performance	+ reduced cycle time by part stacking	+ prepared for innovations in substrates and coatings
Quality	+ low part temperatures, easy to check + no surface defects due to critical chip flow effects	o checking of warm parts possible (staggered tolerance field) + better SPC-Quality due to better energy balance (more energy conveyed by chips and parts)

Figure 1: Wet or dry?

The cutting temperature of the dry hobbing process can be influenced by cutting speed, feedrate and tool coating. This is the reason for different wear developments in identical cutting operations, **figure 2**. The differences in tool life between TiN-coated and (Ti,Al)N-coated tools in the wet process depends only on coating hardness, without any further effects.

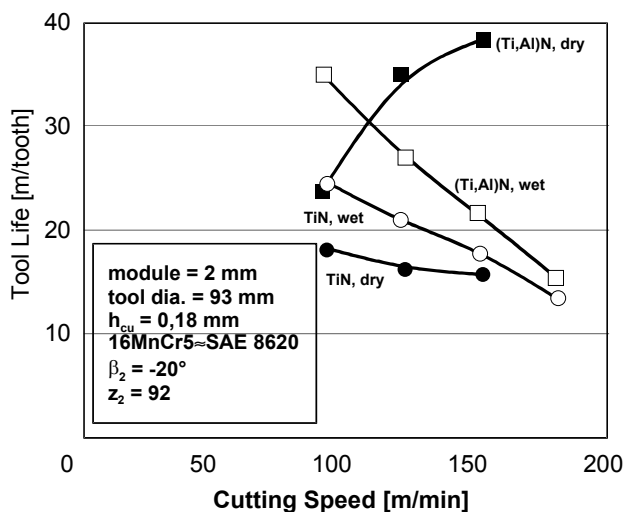


Figure 2: Fly cutter test - Tool life of coated high speed steel /1/

In the dry hobbing process the cutting temperature increases because of the missing surrounding liquids. This is the main reason for a different wear mechanism with (Ti,Al)N-coated hobs. At the end of the cutting action the heated cutting edge comes into contact with air. At this moment the aluminium-content of the coating reacts with the oxygen of the air. This oxydized aluminium (Al_2O_3) remains on the surface of the tool and gives a thin protective layer that indicates a higher tool life.

Requirements on the machine tool

Depending on the workpiece tensile strength, material composition and the recommended workpiece quality, different substrates and coatings are used parallel for gear hobbing. Up today there is no solution existing, that combines the red hardness of carbides with the ductility of high speed steel in

one and the same substrate. The substrates of the powdermetallurgical high speed steels have closed the gap between carbides und conventional HSS, **figure 3**.

The powdermetallurgical HSS can be described as a combination of restricted red hardness together with a sufficient ductility for the interrupted cut. PVD-coatings guaranty a red hardness on the hob surface that copes with the enhanced requirements of PM-HSS tools for dry cutting. Cutting temperatures in dry cutting are calculated for a cutting speed of 200 m/min with approximately 500°C /2/. Compared with HSS-substrates all carbide substrates render a higher hardness, but with a significant lower toughness. Therefore, for interrupted cuts like the hobbing process carbide substrates require a high stiffness of the cutting system and a careful tool handling.

The advantage of carbide tools are a low cutting edge roundness for creating tiniest chips and the red hardness for high cutting speeds. In certain applications it could be realized, that a carbide hob was used with six times faster cutting speeds versus HSS.

Figure 4 shows the influence of the tool substrate on the cutting forces and torques for a hobbing process for a constant machining time. With PM-HSS hobs the process is characterised by a higher feed rate at a lower cutting speed. The result is a higher chip thickness and indicated by this an increase of the cutting force by approximately 40 % and consequently the spindle torque is 60 % higher (with bigger HSS-hob diameter).

Based on this fact today two different machine systems are existing. If high spindle torques are needed the stepped gear drive is the most flexible solution. The gear box between motor and hob spindle reduces the revolutions per minute and increases the available spindle torque. This machine concept is for PM-HSS applications the state of the art and widely used for prehobbing operations before shaving, grinding, honing etc..