

Dry Hobbing Process Technology Road Map

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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

With today's advances in gear manufacturing equipment, there is a necessity to advance the capabilities of tools. In order to exploit new machine potential, tool development with regard to new coatings, new materials, and new design methods has taken place.

The difficulty now is to determine the best combination possible for a given application taking into consideration the specific gear manufacturers' expectations. A systematic approach to identifying the right combination of substrate material, coating, and application technology in order to meet those expectations is discussed in this paper. The intent is to create a "road map" to minimize risk of failure while maximizing the potential return for a given application. An explanation of physical properties of today's materials and coatings is presented, as well as a summary of the results from test applications.

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Introduction

Recent trends in gear cutting technology have left process engineers searching for direction on which combination of cutting tool material, coating, and process technology will afford the best quality at the lowest total cost. Applying these new technologies can have associated risks that may override the potential cost savings. The many interrelated variables to be considered and evaluated tend to cloud the issue and make hobbing process development more difficult.

Considerable work has been done, cooperatively between the tool manufacturers and material vendors, to improve the capabilities of the substrates being used. Efforts by both High-Speed Steel and Carbide manufacturers are yielding materials that allow a continuous expansion of the envelope of productivity gains in gear production.

With today's advances in gear manufacturing equipment, there is a necessity to advance the capabilities of tools. In order to exploit new machine potential, extensive tool developments have taken place in recent years. Building on the successes (and failures) of earlier efforts, there has been an explosion of new technology with both new coatings as well as new materials.

The days of having one broad range coating and limited material selection are long gone. The difficulty now is to determine the best combination possible for a given application, taking into consideration the specific gear manufacturer's expectations.

The purpose of this paper is to:

- Describe current technologies of gear cutting tool materials – specifically the relative properties of High-Speed Steels (HSS) and Carbide grades.
- Describe thin film coating technologies used for both wet (water-soluble or oil) and dry

cutting processes and discuss the properties and merits of these coatings.

- Discuss tool configuration requirements necessary for higher material removal rates and for dry cutting.
- Present application parameters for the use of tools under dry cutting conditions and results of successful and failed applications.
- Discuss the evaluation of the failure modes most common to dry cutting processes.
- Present a systematic approach to aid in the application of these technologies. By evaluating costs and risks associated with various processes for applications, the process engineer can implement new technologies where the savings/risk factor is most favorable.

The scope of this paper is limited to application of tools in the 10 to 20 NDP range. However, the concepts presented can be modified and applied to other applications.

Systematic Approach

1. The first step, before making any changes to optimize an existing process, is to fully understand the current process parameters, costs and failure modes. Define the variables such as part data, material, hardness, machinability, machine capacity and restrictions, tooling rigidity, chip removal issues, speed, feed, number of cuts and shift strategy. Tool design characteristics, material properties, and coatings must be defined. Define the measurables of the present process such as cycle time, part change time, parts per hour, and downtime for hob change. Costs such as tool price, sharpening costs and recoating costs should be known. How much wear is generated for current number of parts produced? Is the failure mode pure flank wear, or is chipping or cratering also causing tooth damage? Without a firm understanding of the present costs, how can the best potential option offering the greatest

chance for improvement with the least risk be identified?

2. Perform theoretical evaluations of cycle time possibilities at various hob diameters, and numbers of threads and gashes. Hob speed, chip load, feed scallop size will be the limiting factors, within the constraints of machine speed and horsepower capacity.
3. Look at material options such as Carbide Dry vs. High Speed Steel (HSS) Dry vs. Wet Cutting Tools.
4. Look at coating options for Wet vs. Dry application.
5. Look at cost per part (CPP) evaluations of the best options from the above choices.
6. Develop a test matrix to try one or two of the choices that show the best cost predictions.
7. Test tools for initial use and throughout sharpening and recoating, evaluating wear performance, part quality, performance through subsequent operations, etc.
8. Compare actual results to estimates.

Tool Materials

The following paragraphs provide a brief summary of commercially available substrate materials and coatings commonly used in the gear cutting industry. Although some of this information may seem academic, it is essential to have a good understanding of the characteristics of tool materials and coatings in order to maximize efficiency of the application.

Far from the days when conventional (cast) M2, M42 and T15 alloys were the predominant materials in gear cutting tools, the tool designer now has an extensive selection of quality high speed steel materials from which to select. In the United States, the newest

generations of materials are manufactured by Particle Metallurgy (PM) for improved manufacturability, toughness and general cutting performance. Due to the prevalence of vacuum hardening and tempering, many of these alloys have evolved over recent years to optimize their heat treatment response.

Although there are a multitude of high speed steels available worldwide, they can be generally categorized into one of several groups based on their physical properties. In order to limit the scope of this discussion, only those materials readily available in the United States are covered.

The most common material in domestic gear cutting tools today is CPM M4 (Crucible Particle Metallurgy). Typically used in the hardness range of 64-66 HRC, it has very good wear resistance, excellent edge toughness and is generally applied on a wide range of applications cutting workpiece materials with hardnesses up to 38 HRC. Since M4 contains no cobalt, it has a relatively low red (hot) hardness. Table #1 shows a comparison of some common gear cutting tool steels.

Upgrade considerations to the base M4 material might be considered to take two paths - increased wear resistance or increased red hardness. CPM 54 is a fairly new alloy based on the M4 grade but with slightly higher carbon for higher hardness and with 5% cobalt for improved red hardness. At the high end of abrasion resistance is CPM T15 with an attainable hardness of 66-68 HRC and applicability to workpiece materials up to 48 HRC.

More aggressive applications (e.g. harder workpiece, faster cutting speeds) may require tools with even higher red hardness. CPM Rex 45, with 8% cobalt, is often recommended as an upgrade from CPM M4. Both alloys contain some amount of cobalt (Co) for red hardness as shown

Table #1. High Speed Steel Compositions

Alloy Type	C Carbon	Cr Chromium	W Tungsten	Mo Molybdenum	V Vanadium	Co Cobalt	Total Alloy
M4	1.4	4.3	5.8	4.5	3.6	---	19.6
Rex 54	1.45	4.3	5.8	4.5	3.6	5.0	24.7
Rex 45	1.3	4.1	6.3	5.0	3.1	8.3	28.1
T15	1.6	4.0	12.3	---	5.0	5.0	27.9
Rex 76	1.5	3.8	10.0	5.3	3.1	9.0	32.7
Rex 121	3.4	4.0	10.0	5.0	9.5	9.0	40.9