Fox says. By incorporating high-level software, CMMs can measure virtually any type of geometry. For example, airfoils, compressor scrolls or turbine blade geometry can be inspected with the appropriate software. In addition, "the ability to incorporate components such as vision probes using edge detection technology and laser line scanning probes have made CMMs much more flexible and powerful," Fox says.

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Progress in Gear Milling

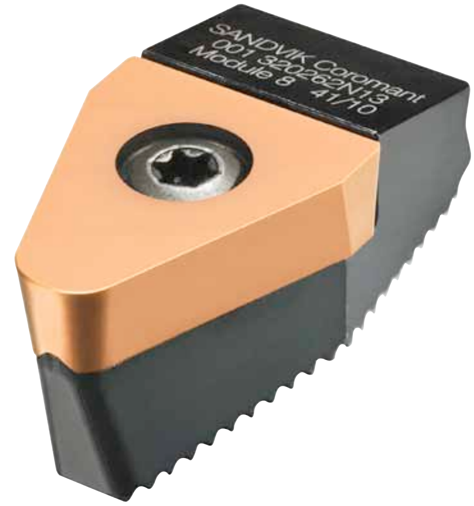
BY AARON HABECK, MARKETING PROJECT MANAGER, SANDVIK COROMANT US

Sandvik Offers Latest Tool Technologies

In addition to volume gear manufacturing on dedicated machines, gear teeth are increasingly being machined as features on various components, as well as gear wheels in smaller batches. Whatever the application, gear milling should perform as well as other metal cutting operations, where technology has moved on considerably. The conventional scene—i.e., specialized production of gear milling using high-speed steel hobs or cutters at moderate speeds, bathed in oil—is changing. Such are the pressures of competition.

Machining centers and multitask machines are increasingly players in this scene, putting gear teeth on wheels and multi-feature components while providing new opportunities. Just like more traditional, dedicated gear cutting machines, these newcomers to the gear industry achieve maximum efficiency. Newly developed, indexable-insert technology is now providing new means to change gears in the machining process.

Progress in tool technology. Manufacturing gears, whether in the form of a gear wheel or a component with gear elements, is a machining-intensive process, therefore efficiency is key to cost effectiveness. High-speed steel (HSS) has for some time been the dominant tool material for gear cutting; however, it is being replaced by cemented-carbide. Most machining areas are today dominated by modern indexable-insert technology based on cemented-carbide cutting edges. This is complemented by solid-carbide tooling, particularly when size makes inserts impractical. The hot hardness difference between HSS and cemented-carbide is consider-



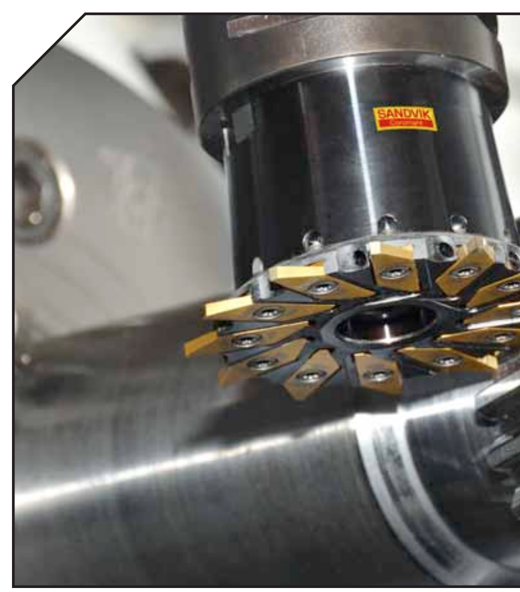
able, determining the difference in performance.

Indexable-insert tools have been used in gear cutting for some time, but overall the technology did not provide the performance advantages or meet the precision demands that are possible today. Gear manufacturers tend to hold on to the solid HSS cutters because it remains a secure, accurate and reliable process. However, HSS is a cutting tool material over 100 years old with a limited development scope. Although it has undergone considerable development as a cutting tool material, it is inherently limited in standing up to the machining temperature and wear-loads that are expected from a modern tool. Today, there is no reason why tools should be the limiting factor in raising productivity and achieving lower machining costs in gear cutting. Generally, the tool life of a modern cemented-carbide insert is five times that of an HSS edge—and at more than 2.5 times the cutting speed as HSS.

Precision—the final hurdle. Recent advancements in indexable-insert technology have overcome the accuracy and tolerance maintenance questions that detractors once cited. This has been an area where ground HSS cutters excelled and held their own—until now. Gear milling with modern, dedicated indexable-insert tooling is achieving results within even closer tolerance classes, according to DIN.

Standards for new indexable-insert tools are Class B-guaranteed, with most criteria holding A–some even AA ratings. Quality on the machined gear wheel is usually at 9, and often even 8. In addition, minimal tool run-out contributes to longer tool life and the elimination of step tendencies on the machined surface. The machined gear profiles are uniformly close to the required finished form while small and even machining allowances for any subsequent operations are achieved. Ground indication surfaces on cutters also make for easy and clear set-up control in machine.

Speed makes the difference. The main advantages that the specially developed indexable-insert technology has provided include metal removal rates in roughing and finishing large volumes of gear profiles, along with the flexibility to improve the economics of small-to medium-volume machining. Efficient and easy tool handling is important in gear milling because of the number of inserts to be indexed. Some tools use clamps instead of screws, which allow accurate changing of inserts within



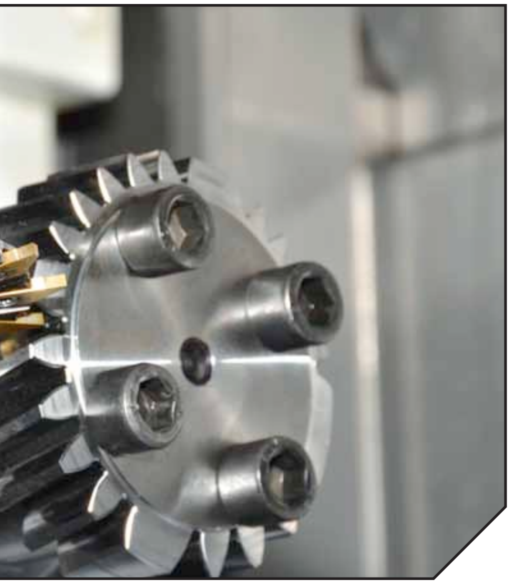
10–15 seconds. Secure, stable insert seats provide reliable performance and are user-friendly.

The recently introduced insert technology for gear milling is partly based on advances in other machining areas. Along with extensive area-dedicated development, this has contributed to a new generation of gear milling tools. This creates a comprehensive program of tools for modules 3–30, disc cutters and hobs along with new machining methods.

New cutting edges. Gear milling is performed with robust disc-type cutters and the process is characterized by interrupted cutting action. In addition to thermal variations on the cutting edge, mechanical interruptions require a suitable balance of hardness and toughness to provide durability and strength for high cutting data. The degree of toughness needed from the tool material is determined by shape and geometry, in addition to entering and exit conditions. However, in gear milling, the demands for edge toughness are influenced also by the relatively small radial depths of cut in combination with the large tool diameters.

Dry machining, without any coolant application, is the preferred method with indexable- insert milling tools and today's high machining rates. It is difficult for even high amounts of coolant to have much effect at the cutting edge, most of which is vaporized. Any remaining coolant will marginally cool the insert as it goes in and out of the cut. Thermal variations are thus amplified, which has more of a negative effect on the insert than with heat. Coolants in gear machining are very much inherited from the use of high-speed steel tooling or the need to reduce heat in the component. However, gear milling with cemented carbide can stand up to high temperatures—eliminating the need for coolant. When applied correctly, there is minimal heat transferred to the component.

In gear hobbing, however, the process is quite different—often involving over 100 cutting edges in a single tool. It is a relatively smooth machining process with continuous cuts, varying in both chip thickness and cutting-force direction. Hobs are designed to provide high precision. HSS hobs normally allow around 50–100 m/min (165–330 SFM) in cutting speed, necessitating coolant. Cemented-carbide hobs, on the other hand, work well at 250–300 m/min



(820–985 SFM)—with or without coolant.

The tool material makes the difference. A modern coated insert grade has the capability to provide high security at the temperatures generated by high cutting speeds and feeds. However, many grades function well in both dry and wet conditions if or when the coolant is necessary for chip evacuation and maintaining component temperature for keeping within dimensional tolerances. When it comes to milling normalized case-hardening steels, the advantage of cemented-carbide inserts is particularly highlighted in the form of higher productivity. For tempered steels a marked extension of tool life at higher cutting data will be the main advantage.

In materials harder than 300 HB, the possible cutting speed with indexable carbide tooling is usually five times higher than with traditional HSS tooling. Important success factors of indexable-inserts in gear milling are those of geometry and manufacturing. Edge geometry and edge preparation are important combination factors with insert grades for achieving the best solution. Establishing the right microgeometry in the form of lands, chamfers and edge rounding decisively affect the strength of the cutting edge and its durability. This has a direct influence on cutting data capability, security and, very importantly, the predictability of quality consistency. Well-developed insert geometry will also provide good chip forming, which is important for evacuation and handling. Finally, the macro- and microgeometry and position of the cutting edge in the tool will not alter, as occurs when an HSS cutter is reground.

A good location is decisive. There are a great number of large inserts in a gear milling cutter where the position of one cutting edge affects the others during a cut. If these positions vary too much, they can negatively affect machining performance (cutting forces) and the capability to achieve the right quality level. In this context the insert location, tool manufacturing techniques and precision insert tolerances are crucial to achieving solutions in a marketplace where quality demands are escalating constantly.

Machine tools and tool holding are also crucial to success. This is where the modern, and especially stable, machines from companies like Höfler, in combination with Coromant Capto as the spindle-tool interface, provide the basis for full utilization of the new indexable-insert technology for gear milling.

The new indexable-insert technology is increasingly used for both disc cutters and hobs. It's also used on specialized machinery through new methods such as uP-Gear Technology and the InvoMilling process, where gear milling can perform very efficiently in multitask machines and five-axis machining centers. This new technology is supported by local and global specialist teams dedicated to gear milling, involving design, application and commercial backing.

The focus has been on the development of a new generation of tools, machining methods and tool manufacturing with full control of all technology and support involved. The result, that which was deemed unthinkable in gear milling less than two years ago, is now a practical reality, available broadly for reviving gear milling performance.

New methods open up new possibilities. In addition to a new generation in tooling, the development of methods for gear milling has resulted in the uP-Gear Technology for bevel gear machining, as used on Gleason Heller five-axis machines. These machines are equipped with user-friendly software and a tool set suitable for the application, providing a new, flexible, productive and cost- efficient solution. The machining time is short compared to an end milling process. Moreover, the actual machine cost is no higher than a traditional five-axis machine as the tool cost is much lower than using dedicated bevel-gear tools. Also, the number of steps needed with this method is reduced thanks to the versatility of the process.

Another unique, new method development is the InvoMilling method for machining centers and multi-task machines: a combination of slot- and turn-milling. It enables the machining of gears with any module and helix angle, both involute and non-involute profiles. Through collaboration with machine tool makers DMG/Mori Seiki, a user-friendly interface in the CNC-control of the machine makes gear-milling easy to perform in a vast number of applications. Previously, most were only possible to do on special-purpose machines.

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