A New Paradigm in Gear Hobbing

A new tooling concept from Sandvik Coromant lowers machining times and costs for hobbing gears, maximizing quality and increasing efficiency.

By Guenter Wermeister
Increasing speeds in all areas, with longer running times and lower noise levels, place ever-greater demands on the precision of gear wheels. International competition and the resulting cost pressures add to the need for a constant search for new saving potentials and optimized production. This, of course, is the background to why new processes are developed, and even old tried-and-tested methods are assessed for being brought up to the latest technical standard.

One of the most cost-effective and precise processes for manufacturing gear teeth is hobbing. For this process, as is the case with a worm gear, the workpiece and tool are continuously meshing in the gear hobbing machine. In doing so, the gear hob cuts the tooth spaces and teeth in the workpiece to the shape that is required for the pairing of the gear-wheels in the finished gearbox. The latent sources of error present in the classic part process—profile deviations and pitch errors—cannot occur here, because toothing in the hobbing process is produced through generating enveloping cuts during the continuous generation of two bodies with each other.

A further advantage of the hobbing process is that in addition to gearwheels, workpieces with other profiles can also be created—spline shafts or ratchet wheels, for example, provided they have spaces in the same form and pitch.

**THE TOOL**

The gear hob has the shape of a single or multiple cylindrical tool with cutting edges distributed around the circumference combined with chip flutes. The cutting materials have up to now been mainly high-alloy high speed steels (HSS). In addition to powder-metallurgically manufactured HSS solid carbide cutters, tools with inset carbide bars or rails are also used for machining. In fact, the classic HSS tools still have a market share of more than 50 percent. The reason for this lies in the fact that both solid carbide mills as well as tools fitted with fixed carbide cutting edges are not able to fulfill all requirements. This includes above all heavy loss of service life after regrinding, or individual edge fractures that make it necessary to replace the entire cutter. In order to regrind the tools it is often necessary to then remove the coating, and this deprives the carbide cutting edge of the bonding agent cobalt.

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**Fig. 1:** The CoroMill 170 is a high performance disc cutter for large gear teeth, used for precision and reliability in roughing external and internal gears.
This leads to a reduced tool life due to brittleness of the cutting edge, giving it a less predictable life.

Where large modules are involved, over the last few years tools with tangentially mounted carbide indexable inserts have become increasingly popular. This solution provides clear advantages. Cemented carbide can also be used as a cutting tool material for gear hobs having large diameters, and in addition the cutter bodies have a long tool-life and can be fitted with different tool-material grades that have been adapted to the respective workpiece material and the tooth geometry. Thus, one and the same cutter body can be used for different tasks, which reduces the number of tools required and therefore the stocking requirements. This concept also makes it possible to achieve not only the required profile accuracy, but to also significantly reduce manufacturing times, and considerably reduce reconditioning costs involved in the regrinding and coating of tools.

EFFICIENT GEAR CUTTING

Sandvik Coromant is relatively new to the field of gear cutting tools. As the global leader with a comprehensive tooling offer, it was the natural objective to develop not only convincing tool concepts for gear cutting, but also to cooperate closely with qualified partners in terms of the machine manufacturers and customers. Two products have up to now marked a successful entry into the manufacture of gear cutting tools: the CoroMill 170 disc cutter in the module range 12-22, and large gear hobs with tangentially fitted indexable inserts. Both tools have provided considerably improved performance.

The uP-Gear process for complete production of bevel gears having spiral gears in only two clamping arrangements on five-axis machining centers was a further successful step towards becoming a full-service provider in gearbox production. Sandvik Coromant developed this technology together with Voith Turbo and Gebr. Heller Maschinenfabrik GmbH. As a logical consequence of the previous successes, Sandvik Coromant is now working on the next step: the manufacture of gear hobs with exchangeable full profile indexable inserts.

In contrast to tangentially fitted indexable inserts, where not more than two cutting edges usually make contact, a gear cutter with full profile indexable inserts also creates three flank chips. This means that the circumferential cutting edge must be accessible on three sides for material evacuation. This results in specific demands on the
interface between the indexable insert and cutter body or, if used, the shim or cartridge and the indexable insert. In addition, the positioning and clamping of the indexable insert must take place with the greatest of accuracy in order to be able to comply with the tight tolerances of DIN 3968.

A new type of insert seat has been developed that also guarantees a precise positioning and fixing of the indexable insert in the rough production routine. Because the inserts, depending on the module size and intended use, can be single or double-edged, it is not a question generally about multi cutting edge inserts: Although the cutting edges are located on three sides of the circumference, on closer observation we see that these are single edge or double-edged indexable inserts that naturally can then also be called “indexable inserts.”

For the production of gear hobs with indexable inserts, Sandvik Coromant builds on expertise with well-known partners. Along with Höfler Maschinenbau GmbH, a well-known manufacturer of specialized machines for gear hobbing and grinding, Carl Zeiss GmbH was also

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**Fig. 2:** The precision ground inserts on a conventional hob ensure good component quality when hobbing a spur gear.

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called in to join the team as an expert in industrial metrology for precisely measuring finished tools and gearing. The cooperation also included also working with some well-known gearbox manufacturers and several renowned universities, for example the Lunds Institute of Technology (Sweden) and the WZL (Laboratory for Machine Tools, RWTH Aachen) gear working group.

INITIAL RESULTS

The initial field tests with the new hob cutters have been completed and analyzed. It was demonstrated that a gear hob fitted with cemented carbide indexable inserts naturally does not fulfill the accuracy requirements that a one-piece hob made of HSS or solid carbide is capable of mastering. However, compliance with grade B in accordance with DIN 3968 can be assured, which means that gearwheel grades of 9-11 in accordance with DIN 3962 can be manufactured. If a higher workpiece grade must be attained, a follow-up process with a one-piece hob or a grinding operation is required. The hobbing quality is not only determined by the gear hob grade. Also influential are a secure clamping arrangement of the workpiece, accuracy of the gear hobbing machine and the concentricity and run out of hob along with the workpiece.

Overall the results of the field tests have demonstrated, under three important criteria, real advantages of the new hobs:

- decreases in machining times and hobbing costs per component, and tool-life increases. A detailed look at the results reveals real levels of improvements.

SHORT MACHINING TIMES

The primary processing time during gear hobbing is determined, among other things, by the cutting speed and the workpiece axial feed. The matching of steel type and cutting tool material decreases in machining times and hobbing costs per component, and tool-life increases. A detailed look at the results reveals real levels of improvements.

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as well as the stability and performance of the machine tools used are the deciding factors in determining the most cost effective cutting speed. Tests performed under real production conditions demonstrated that the cutting speed, while retaining the feed rate of each rotation of the cutter, can usually be more than doubled. In this way the machining time of 200 minutes was reduced to 90 minutes per gearwheel, in one case.

Carbide cutting edges can bear a much higher chip load than HSS cutting edges. This means that significantly higher feed values per tooth can be achieved. Moreover, a reduction in the number of effective cutting edges is more than compensated by applying this method.

When determining the feed rate, the chip load—the theoretical maximum chip thickness that is created when cutting the chips off the tooth heads—should always be recorded and used for calculating the feed rate. If all of the decisive factors, consisting of the performance of the machine tools and the workpiece material allow it, it is possible to machine chip loads of up to 0.35 mm and cutting speeds of up to 350 m/min with the new tool, depending on the module in question.

Fig. 4: Rough milling of tooth spaces on a bevel gear can prove to be challenging. With uP-Gear Technology, the solution lies in flexible five-axis machining centers that allow manufacturers to carry out machining operations on a variety of different tooth geometries and components.
LONGER TOOL LIFE

In profitability studies for gear hobbing, instead of the usual specified tool life in minutes, the hob is evaluated in terms of tool cutting length. This length corresponds to the sum of the lengths of all the machined workpiece teeth between two resharpenings or the changing of indexable inserts on the tool.

Under optimal conditions—i.e. with the best possible coating and cutting edge preparation of the carbide hobbing plates—tool lengths per cutter change have been achieved in field tests that were at least three times higher than with coated HSS tools. The higher feed per tooth also contributed to this. A feed per tooth that is too low has the effect of promoting wear, shortening the tool life and causing excessive heat generation in the workpiece. So that carbide indexable inserts can also unhesitatingly be used for dry machining without loss of tool life, the feed rate should always be selected so that the majority of the heat is led away with the swarf. Longer tool

Fig. 5: The full profile hob, designed with the conventional HSS cutter in mind, features indexable carbide inserts that allows high productivity through higher cutting speeds and feed rates in a helical gear.
life also means a gain in production time, because when the tool life is, for example, tripled, 66 percent of the setup time is no longer required and can now be used for machining.

What is seldom considered is the waste due to setup which occasionally occurs during series production: The regrinding of blunt cutters leads to different cutter diameters and always requires a readjustment of the machine settings. Here again the risk sank by 66 percent with the new tool.

There is also a shortening of the time usually required for reconditioning the blunt HSS hobs, which have to be sent out for regrinding and recoating. This is associated with a lengthy period of time, starting from the tool change through to the delivery of the finished re-conditioned tool. Naturally, with the new Sandvik Coromant tools, it is still recommended the shifting takes place to optimize tool life and improve the cost efficiency. In addition, indexable inserts that only show single-edged wear after use, can be changed from left to right.

LOWER HOBING COSTS

The main objective of further developments in the tools is to lower the direct and indirect production costs. At the same time, the quality of the workpieces to be machined should be maintained or even improved further. In addition, production reliability must be guaranteed.

The new full profile hob from Sandvik Coromant satisfies the tool-related requirements completely, even the first time it was used. The proportional tool costs could also be considerably reduced by a minimum expenditure on investment, stocking, handling, and reconditioning costs. Beyond this, a lower capital commitment was achieved through a significantly lower number of hobs in circulation. A further advantage is that the output per
day could be improved significantly through an increase in the cutting speed, thereby also reducing the actual cutting time (a 50-percent saving was exceeded several times over). The time gained for using the machine by shortening the cutting time and setup time can be used to further increase the output. In some cases it was no longer necessary to use cutting oil or lubricants at all, which increases the tool life and also reduces the emissions in the form of oil mist or steam. The costs for using lubricant or cutting oil should not be underestimated here, because depending on the respective case of application, they often account for some 15 percent of the overall production costs.

**THE BOTTOM LINE**

With the new hob cutters the user is provided with tools that can be used for cost effective and reliable production, that lower investment costs, are easier to handle, and that can make the operation independent of any external tool reconditioning.