Skiving Is Thriving on a Global Scale

Skiving Gears is a Win-Win for Gear Makers and Buyers

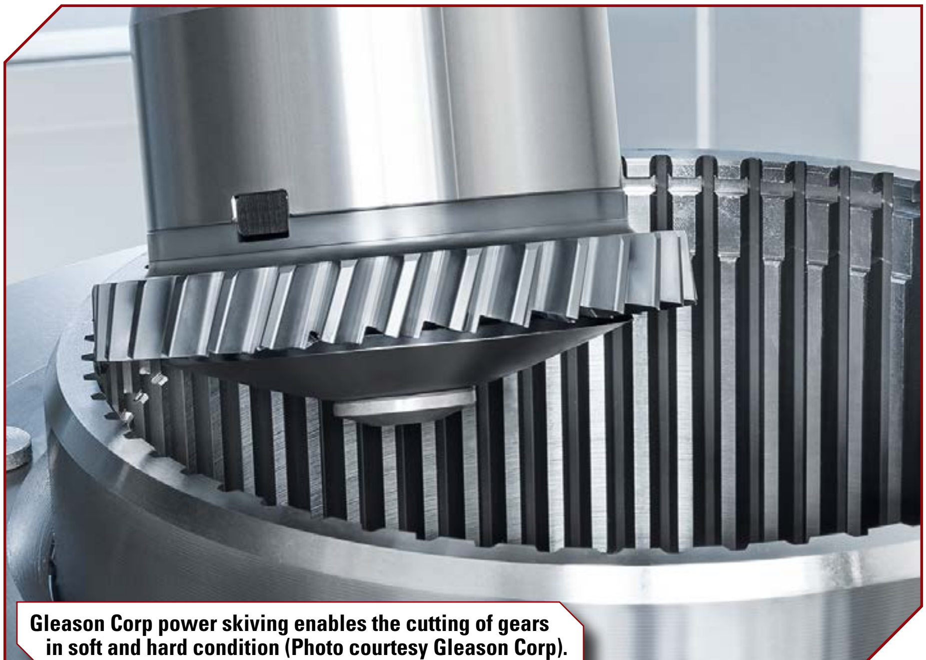
Jack McGuinn, Senior Editor

Call it new wine in old bottles, or old wine in new bottles, but gear skiving has certainly aged well over time. Gear skiving's evolution, perhaps gaining momentum most dramatically since around 2004, has ultimately led to rather dramatic technological advancement and cost saving in the manufacture of certain gears.

But before we get too far along, it's important to make sure everyone knows what we're talking about. The term "skiving" has been used to describe a wide variety of processes in a wide variety of industries over the years. Twenty or thirty years ago, if you said you were skiving gears, most people would assume you were talking about skive hobbing or hard hobbing, which is a completely different process.

When we talk about gear skiving today, we're referring to modern derivations of the process originally invented by Julius Wilhem von Pittler, way back in 1910. The process uses a disc- or gear-shaped cutter (often very similar in appearance to a gear shaping tool) and employs synchronized tool and workpiece motions, with the cutting motion generated by intersecting tool and workpiece axes.

Among its attractions, the gear skiving process is considerably faster than shaping, for example, while boasting enhanced chip removal, and is demonstrably more cost-effective. Major, relatively recent breakthroughs in areas such as intelligent software, machinery and tooling stiffness, amped up speeds and feeds, and tool coatings has positioned gear skiving as the go-to, most productive process for the manufacture of many types of internal gears, and even some external gears as well. As you read the following Q&A with industry experts, you will notice that gear skiving has many variations, along with many different names, including "power skiving," "hard skiving," "Super Skiving," "hard power skiving" and, as Profilator calls it — "Scudding" or "hard Scudding."



Gleason Corp power skiving enables the cutting of gears in soft and hard condition (Photo courtesy Gleason Corp).

And so from this point forward, we'll use "gear skiving" as the generic term for all of the above.

Participating in this Q&A are:

Vincent Affolter, general manager Affolter Technologies SA; **Dr. Nicklas Bylund**, Sandvik Coromant director, customized automotive solutions; **Scott Knoy,** GMTA vice president; **Dr. Patrick Labenda**, Klingelnberg head of application engineering, bevel gears; ; **Phillip Ruckwied**, EMAG manager of cutting technology; **Dwight Smith**, vice president, Mitsubishi Heavy Industries America, Inc., machine tool division; **Udo Stolz**, Gleason vice president of worldwide sales and marketing; **Tom Ware**, Star SU LLC product manager, gear cutting tools; **Dr. Oliver Winkel**, Liebherr head of technology development; and **John Lange,** longtime gear professional. (***In the spirit of full disclosure, Lange is a Gear Technology Technical Editor and former longtime Gleason-Pfauter gear specialist. Thinking it would be helpful to add an independent view, we invited him to the discussion.***

Please describe the newest gear/skiving-related tools and how they enhance gear skiving.

BYLUND. Power skiving tools exist both as solid tools in high-speed steel and carbide. For machines with the capability of synchronization at high speed, solid carbide tools are definitely preferred (due to) better tool life and productivity at the same time. From modules 2.5/DP10 tools with carbide inserts are a good alternative.

WARE. The use of solid carbide tools has increased cutting speeds and extended tool life.

WINKEL. Dominant are actually modern PM-HSS tools with the newest AlCrN-coatings to enhance tool life. But essential is the mathematically correct profile design, so that the first part is a good part. This was in the past not the case, because some assumed that a skiving cutter is the same as a shaping cutter. Indeed, it looks similar, but the profile is very much different, so several loops of profile optimization were necessary. Liebherr did its homework to develop the necessary mathematics to ensure the correct skiving cutter profile.

SMITH. The newest tool development is MHI's three-piece assembled cutter which was engineered to further advance tool life and metal removal rates. The patented Super Skiving tools have multiple cutting edges for creating the tooth space rather than the single cutting blade of conventional pinion type cutters.

KNOY. The newest application of the Scudding technology is the "hard Scudding" process. In "hard Scudding" we finish a gear in the hardened state as an alternative process to grinding or honing. We use Star-SU solid carbide Scudding tools along with the best coating available on the market, which is currently the Balinit Altensa coating provided by Oerlikon Balzers. Additionally, the use of indexable roughing tools in Scudding coarse-pitch gear applications has proven to be an excellent way to control tool cost.

STOLZ. For larger modules, a combination of cutters with inserted carbide blades for roughing and PM or solid carbide cutters for finishing seems to be the best option; of course depending on the lot size. For hard finishing, carbide cutters are a must.

It is not so much the tool material which makes the difference, it is the understanding of the process in detail, in combination with the ability to design and manufacture the right cutter based on the application.

Please describe the latest updates relative to gear skiving machinery and how it enhances gear manufacturing.

KNOY. Profilator has made dedicated Scudding machines since 2005. We offer horizontal and vertical machines and that allows us to offer the machine that best fits the application. In many cases our competition has started their machine developments by using a hobbing platform, but using a repurposed machine platform has not been a long-term solution for any of the people in this market. Several 5-axis milling machine manufacturers have tried to include gear skiving in their machinery with limited success. These machines lack synchronized drive packages that do not allow them to produce a high quality gear.

LABENDA. We have the gear cutting machine C30 with universal application for bevel gears and power skiving for internal and external gears.

WINKEL. Very important is the direct drive technology for high spindle and table rpm, and high gear accuracy while assuring optimal synchronization between workpiece and tool spindle. In addition, the high dynamics of the skiving process requires a high machine rigidity and stiffness to get reliable and robust process settings. The automatic choice of optimal drive control parameters on Liebherr skiving machines is an important feature to support stable cutting processes from the beginning.

To achieve a high process capability, especially on internal gears regarding surface quality and to avoid chip weldings, the precise and constant positioning of the coolant nozzle is quite important. Liebherr has here besides a manual setup solution a quick-change option to easily change over from one gear to the other and keep the proven setup.

SMITH. The MSS300 from MHI fulfills the machine tool requirements with massive guideways and a rigid tool spindle and column. Two servo drives operate the vertical axis for power and control. Long-term process stability is assured by the special design of the machine base to minimize or eliminate thermal distortion.

RUCKWIED. Advances in machine technology with the electronic gear train have resulted in a more precise maintaining of the transmission ratio between tool and workpiece, while the speeds in the generating train could be increased. Another advantage of power skiving machines from EMAG is the fact that both rough-machining (turning) and finish-machining can be done in one clamping operation. Including the turning process in the same clamping operation prevents re-clamping errors, and is an effective way to eliminate radial deviations.

STOLZ. Key for a successful power skiving process is the stiffness of the system, where the stability of the machine plays an important role; especially also for hard power skiving.

In addition, the flexibility of the machine is very important. Features like stock dividing, automatic tool changer, automatic loading/unloading and integrated deburring are enhancing the process. With the same power skiving system we have the possibility to cut gears in a soft and hard condition. In many cases we are eliminating an additional manufacturing step by integrating the deburring capability into the power skiving tool for internal gears or adding a rotary chamfering unit for shafts on our horizontal machine.

The MSS300 from MHI fulfills the machine tool requirements with massive guideways and a rigid tool spindle and column (Photo courtesy MHI).

Are there any anticipated or pending technology gains that would further the benefits of gear skiving?

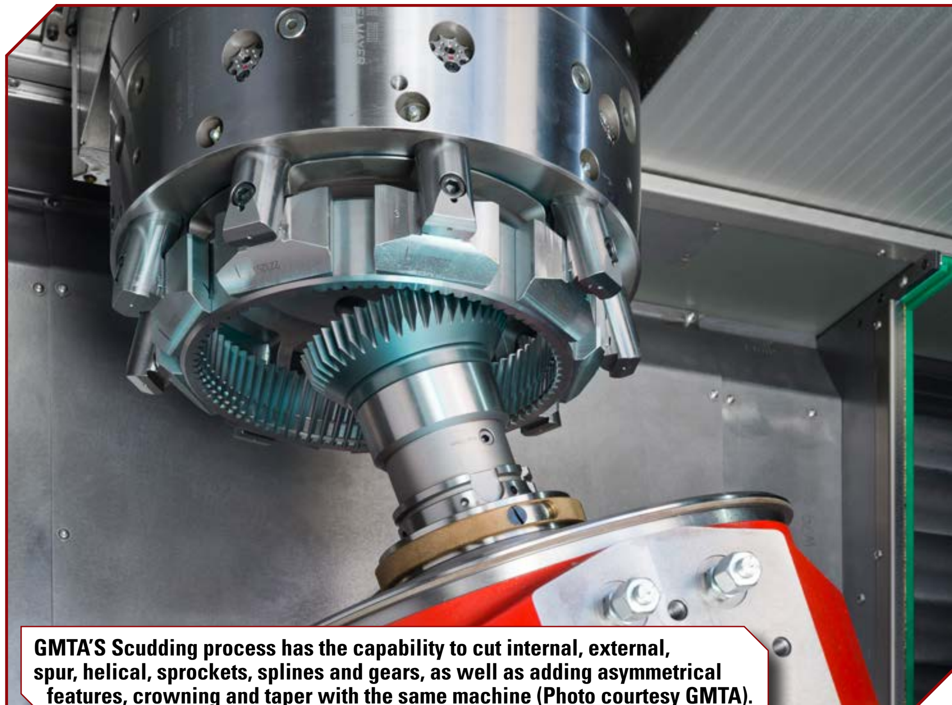
STOLZ. Today, power skiving materials in the soft condition is state of the art. An interesting application with significant potential is hard power skiving. Today there is no efficient process in place to fine finish small-to-medium internal gears in the hardened condition. Power skiving has the potential to be a game changer.

WINKEL. Liebherr just recently introduced its newest gear skiving machine with the option of a tool changer. This enables the customer to either run the machine longer without any operator or to cut multiple gears in one setup without compromises to the tool design. Also the changeover to other parts is simplified by a tool changer.

The other new technology is hard skiving. This enables the customer to machine the parts soft and hard on the same machine. This lowers investments for additional machines. Furthermore, there is an additional option for hard finishing — especially of internal gears, which regarding its productivity is much faster than e.g. internal profile grinding but not as accurate.

Regarding Liebherr, we think it is also very helpful to support the operator with an MC control that is gear technology-driven and especially dedicated to gear skiving. So programming and machine corrections for lead, profile and MOB are easily possible.

RUCKWIED. Compared to gear shaping, the power skiving method provides 2 to 6 times more productivity and tool life.


GMTA'S Scudding process has the capability to cut internal, external, spur, helical, sprockets, splines and gears, as well as adding asymmetrical features, crowning and taper with the same machine (Photo courtesy GMTA).

What Took So Long?

Just for some perspective, what do you think prevented skiving for gear production from being developed sooner?

STOLZ. Power skiving is a high-frequency process. In the past, the missing stiffness in the axis drive systems made it difficult to prevent vibrations.

Due to the cross-axis angle necessary for power skiving, the process is much more complex compared to shaping. There was no technology software available to help understand the process in detail and to design the cutter and the process very precisely.

In the meantime, substrates and coatings for cutters have evolved and are contributing significantly to the success of the process.

In the past it was more a trial-and-error approach.

LANGE. High power and speed for the two rotational axes (tool and work spindle) and cutting tool design parameters once you had a machine that could handle the cutting forces, so the results of the tool design were not clouded by machine weaknesses. The cutter design is extremely important for this process to work!

AFFOLTER. There were probably two aspects. First, the existing processes (hobbing, shaping, broaching) are well-known, widespread and in some applications better suited. Second, the power skiving needs high rotating speed and high torque and precise interpolation; not anyone can reliably manufacture such CNC machines.

LABENDA. The reason is that power skiving is a very dynamic process and requires very stable machines and high accuracy for the coupling of the axes.

WINKEL. Regarding the machine, the drive technology was a key factor. High rpm and perfect synchronization plus high rigidity are essential.

Regarding tools, tool life was and is the main topic in gear skiving. But new substrates and coatings as well as better technology understanding helped to improve tool design and performance.

Regarding the technology, the introduction of the multi-pass-cutting-strategy to reduce negative rake angles was a big step forward to get more reliable processes and tool life.

Finally, the development of the mathematical basics and high-sophisticated simulation software used on modern computers set the basis to avoid bad process and tool designs.

SMITH. Skiving was held back by machine tools that weren't rigid and stiff enough, and lacked robust spindle synchronization.

Affordability

Is gear skiving an expensive startup? If so, please elaborate, e.g.—is it tooling? coatings? software? Can we assume that gear skiving tooling is more expensive than conventional tooling? If so, why is that?

AFFOLTER. For our worm screw power skiving process, the machine can be the same as the one use for standard hobbing, because the spindles driving the parts can reach high speeds (higher than 10,000 rpm). However the tool for power skiving is about 30-50% more expensive than a standard hob. But the life time of such a tool is quite high, especially cutting brass (between 30,000 and 40,000 parts between each re-sharpening). The software used is our standard *Affolter Gear* (same as for hobbing).

KNOY. The tooling is generally the same cost as a gear shaper cutter. The materials and coatings are the same and the size and geometry are similar. As it is newer technology, the tool may cost nominally more as the manufacturing process to make these tools is not as developed as the process to make the shaping tools.

STOLZ. Depending on the individual situation, for the customer in most cases it is a tremendous cost reduction opportunity. On one hand, a power skiving machine can replace several shaping machines. On the other hand, for small-to-medium lot sizes, power skiving can be a very efficient alternative to broaching, as it offers a much higher flexibility. Large inventory in broaching tools and long delivery times can be avoided. Modifications in profile and lead direction can easily be accomplished.

WINKEL. In skiving, the clamping fixtures for the workpieces are more sophisticated than in shaping, due to the higher process dynamics. It has to be considered that typically the skiving cutters are workpiece specific while in shaping different number of teeth or profile shift coefficients can be produced with the same shaping cutter (e.g, splines). Compared to broaching, the skiving machine is much cheaper and also the tools as well as the reconditioning. But again, the fixtures are the driving cost factor in skiving regarding investment, since there are more or less no fixtures in broaching.

SMITH. Gear skiving, or Super Skiving as MHI refers to it, is on par with other gear cutting processes in regards to startup costs, slotting in between shaping and broaching. Due to their superior tool life, the Super Skiving tools from MHI deliver a lower-cost-per-unit than ordinary pinion type cutters.

WARE. The overall manufacturing cost is lower with power skiving since the cycle time is much lower than with shaping technology. Less work in progress (= less cost) is possible if CNC machines are able to do the whole component, including the teeth. As in all machining the workpiece-tool-machine analysis (in that order) must be made.

New Applications?

Is gear skiving equally effective for both internal and external gear cutting? Or one more than the other?

STOLZ. We see the highest benefits for internal gears and external gears with shoulders, which cannot be hobbed. If hobbing is possible, it is in most cases the more efficient process. Just imagine the number of teeth on a hob and on a power skiving cutter. If you assume the same length-per-tooth, you will find the lifetime of the hob between re-sharpenings to be much higher.

In some cases there is not enough clearance between the gear and a shoulder even for power skiving. In these cases, the cross-axis angle needs to be reduced, which impacts the efficiency of the process. In these cases, shaping may be the better option.

WARE. Power skiving is an alternative process to shaping, so hobbing is still the most efficient process for external gears. Like shaping, it can generate both internal and external gear teeth. The cross axis angle between the cutter and the workpiece does limit some applications.

LANGE. Some external cutting of shaft parts requires shaping, so a win-win for power skiving over shaping — assuming the power skiving process can be applied. However, if it can be hobbed, I think I would stick with hobbing — especially if a pre-finishing process where a multi-thread hob can be used. Hobbing should be faster and tooling cost less. I would say the cost for shaping larger internal gears was the most significant driver for the development of power skiving. Add to that better quality and, I believe, similar or less tooling cost. The machine cost is more than a shaper but not four times more expensive since cycle times are many times four times faster! What are plant floor space and less machine operators worth? I believe the (greatest) impact of this process appears in the construction machine industry and larger, internal gears previously being shaped.

KNOY. When you are using the Scudding process you are able to cut internal, external, spur, helical, sprockets, splines and gears, as well as adding asymmetrical features, crowning and taper with the same machine. As noted above, the software provides the direction for the machine. The flexibility of the process is one of its best features. Most people see Scudding as a good process for internal gears, which it is. However, the scudding of external gears can provide a better quality part in less time than you can make by the hobbing process.

WINKEL. Skiving is applicable for external and internal gears, but if there are no other advantages or restrictions to the external gears (like interference, or positioning to other skived gears) hobbing is always more cost-effective and productive.

SMITH. The greatest advantage is in the volume production of internal ring gears, both spur and helical. For external gears, hobbing will be used except in cases with interfering part geometry. For many applications with recessed gear or spline features, shaping is the preferred process since skiving has limitations due to the crossed axis needed.

BYLUND. For internal it is especially effective since the alternatives such as shaping (slow) and reaming (very inflexible and cumbersome) are not so good. For externals, power skiving is a good alternative for a shop that is investing in new technology since if using a multi-axis CNC, both internals, externals and other parts can be made.

RUCKWIED. Internal gear cutting is more effective because of competition from the technologies of broaching and shaping. External gear cutting with gear hobbing technology is often more effective with the use of two or more hobs on the tool. If machining is next to a face, external gear hobbing is not possible. Therefore gear skiving is an effective solution.

EMAG power skiving machines enable both rough-machining (turning) and finish-machining in one clamping operation (Photo courtesy EMAG).

Skiving Gearbox Components

Gear skiving has been touted as a process for producing "cost-saving gearbox components," and that workpieces with constraining contours can be produced efficiently using this method."

LABENDA. With our software we can manufacture gears with modifications. That means time saving when modifying internal gears instead of planetary gears.

STOLZ. When designing a gearbox, there are two main targets. The gearbox should be as compact as possible and cost competitive. Compactness means sometimes very small clearances between the gear and a shoulder or another contour, which require shaping as a manufacturing process. Gleason can tell customers upfront precisely what clearance is necessary as a minimum to be able to use the extremely productive power skiving process. If it can be accomplished without major compromises, especially in a high-volume production, the savings can be significant.

Related to "workpieces with constraining contours," take for example an input or output shaft. For shaping a spur gear or a spline, the shaping head being in the same plane with the tailstock has a high risk of collision, if the cutter diameter is not large enough. Power skiving, due to the cross axis angle, can be less critical as you are moving the power skiving spindle interference contour away from the tailstock.

KNOY. The size of the gears is getting smaller, but the loads and torques are increasing. Scudding can assist in this move as it does not require clearance to evacuate the chips, as gear shaping does. This means as the clearance grooves are eliminated as a function of the scudding process, the "weak point" in the gear is also eliminated. This allows that the entire gear can be reduced in mass—but still provide the same strength. Smaller components mean smaller, more efficient transmissions. This is also evident to the extent that speed enters the equation. The possibility to complete all geometries desired has existed for some time—just not economically.

WINKEL. (Designers) are actually checking in many cases if they can change the shaping design to a "skiving design." This focuses especially on the higher necessary overrun of the skiving cutter compared to the shaping cutter, which is caused by the cross-axis angle.

RUCKWIED. There are solutions where two parts were machined and combined can be designed and machined as one part with the technology of power skiving. Gear shaping on one part was (more) expensive than machining two parts with gear broaching and welding them together.

Gear designs against faces needed to be machined with gear shaping that was very often (non-productive) for series solutions. The power skiving technology with its productivity gives the designers of parts and planners of machining operations a new flexibility and productive option.

LABENDA. With our software we can manufacture gears with modifications. That means time saving when modifying internal gears instead of planetary gears.

BYLUND. As with all manufacturing technology requirements on workpieces change. Power skiving does not work if there are shoulders close to the gears or splines, or when the teeth are very deep into the part. "Parts designed for power skiving can be efficiently power skived."

RUCKWIED. There are solutions where two parts were machined and combined can be designed and machined as one part with the technology of power skiving. Gear shaping on one part was too expensive than machining two parts with gear broaching and welding them together.

Gear designs against faces needed to be machined with gear shaping what was very often too low productive for series solutions. The power skiving technology with its productivity gives the designers of parts and planers of machining operations a new flexibility and productive option.

Liebherr's skiving process includes direct drive technology for high spindle and table rpm, and high gear accuracy, while assuring optimal synchronization between workpiece and tool spindle. (Photo courtesy Liebherr).

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