

5-Axis Gear Manufacturing Gets Practical

Exciting new machine, cutting tool and software technologies are compelling many manufacturers to take a fresh look at producing their larger gears on machining centers. They're faster than ever, more flexible, easy to operate, highly affordable – and for any type of gear.

Uwe Gaiser

Larger bevel gears have typically been produced on dedicated machines or, less frequently, on standard 5-axis machining centers using end mill cutters. But neither solution has been ideal for a relatively small, but significant number of large gear jobbers and vehicle and equipment manufacturers. Dedicated machines are remarkably productive, but prohibitively expensive for low volumes; standard machining centers are inherently flexible, but too slow to be practical for even the lowest of volumes and lot sizes.

In 2011, Gleason moved to fill this void by forming an alliance with Heller, a leading manufacturer of 5-axis machining centers used for rigid, 5-axis simultaneous machining. By drawing on the collective strengths of both companies — Heller's 5-axis processing capabilities and the stability and rigidity of its machining center platform, and Gleason's bevel gear processing expertise and *CAGE* gear design software — the newly formed Gleason-Heller partnership significantly narrowed this age-old performance gap. The new series of Gleason-Heller 5-axis machines that resulted could indeed produce bevel gears much faster than their 5-axis counterparts, while maintaining typical machining center flexibility.

Mission accomplished? Not quite. The marketplace wanted more. For many, the ability of the machining center to produce larger bevel gears many times faster than what was possible on other standard machining centers wasn't quite enough to justify a purchase. In day-to-day, practical application, what these users really needed was a machine that could easily produce all types of gears and gear tooth geometries: everything from spiral and hypoid bevel gears, straight bevel gears to spur, helical, double-helical and herringbone cylindrical gears. And, of course, all the other general machining tasks that you could throw at it. The end result would be the nearest thing yet to a universal 5-axis machine — a machine designed to be so versatile and easy to use that it would rarely sit idle.

More productivity — start to finish. Several 5-axis horizontal-spindle machining centers now comprise the Gleason-Heller line, ranging from the 6000 series for workpiece diameters up to 1,000 mm, to the FT 16000 for workpiece diameters as large as 2,500 mm. The inherent static and dynamic stability of the Heller machine platform and its extremely robust, high-torque/high-power spindle design provide the ideal platform for the application of a wide range of highly productive inserted-blade disk-type cutters. Heavy milling of a forged raw part, profiling, protuberance machining, flank finishing and profile finishing of the hardened gear — essentially machining the gear complete from a blank — can now take place in as little as two to three hours, vs. the two to three days needed with a standard 5-axis milling machine using end mills. And for those that have



Figure 1 New technologies have converged to finally make it practical to apply 5-axis machining for production of many different gear types, all with high quality.

experienced the less than optimum surface finishes and quality that often result from the use of end mills, it's important to note that DIN 5 or better quality is now achievable on these new machines.

Empowering the operator. But the real “game changer” for the end user is the power that comes from the application of the new suite of Gleason-Heller software. Producing gears complete in just a few hours will look good on paper to many customers — but almost all will ask the question: Can my machine operators really produce high-quality gears of all types as easily as they would the much simpler “prismatic” parts they're used to? After all, skilled personnel are in short supply and gears have never been more complex. To make this technology truly practical, every operator will, with just a few easy steps and minimal knowledge of gear design, be able to automatically generate the optimum parts program and 3D models for



Figure 2 Gleason-Heller's product offering includes models for workpieces as large as 2,500 mm in diameter, with various worktable and pallet changer options.

even the most complex gear designs—bevel and cylindrical. Furthermore, the system will also need to automatically make the first-part corrections, which are so vital to prototyping and small lot production, thus eliminating the costly and time-consuming trial and error common to traditional gear development and production.

The same powerful and highly automated *CAGE* gear design software capabilities that allow Gleason's dedicated bevel machine customers to produce finalized gear designs with optimized contact patterns with minimal trial and error is available to Gleason-Heller users. But that's not the half of it. *CAGE* functionality is just one part of the new *Gleason 5-Axis Gear Studio (G5S)* software system. *G5S* seamlessly interfaces with the Heller *uP-Gear* CAM system, providing all the input data, corrections and flank modifications needed for *uP-Gear* to generate a 3D geometry model of the gear for visualization, and the

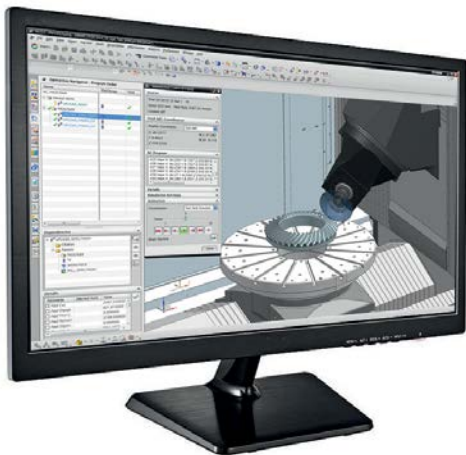


Figure 3 Design inputs from Gleason's new 5-Axis Gear Studio (G5S) software to Heller's uP-Gear CAM system allow the user to easily, and quickly, generate a 3D geometry model of the part, and the optimum NC parts program needed to produce it.

optimum NC parts program needed to produce it. The process is further facilitated through the use of Siemens NX software, which runs on the machine's standard Siemens 840D SL CNC. *NX* is one of the most powerful and versatile 3D CAD modeling tools available—and a vital component in the optimization of the gear design and all the required machining operations. On a Gleason-Heller, all the heavy lifting is ultimately done by the software, and the operator's role is one that almost any competent machine operator can perform, with minimal gear design knowledge required up front.

Nor is the use of *G5S* and *uP-Gear* confined to just spiral and hypoid bevel gears, with face milling and face hobbing tooth geometries. The software now fills the long-standing void that has existed for the automated design, optimization and production of many types of different cylindrical gear designs. Even straight bevel gears, and the desirable tooth geometries produced on conventional two-tool generators or by Gleason Coniflex technology, can be replicated. In every case, this powerful suite of software, and an expanding array of pre-existing routines and modules, enable the end user to quickly and easily optimize gear design and important features and characteristics such as flank geometries, contact patterns and profiles on a wide range of gear types.

Closing the loop on quality. For many jobbers and vehicle and components manufacturers, optimizing the designs of prototypes and parts produced in lots as small as one involves slow, costly and painful trial and error, as parts are cut and inspected, designs and programs are refined, and the process starts anew. With a Gleason-Heller machine, this time-consuming process is all but eliminated. Instead, newly developed *Gleason Correction* software, working in conjunction with the customer's CMM or a Gleason GMS gear inspection system, generates inspection files and transmits the new machine settings needed to correct flank form deviations and other important characteristics back to *G5S* so that production of even single-part lot sizes is fast and efficient.

A total solutions approach. A "total solutions" approach was taken in developing this new generation of Gleason-Heller machines so that users would have, at their fingertips, all the components needed to simplify setup and operation, reduce costly non-productive time, and speed production. In other words—everything required to take cost out of the workpiece. For example:

- The machines are capable of running the right cutting tool for the job: inserted blade disk-type cutters for all the typical gear roughing, semi-finishing and finishing operations, and

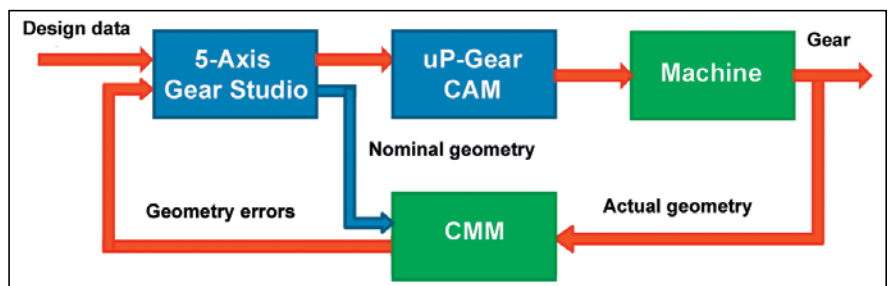


Figure 4 The suite of Gleason-Heller software "closes the loop" on quality and eliminates typical gear development trial-and-error time and cost by using gear inspection data to automatically correct parts programs.

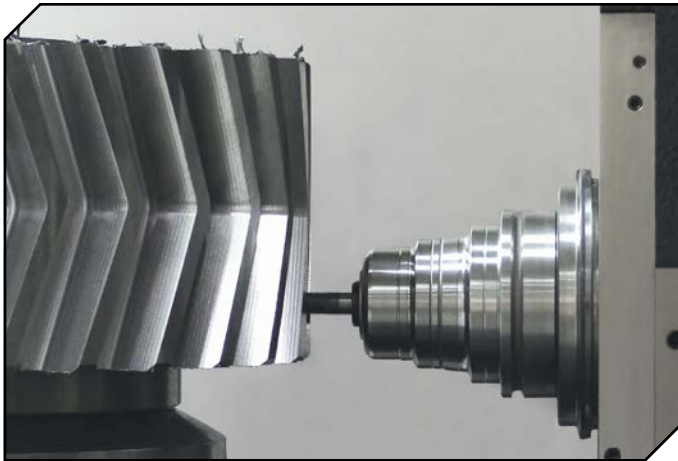


Figure 5 Gleason-Heller machines can accommodate a wide range of larger bevel and cylindrical gear types, including herringbone and double-helical.

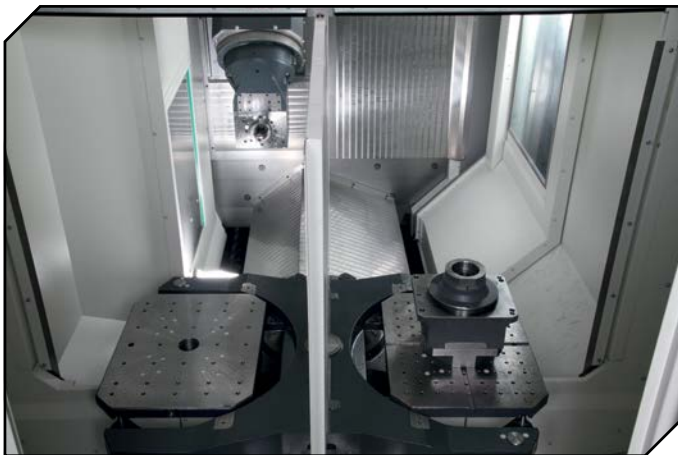



Figure 6 P-type machines are equipped with automatic pallet changers to allow workpiece setup in parallel with machining.



Figure 7 Even true turning operations can be performed on C-type machines equipped with high-speed worktables.

Gleason's new inserted blade SlimLine cutter, for gears with more complex tooth geometries. Automated tool changing of all the different tools is standard.

- The machines are equipped with the Gleason zero-point workholding system, which greatly reduces non-productive workpiece setup time by simplifying typically tedious manual workpiece setup and alignment. A first-part checking probe also is integrated in the machine to automate that critical step in the setup process.
- Models are available with different worktable designs: F-type for orthogonal turn-milling operations, or C-type with higher speeds for real turning operations.
- Models are available as simple table machines (T-type), or with automatic pallet changer (P-type) to set up workpieces in parallel with machining.

The new Gleason-Heller machines are indeed making a strong case for more 5-axis machining of larger, high quality gears in low volumes. It's never been faster or more affordable. For those gear jobbers seeking to expand their markets, or the manufacturers of vehicles and machines for construction, marine propulsion systems, mining, energy and transportation searching for lower cost and more control over quality, Gleason-Heller provides a new option. 

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During studying mechanical engineering, Uwe Gaiser was instrumental in the development of first-correction-capabilities of 3D-measurements of bevel gears with the Gleason G-AGE software releases worldwide. His final diploma topic at the University was Single-Flank testing of automotive bevel gears at a well-known luxury car manufacturer. Since then, working for Gleason Corporation, he has filed several bevel gear related patent applications in the area of bevel gear grinding, blade geometry and production methodologies.