Gear Factory of the Future

Edited by Matthew Jaster, Senior Editor

What does the future hold for the global gear industry? We're asking these questions regularly in the pages of *Gear Technology*. Electric drivetrains, advanced optical metrology, an increase in automation and robotic capabilities, 3D printing, and the Industrial Internet of Things (IIoT) will continue to change the look and feel of the shop floor.

The following three articles from Klingelnberg, GAM Gear and Gleason examine many of the changes taking place in gear manufacturing today.

Figure 1 Pitch Measurement with HISPEED OPTOSCAN.

Klingelnberg

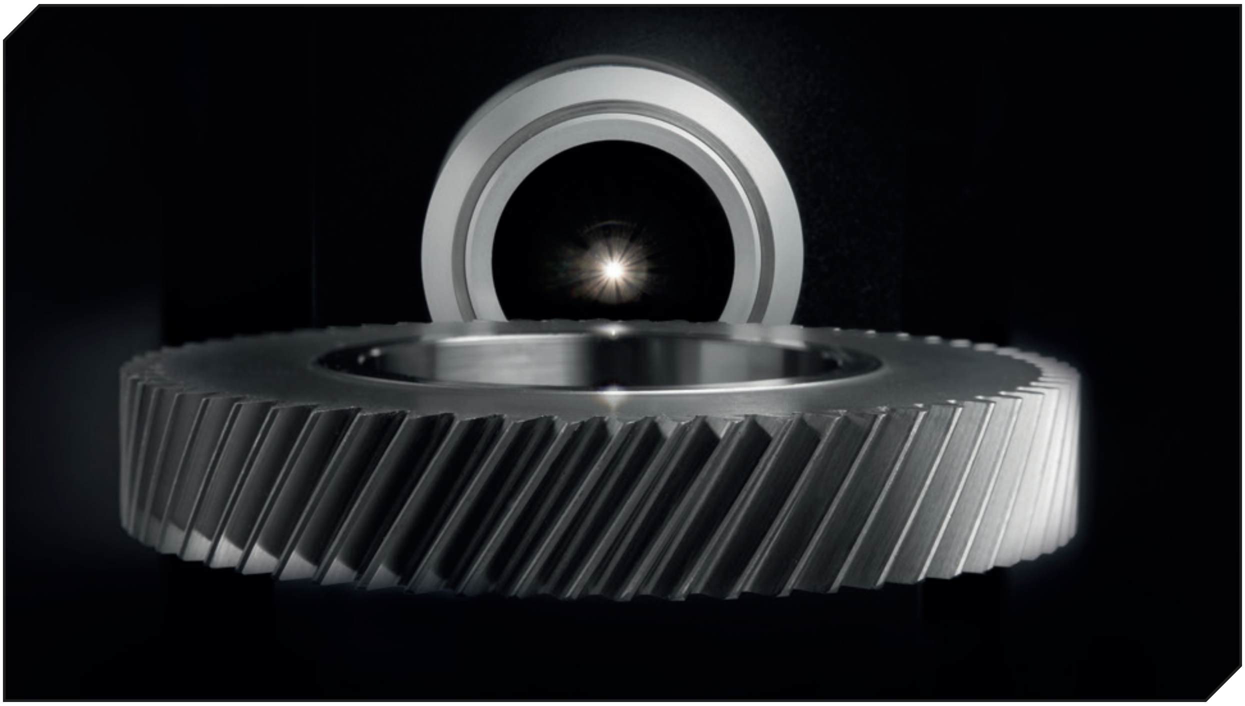
Advances Optical Metrology with Sensors and Data Acquisition

Klingelnberg first presented the initial development stage of the hybrid solution with optical metrology at the EMO Hannover exhibition back in 2017. The application at that time centered on digitization of axially symmetrical gear components. Components such as bevel gears and cylindrical gears, and other geometries as well, can thus be measured with an extremely high point density (digitized), followed by additional processing. This additional processing is extremely flexible. In addition to simply depicting the results as a 3D model, comparisons can be made against a CAD target geometry, or a geometrical evaluation can be conducted by creating sectional views. This application is used for reverse engineering, for example.

In the last three years, Klingelnberg has significantly advanced their Optical Metrology system. Particularly in terms of sensor systems, measured data acquisition, and further processing, there has been significant progress.

High Accuracy in the Sub-Micrometer Range

In the first development stage, a high-precision laser triangulation sensor was used. This sensor technology is well suited to the digitization application described above. However, physical limits in laser triangulation restrict its use for measurements in the sub-micrometer range on gear components. Because tactile gear metrology on the precision measuring centers over the years has achieved an extremely high level of maturity and thus also an impressive measuring accuracy, customers' expectations for optical metrology on a Klingelnberg measuring machine are correspondingly high. A restriction in accuracy that is accepted for digitization is not acceptable for other measurement tasks.



New White Light Measurement System

For this reason, Klingelnberg has been focusing its efforts on the entire signal chain in optical metrology and has joined forces with other development partners to develop a white light measurement system tailored specifically to the requirements of gear measurement. In this system, the active, current-carrying elements, such as a high-power light source, electronics and signal processing, are arranged separately from the sensor in the control cabinet. The distinct advantage of this is that it prevents thermal effects from occurring on the sensor itself as well as in the area surrounding the sensor — on the 3D tracer head, for example.

Compared to a laser sensor, this sensor has a significantly more favorable, compact design. In addition, in contrast to a laser sensor, this sensor works equally n all directions due to the coaxial light directed toward the component surface and back. The large lens aperture enables measurements with highly inclined surfaces, which are inevitable occurrences on gearings. Thanks to the system's high resolution, measurements in the sub-micrometer range are now ensured.

Reducing Measurement Times in Serial Measurement

Digitization of the entire component is an application for which optical metrology is ideally suited. For serial measurement of high-precision ground running gears, however, it is not necessary to measure the entire component geometry with a high point density. Instead, the focus is on high measuring accuracy at the level of the tactile measurement while also reducing the measurement time. For this reason, Klingelnberg has worked out a solution to this with its latest development stage in optical metrology.

In serial measurement of a cylindrical gear, the profile and lead are typically measured on three or four teeth, and pitch measurement is performed on all teeth. This tactile pitch measurement necessarily involves inserting the stylus into each tooth space. With optical measurement, by contrast, nothing is inserted into the tooth spaces. Accordingly, pitch measurement offers the greatest potential for reducing the measurement time. Through optical measurement of the pitch using one continuous, uninterrupted rotation of the component, the measurement time advantage increases with large numbers of teeth to up to 80 percent. It is not necessary to scan a large area of the gear with multiple revolutions.

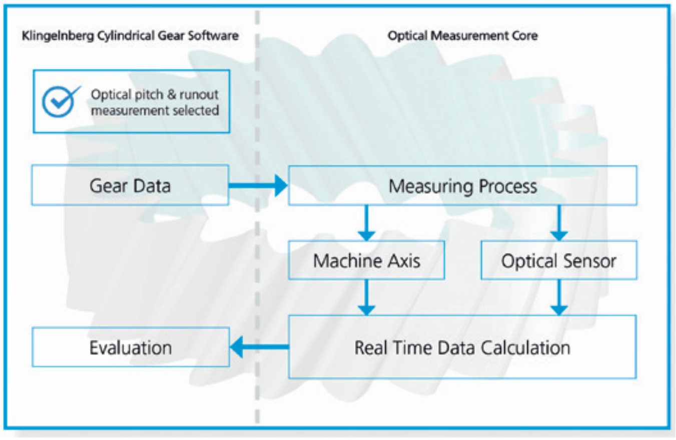


Figure 2 Schematic diagram of a measuring run.

Figure 3 Optical sensor retracted.

This optical pitch measurement is combined with the tactile measurement of the profile and lead. Overall, the total measurement time decreases by up to 40 percent. Thus in cases where there is a high utilization rate of the measuring machine, the costs for the optical metrology option are quickly recovered.

High-Precision Measuring Results

Decreased measurement time is not the only key factor, however. Just as important is a high achievable accuracy of the measuring results, even in the case of extremely complex gears with ground surfaces and steep profile angles. This is the result of intensive optimization of the sensor technology, the analysis algorithms, and the measurement strategy.

The only difference in operation is that optical pitch measurement must be selected in the same cylindrical gear measurement software customers are already familiar with. The measuring cycle is automatically modified accordingly, and the pitch measurement is performed with the optical sensor. The changeover between the tactile 3D NANOSCAN probing system and the optical HISPEED OPTOSCAN sensor takes place automatically within approximately 1.5 seconds in conjunction with the entire measuring run.

During a series of internal analyses, Klingelnberg evaluated a typical component spectrum of cylindrical gears from the area of passenger car transmissions, electromobility and gauges. In a range of gear geometries with different reflection and absorption characteristics, as well as various gearing qualities, accuracies on par with tactile measurement were achieved. The system can be used even for gears with extremely fine surfaces and roughnesses of Rz=1 µm.

To determine without a doubt whether a component is suitable for optical measurement and whether a corresponding measurement time advantage can be achieved, Klingelnberg provides customers with test measurements and demonstrations in their premises.

The More, The Better

In terms of the measurement time advantage that can be achieved, one thing is true: The more teeth there are, the greater the advantage.

Next Development Stages

The system offers great potential for further applications. In particular, for measurement tasks consisting of tactile operations involving time-consuming individual touches and complex movement patterns, optical metrology is able to reduce measurement time. But optical measurement is also ideal for fast scanning sequences on complex geometries.

Figure 4 Component spectrum

Dr. Christof Gorgels, director of product line precision measuring centers at Klingelnberg, provides an outlook: "For the further development of the system, we already have a number of ideas, including tooth root and tip measurement, axis position, roundness and other form measurement tasks. And we would like to use our customers' feedback to set priorities. That is why we are delighted at the keen interest in Klingelnberg Optical Metrology and the conversations with users that we have had as a result."

www.klingelnberg.com

A Cobot Companion

Fusion Cobotics and GAM Enterprises Collaborate on CNC Robotic Solution

According to robotics.org, collaborative robots (cobots) currently account for three percent of the total robotics market. This number is expected to reach 34 percent by 2025. Cobots are complex machines that work hand-in-hand to support—and in some cases completely relieve—human operators. They work via force sensors that allow the machines to operate on shop floors without the need for safety fences or guards. They can safely operate in the same workspace as their human counterparts.

When GAM Enterprises, Inc. (formerly GAM Gear) needed a robotic solution to load and unload parts, they collaborated with Fusion Cobotics on a potential solution. This is just one of many examples where automation, motion control and robotics are potentially altering the look and feel of the production floor in manufacturing. It hints at a future where manufacturing companies will have the opportunity to free-up their skilled workers for more important tasks while the cobots tackle the grunt work.

A Need for Added Capacity

GAM Enterprises, Inc., located in Mt. Prospect, Illinois, is a provider of precision mechanical power transmission components used in the automation of machinery. GAM has a broad product range of gear-reducers, servo-couplings, safety-couplings, clamping systems, motor mount kits and other specialized mechanical solutions.

Prior to the initial discussion with Fusion Cobotics, GAM required its own personnel to load and unload parts from its machine. Production would stop at the end of the business day and resume the following morning.

"Our production is comprised of high-mix low-volume manufacturing runs, we hire primarily highly skilled CNC setup personnel to operate our machines," said Craig Van den Avont, president at GAM. "It is not an efficient use of our CNC operators' time to load parts when they can be doing more job setups."

In addition, Avont said that the company needed more production time/capacity to run parts.

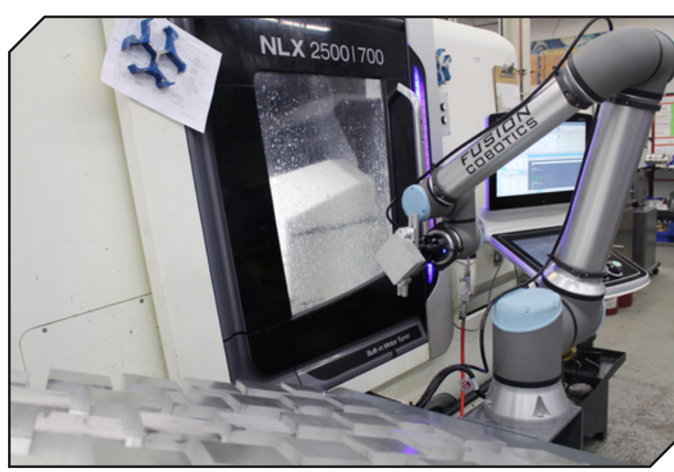
"We wanted to extend the workday into the evening in order to finish a production run and start a new job the next day," he added.

A Cobot Solution

Fusion Cobotics, located in Burr Ridge, Illinois, is a CNC systems integrator for collaborative robots, focused on automating machine tending solutions for CNC turning and milling machines to increase productivity. The company offers complete and proven, turn-key machine tending solutions that help metalworking companies become more profitable, even in small batch processing, by offering standard, affordable, easy-to-learn, easy-to-use, automation systems that can be applied to any type of CNC equipment.

Fusion installed the FC02—a CNC machine tending system based on Universal Robots' UR10e cobot—at GAM because it is an extremely flexible collaborative robotic solution that can tend to the simple repetitive tasks of loading and unloading parts from GAM's CNC equipment.

"By automating the machine tending with the Universal Robots' UR10e collaborative robot, they freed up their highly trained machinists to apply their skills to more advanced tasks such as setting-up for the next job in another machine, CNC



Fusion OEM, a Certified Systems Integrator of Universal Robots (UR), installed the FC02—a CNC machine tending system based on UR's UR10e cobot.

programming, and parts inspection," said Craig Zoberis, president, Fusion Cobotics.

The system includes a Universal Robots' UR10e for efficient, uninterrupted machine tending throughout the day and into the off-shifts (lights-out) enhancing the ROI of GAM's CNC equipment while having predictable output.

"The key feature is the nature of the Universal Robots' collaborative robot technology where humans can work safely in close proximity of the equipment without tying up valuable plant floorspace," Zoberis said.

Also, the easier to use, intuitive, conversational type programming language allows for efficient reprogramming of the equipment from job to job in a high-mix, low-volume machining department—an added bonus for the variety of work GAM handles on a daily basis.

Fusion supplied all the required hardware for the application, complete installation, integration to the CNC, required on-site training, trial production run, and remote support in case there is an issue with the equipment after installation.

GAM's production is comprised of high-mix low-volume manufacturing runs. Having the Universal Robot free up skilled operators from tedious machine loading, enables the company to use its personnel more efficiently, setting up more CNC runs.

Operational Ingenuity

According to Van den Avont, GAM treats its cobot similarly to how one uses a bar feeder on a lathe. "We set up the machine along with the cobot, then let the machine run unattended until the job is complete," he added.

"The key for us was to not get hung up trying to keep the cobot running every day and through the night. Most companies don't use their bar-feeder for every job, 24 hours a day, so why apply the same logic to a cobot for chucking jobs? We use the cobot on chuck jobs with the idea that we want to extend our workday by "X" hours to complete a job and move onto the next one. The incremental added capacity is huge," Van den Avont said.

One area that proved challenging, however, was chip control. GAM operators didn't account for the fact that every time an operator loaded a part, they also used compressed air to blow out the CNC door tracks. "We must pay extra attention to chip control to prevent nuisance automatic door jams," he said.

Future Considerations

The 'on the job' learning process has led GAM to consider expanding its family of CNC machines with cobots in the future.

"We will plan our daily operation around a setup person handling multiple machines with a cobot performing the repetitive part loading," Van den Avont said. "New CNCs will be purchased with all the interfaces and automatic door systems installed at the factory."

By examining automation, motion control and robotic solutions, machine shops can increase their output with efficient, reliable, uninterrupted machine tending throughout the day and into the evening shifts.

This enhances the ROI of CNC equipment and gives companies the flexibility to utilize their highly trained machinists to apply their skills to more advanced tasks.

"The FC02's collaborative robot allows GAM to automate safely without tying up money and valuable floorspace that is required by conventional robotic machine tending solutions," Zoberis said. "In my opinion, increased overall reach of the cobots would help with the larger CNC machines that are on their production floors."

www.fusionoem.com
www.gamweb.com
www.universal-robots.com

Gleason

IMPROVES HARD FINE FINISHING OF GEARS

DR. ANTOINE TUERICH, GLEASON CORPORATION

In conventional gear manufacturing, quality control is performed randomly. This is primarily due to the significantly longer time required for inspection as compared to the actual production time, and limitations in metrology capacity. In fine machining of hardened gears it is not unusual to inspect as few as 5% of the finished components. In order to guarantee close to 100% reliability, statistics are used to validate most of the gears produced. By deliberately narrowing down the tolerances,

GRSL Double Flank Roll Tester with Integrated Laser Checking can assure up to 100% quality inspection.

it is possible to guarantee compliance with the actual drawing tolerances with a sufficiently high probability (typically > 99.99%). This method is commonly used for machine and process capability studies, and the cmk and cpk values used as a basis are usually above 1.67. Statistically, the reject rate is only 0.57 components per 1 million manufactured components, but this means that only about 50% of the actual required drawing tolerances are available as manufacturing tolerances. Additionally, the constantly increasing power density of gears and the growing importance of noise behavior are leading to increasingly tight tolerances. Clearly, the heavy reliance on statistics poses a significant problem for a growing number of gear manufacturers seeking to achieve 100% compliance for today's very high quality gears.

Gleason's fully automated HFC with integrated grinding, washing, marking, in-process gear inspection and optional gear noise detection.

Up until now, much of the focus on production floor inspection has been on achieving objectives such as establishing a 'closed loop' connection of inspection to production machine, and putting a shop-hardened measuring machine in close proximity to the production machine to save valuable queue time. Gleason's new GRSL roll testing device with integrated laser measuring technology, however, takes a completely different approach: greatly reducing measuring time so inspection can take place within the time allotted for production. This now opens the possibility for actual, 100% inspection of all manufactured components. End result? There is no need for additional narrowing of tolerances and the 100% inspection of all manufactured components can be accomplished in-process without slowing production.

A good example of how this new inspection approach brings added value to the gear finishing operation can be found on the new Gleason Hard Finishing Cell (HFC). It's a fully automated system with robot loading that integrates modules for auxiliary processes in order to meet specific customer requirements easily and flexibly. This revolutionary concept, when presented for the first time in 2020, demonstrated a complete process sequence including Threaded Wheel Grinding, washing, laser marking, measuring and part handling in a stackable basket system. The HFC concept can also be easily applied to any desired process, with a single system replacing a number of machines.

HFC's 100% inspection capability results from the new GRSL, Gleason's latest Double Flank Roll Tester with Laser Technology, which is fully integrated into the system. The component to be tested is loaded by robot onto the GRSL. During the gear inspection, a laser scanner is used to measure all gear characteristics. All relevant information for profile, pitch, runout and — if desired — lead measurement is available. This is done for every tooth and not, as is usually the case, on just four sample teeth distributed over the circumference.

In addition, the measurement results from all teeth can be used for advanced waviness analysis using Fourier analysis to detect not only the mesh harmonics of the gear but also the so-called ghost frequencies. In many cases, depending on the amplitude, these frequencies are significant contributors to problematic noise characteristics of the gear.

Now, GRSL makes it possible to perform all these analyses on up to 100% of the gears, in real time, and without impacting precious production time. The geometrical deviations of the gear determined by the GRSL inspection are relayed back to the production machine by means of a closed correction loop. Both fully automatic correction and real-time adjustment of the corresponding parameters can be achieved. Compare that to the conventional measurement process that takes place in the Quality Lab, where 45 to 60 minutes may well pass between removing the component from the machine and providing the measurement result. With HFC's in-process inspection and Closed Loop, the desired correction ensuring optimum quality during the ongoing production process is much faster.

Components with characteristics that fall outside the tolerances, including noise analysis using the advanced waviness analysis, are automatically rejected. It is also possible to create extensive trend analyses of individual features and perform necessary corrections before parts get out of tolerance.

Gleason

OFFERS BURR-FREE GEARS FOR E-DRIVES AND TRUCK-SIZED GEARS

GOTTFRIED KLEIN, GLEASON CORPORATION

Cylindrical gear chamfering and deburring is perhaps the least appreciated process because it adds cost without delivering apparent improvements in gear quality. There is a growing recognition, however, that the chamfering process — if performed well — provides significant improvement in cost-per-piece as well as many benefits in subsequent handling and processing

Chamfer hobbing for burr free flanks.

New Genesis 280HCD for hobbing and chamfer hobbing or fly cutter chamfering.

operations downstream. No wonder manufacturers of automotive- and truck-sized gears are now keen on exploring new technologies to chamfer gears more cost-efficiently and with greater precision.

With development of the Chamfer Hobbing process, chamfer cutting technology has made an important leap forward. Chamfer Hobbing is a chamfer cutting process for medium- and high-volume production and dry or wet cutting of "automotive-sized" gears, designed to fulfill most of today's most common chamfer tolerances and those expected in the future. The chamfer on the left and right flank is cut in a generative mode using separate, dedicated chamfer hobs made of High Speed Steel (HSS) materials featuring an AlCroNite® Pro coating for longer tool life. The hob profile is specifically designed for the particular chamfer form to be realized. The benefits of this process are burr-free face sides of the gear as well as no measurable burr on the edge between chamfer and gear flank. As a result, gears are perfectly prepared to meet the requirements of subsequent hard finishing operations. Finally, Chamfer Hobbing brings an entirely new level of economy to this operation, with a tool cost per workpiece of as little as 1 cent.

For gears up to 400 mm and module 8 mm and smaller batch production the highly flexible Fly Cutter Chamfering process (Chamfer Contour Milling) can be applied. The universal fly cutter tool with indexable carbide inserts creates the chamfer via multiple cuts. Chamfer angle, chamfer size and chamfer form (with or without root chamfering) depend solely on programmable machine movements, providing the highest flexibility for coarse pitch gears — even with different modules, pressure angles or numbers of teeth.

Chamfer Hobbing and Fly Cutter Chamfering each provide specific benefits depending on quality requirements, lot sizes and processing strategy. Both chamfer processes can be integrated on various models of Gleason Hobbing Machines, and performed in parallel to the main hobbing process for minimum cycle time and maximum productivity.

www.gleason.com