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THE GEAR INDUSTRY'S INFORMATION SOURCE

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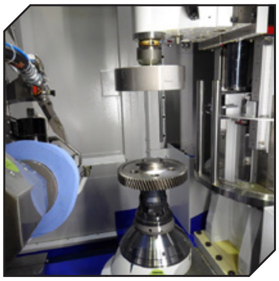
GT Revolutions

Liebherr's SECLA – One for (Almost) All



SECLA offers easy operation combined with maximum flexibility and short setup times. These are the clamping arbor features that Liebherr has been successfully using in its own gear cutting machines for many years. Anyone who buys a SECLA from Liebherr benefits from manufacturing to after-sales service, as the company offers everything from a single source.

www.geartechnology.com/blog/secla-one-for-almost-all/

DVS Examines Key Factors for e-Mobility

Electric drives for vehicles continue to be technically challenging in terms of range, efficiency, and sustainability, among other things. This means that the mobility of the future is still in the development phase, albeit at a very advanced stage. The stringent requirements of electromobility also increase the requirements on the components, processes, and machinery. DVS is answering these challenges with modular system solutions.

www.geartechnology.com/blog/dvs-examines-key-factors-for-e-mobility/

Real-Time Results

Starrett helps produce accurate and repeatable production runs with the latest metrology equipment. *Gear Technology* recently caught up with CW Moran, marketing specialist at Starrett, to discuss gear metrology and inspection technologies.

www.geartechnology.com/blog/real-time-results/

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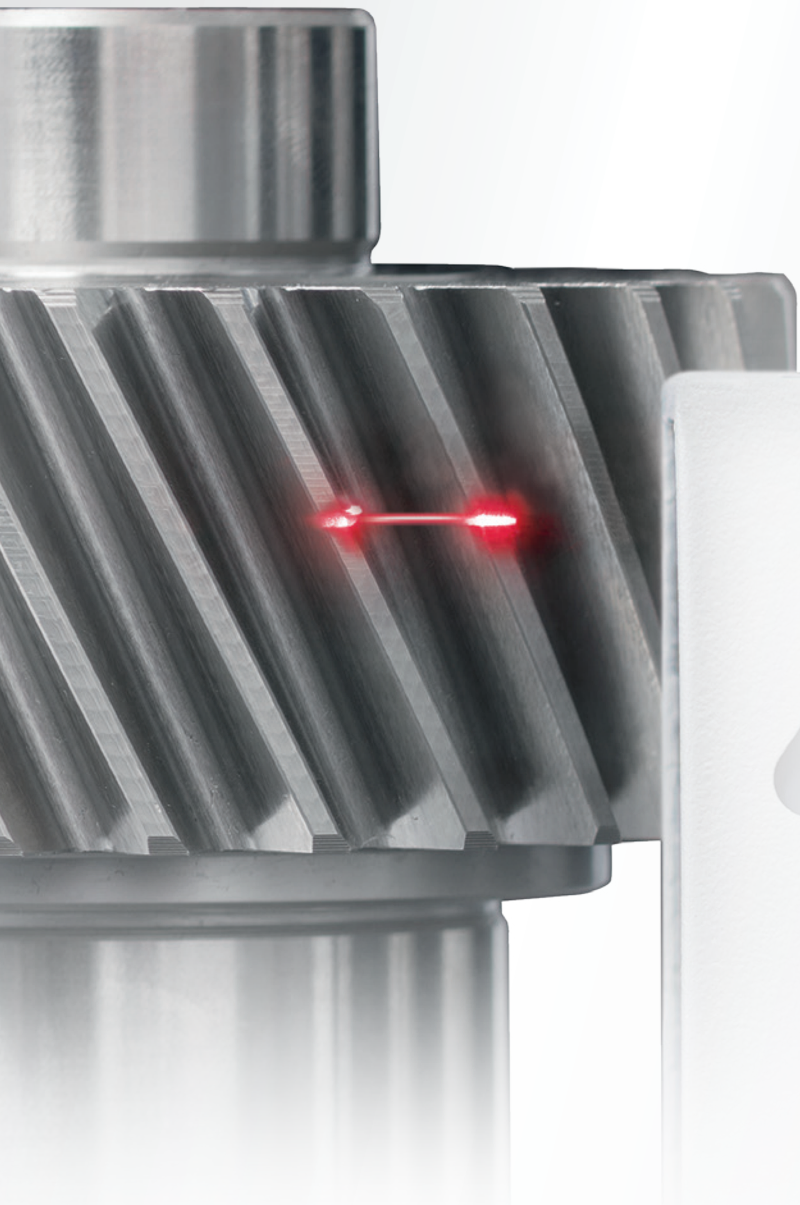
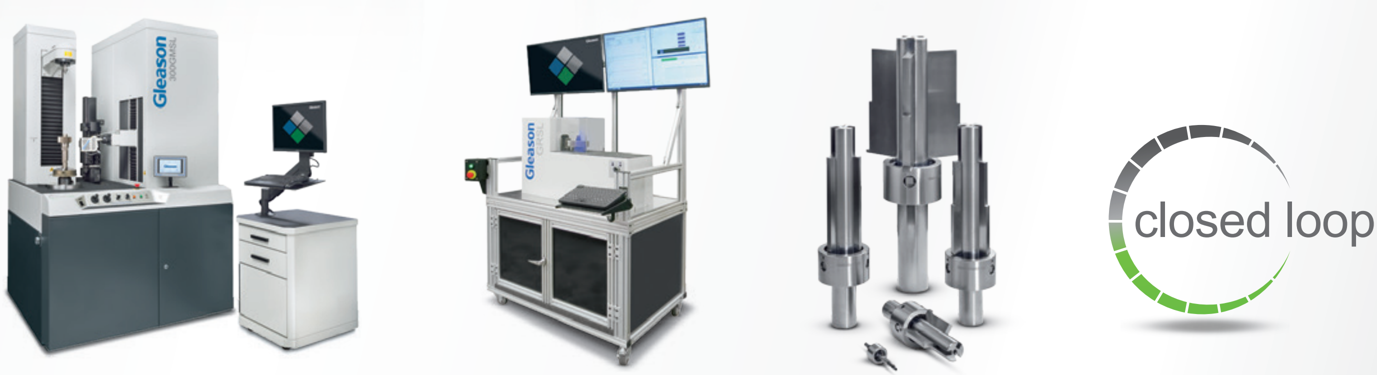
Michael Goldstein founded Gear Technology in 1984 and served as Publisher and Editor-in-Chief from 1984 through 2019. Thanks to his efforts. the Michael Goldstein Gear Technology Library. the largest collection of gear knowledge available anywhere. will remain a free and open resource for the gear industry. More than 36 years' worth of technical articles can be found online at *www.geartechnology.com*. Michael continues working with the magazine in a consulting role and can be reached via e-mail at *michael@geartechnology.com*.





Gleason
Gleason
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Maximizing Power Density

Publisher & Editor-in-Chief
Randy Stott

Increasing the power density of a gearbox is often a design engineer's primary goal. When you can maximize the amount of torque being driven without increasing the size and weight of a gearbox, you've won, because consumers and users of gearboxes want big torque in a small package.

But the desire to maximize power density applies to more than just gearboxes. Take trade shows, for instance. The same principle applies, except instead of torque, the goal is to maximize knowledge. There's no better place to see that in action than the upcoming MPT Expo.

Sure, this year's MPT Expo is going to be smaller than at any time in recent memory. The world's continuing struggle with COVID pretty much guarantees that there will be fewer exhibitors and fewer attendees than anyone is used to. But that doesn't mean you shouldn't go.

In fact, I encourage it, because MPT Expo is the power density king of trade shows. What it lacks in size, it more than makes up for in focus. All the leading suppliers in our industry will be there, across the complete supply chain. If you manufacture gears, you'll find more knowledge, experience and technology on the show floor at MPT Expo than you can find anywhere else. So if you have questions about how to integrate skiving into your manufacturing operations, the experts will be at MPT Expo to help you. Similarly, if you have challenges in workholding, heat treating or inspection, the experts will be there. They'll also be there to show you ways to increase productivity by employing the latest technology in machine tools, tool coatings and more. And if you need to outsource your gear manufacturing, or you need specialized gear manufacturing capabilities, you'll find many of the world's leading gear manufacturing job shops and manufacturers of gear drives exhibiting as well.

Sure, you can read about all those things in our magazine (especially in our show coverage, beginning on page 24). Or you can visit the websites of all the suppliers to learn about their latest products. But nothing beats the give and take of a one-on-one conversation with someone who not only understands your problems, but also has the experience to help you solve them — who, in fact, has probably already solved similar problems for companies just like yours. MPT Expo is where you meet those people, where you have those conversations and where you build the relationships with experts who can help you for years to come.

I know travel is difficult, and some of you may not be able to make it to St. Louis this year. But I also know that many of you have begun business travel again, and if that's the case for you, then MPT Expo is the place to be from September 14-16.

If you do make it to the show, please come find me at the AGMA booth, where I hope to have the same kind of in-depth, meaningful conversations with readers that have guided this magazine since it began more than 37 years ago. I'd love to learn more about what you're thinking, how your business is doing and how we can provide more and better information to help you navigate the trends and technology of our industry over the next few years.

I've been coming to this show (including its predecessor, Gear Expo) since 1995, and every year I'm impressed by the level of technological know-how gathered together in one place.

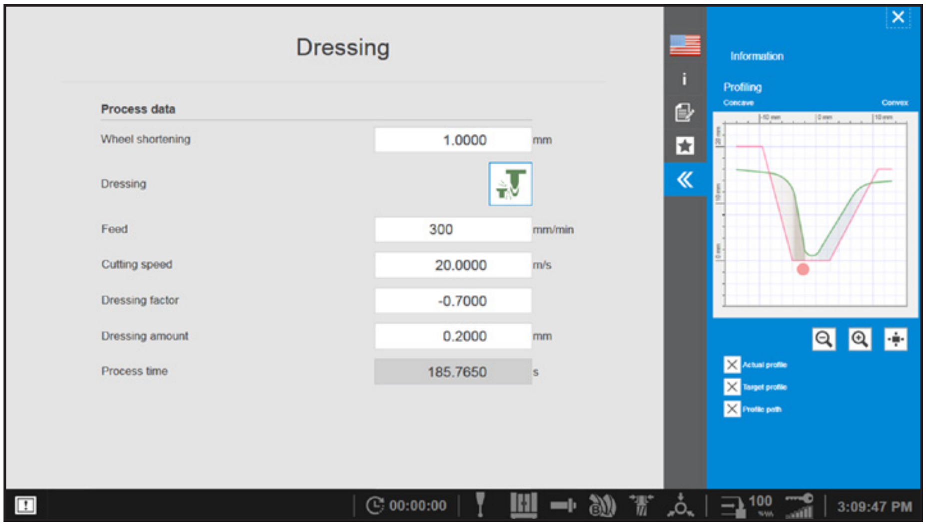
It may be a small show, but it's got a lot of power, and I hope to see you there.

Klingelnberg

INTRODUCES DRESSER CONTACT CONTROL

The full capacity of gear grinding machines flexibility can only be used when the dressing process for profiling the grinding wheel is highly precise. Highly economic grinding requires a high removal rate and therefore a significant wear of the grinding wheel with the risk of non-proper profiling. This dilemma can be eliminated with Klingelnberg's Dresser Contact Control. Two conflicting targets are brought together: highest precision of the grinding wheels profile and the most profitable dressing process parameters.

For gear grinding machines profiling of the grinding wheel is an essential function. This so-called dressing operation removes the worn-out surface and applies the correct profile on the grinding wheel. This is done using a diamond coated dressing tool. The machine performs movements of the dressing tool and the grinding wheel to achieve the proper profile.



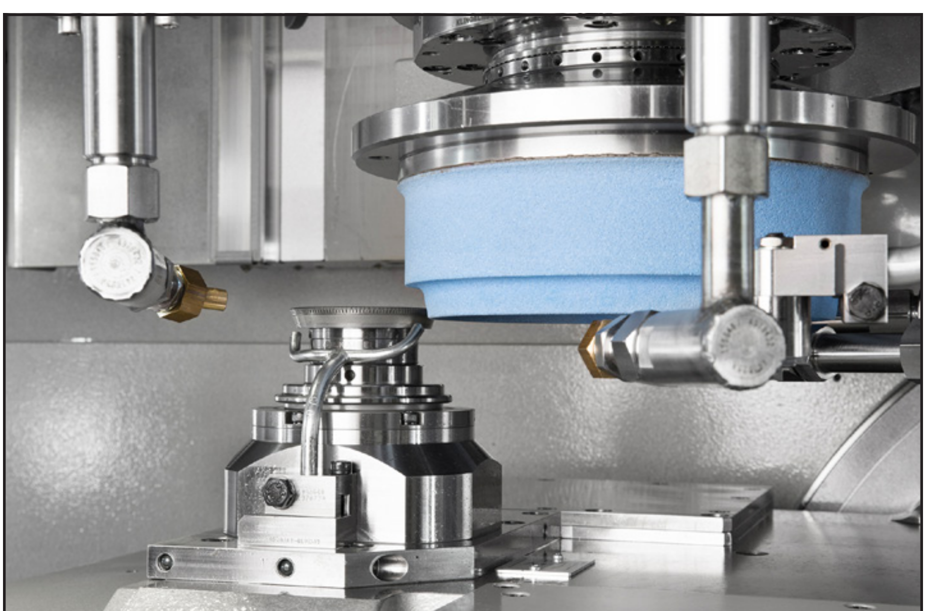
Dressing parameters and view of dressing roll and target profile of grinding wheel.

The Dressing Process

When grinding bevel gears a cup shaded grinding wheel is used. The dressing tool is diamond coated disc with a radius on the outside diameter. Profiling the grinding wheel is done with the outside of the dressing tool.

Each dressing operation reduces the length of the grinding wheel by the so-called dressing amount. The geometry of the profile on the outside and inside will not change along the service life of the grinding wheel. The dressing amount must be big enough to guarantee a proper profile after the dressing cycle.

And this is the problem! In case of a dressing amount being too small it will happen that we do not get the proper profile on the grinding wheel. If the dressing amount is too big, the dressing tool will wear out unduly and the service life of the grinding wheel decreases.



Dressing tool and grinding wheel.

Challenges in Bevel Gear Grinding

At a first glance this problem does not seem to be complicated. When looking more detailed to this task the challenge is the typical shape of a grinding wheel for bevel gears. Since the lengthwise crowning requires tilting of the grinding wheel the flank angle of the outside profile is significantly smaller than that of the inside. Consequently, the removal on the outside is drastically smaller than the removal on the inside.

Experienced operators set the dressing amount such that a reasonably big removal is guaranteed on the outside of the grinding wheel. Typical flank angles of 10° outside and 30° outside and a dressing amount of 0.1 mm create a removal of only 0.017 mm on the outside and 0.058 mm on the inside of the grinding wheel. This dressing amount will only guarantee a safe grinding process as long as the wear on the grinding wheel is significantly less than 0.017 mm. In case this cannot be ensured, the dressing amount must be increase for example up to 0.15 mm. This is on the safe side, but the service life of the grinding wheel will be reduced by more than 30 percent at the same time.

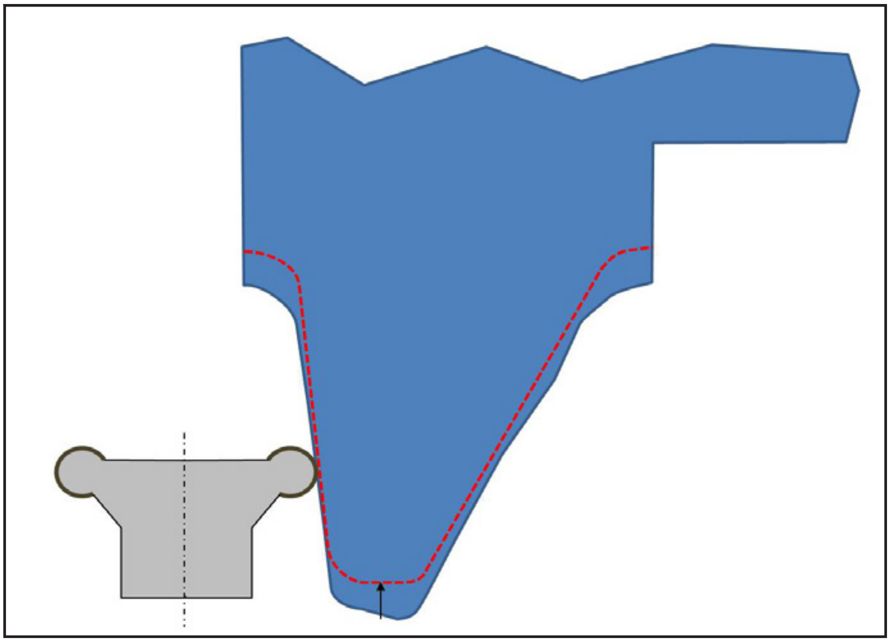
This is the starting point of Klingelnberg Innovation called Dresser Contact Control. All bevel gear grinding machines of the G-Series now have an acoustic emission sensor integrated in the dressing spindle. During the dressing operation this sensor checks if there is really contact in between dressing tool and grinding wheel. This can be seen in real time display on the controller by a blue bar along the dressing path. In case the contact tears off the machine software will repeat the dressing operation.

In collaboration of the acoustic emission sensor and the KOPG software there are many advantages:

The profile of the grinding wheel is always correct independent from the dressing amount.

The dressing amount can be reduced to a reasonable minimum. In case a gear was ground having a large material allowance of having large heat distortions both causing a excessive wear of the grinding wheel the next dressing cycle will be repeated as long until the proper profile on the grinding wheel is guaranteed.

When profiling a new grinding wheel, the sequence of dressing operations will be stopped as soon as the proper profile is shaped on the grinding wheel.



Typical dressing wheel profile before and after dressing.

With the new Dresser Contact Control feature not just the process reliability of bevel gear grinding is improved but also cost reduction is guaranteed: instead of applying a dressing amount of 0.1 mm this can be reduced down to 0.8 mm. The effect is a reduction of up to 20 percent in the pro rata tool costs.

www.klingelnberg.com

WFL

OFFERS VARIETY OF MEASURING TASKS FOR COMPLETE MACHINING

In order to reliably manufacture complex workpieces with high quality requirements, it is necessary to control the processes by means of a closed-loop process. The production of small batch sizes — sometimes only of individual parts — usually involves expensive blanks which are difficult to procure and can quickly be "wasted." Therefore, since the beginning of complete machining, WFL has paid great attention to measuring workpieces in the machine and has developed cycle packages for a wide range of measuring tasks.

These measuring methods ensure highest manufacturing accuracy with tightest tolerances on complex workpieces. There is a wide variety of measuring devices such as switching measuring probes, scanning measuring probes or ultrasonic measuring devices.

Manual measuring versus automated measuring

In order to meet today's requirements, measuring is an integral part of future-oriented manufacturing processes. The closed-loop approach tries to create a simple and efficient cycle between the production system, machine, human and measurement technology. One of the most important aspects in this cycle is measuring during manufacturing processes.

Measurements can be carried out manually and automatically during a manufacturing process. With manual measuring, the operator is responsible for measuring and measurement data management, whereas the machine takes on both tasks in the case of automated measuring.

Manual measuring is still very important in today's production, but it is increasingly replaced by rapidly developing innovative measuring techniques. At first glance, measuring equipment for manual measuring seems to be more affordable than modern measuring equipment, such as measuring probes. However, over a long-term production period, innovative measuring equipment and techniques are more efficient and cost-effective.

When using manual measuring equipment, random measuring errors must be expected. These occur with every measurement and are very difficult to find. Process interruptions, which are necessary to carry out measurements, result in longer production times. For this reason, only a low level of automation can be achieved. Since the tool correction is calculated by the operator, there is a higher error rate compared to an automated process.

All in all, the advantages of modern measuring technology, e.g. measuring with a measuring probe, outweigh any possible disadvantages in an innovative, automated production process.

Automated measuring is playing an increasingly important role in the manufacturing process. Thanks to the use of smart measuring equipment and techniques, a high degree of automation can be reached. This in turn leads to shorter production times. The process is no longer interrupted, there are fewer measurement uncertainties, and, in addition, one single measuring probe can be used for a wide variety of measurements. Innovative measuring equipment and strategies make MILLTURN complete machining centers even more efficient and versatile than before.

The measurement process

Measuring probes have to be calibrated before they can be used for measurement. The calibration always takes place before the machining process and is carried out by the operator. The individual measuring points that were determined with the probe are evaluated after measuring. Various algorithms are available for analysis. The results are then evaluated, and a correction is calculated. Most of the time, a tool correction is determined based on the measurement results and automatically assigned to a tool via a WFL cycle. In addition, the individual results can be recorded, and a detailed analysis can be carried out at a later point in time.

Measurement strategies and possibilities

The right measurement strategy is crucial for a successful measurement process. The new generation of measuring probes offers extensive possibilities and should be part of every future-oriented, automated production process. Not only workpieces, but also complete contours and profiles can be scanned with the new measuring probes. This new and unique method unleashes an unimagined efficiency and versatility of WFL's MILLTURN machines. WFL has developed its own cycles and measuring strategies for a wide range of applications in order to make the best possible use of the new generation of measuring probes and a MILLTURN.

Measuring strategies for the measurement of gears replace manual measurements by machine operators. The correction for the tool is determined automatically. This measurement process is essential for reliable gear machining

and can be simulated with WFL's programming and simulation software CrashGuard Studio.

Scanning measurement of roundness and axial run-out

Since the exact deflection angle can be determined with new switching heads, the exact roundness and axial run-out can be measured on the workpiece, for example. For this reason, it can be checked before machining whether the blank meets the requirements. If this is not the case, either the program must be changed or the blank must be exchanged in order to avoid any machining problems. Since programs have flexible structures, they can usually be adapted automatically using a parameter program. In automated production, blanks should always be inspected in order to avoid problems and downtimes.

The new measuring probes can measure roundness as well as entire profile contours. WFL has developed measuring cycles and strategies for implementing highly complex measuring applications in one machining process. These cycles allow scanning any kind of profiles and calculating corresponding tool corrections. Therefore, different form milling cutters, which together create a contour profile, can be automatically coordinated via the WFL measuring cycles.

Surface quality can be measured with a new generation of special measuring probes. This means that any problems occurring during a machining process can be reacted to at an early stage, which avoids costly downtimes and scrap parts.

Thanks to the possibility of scanning profiles and evaluating the results, WFL has developed cycles especially for gearing technology, which, for example, allow measuring the flank profile or the tooth trace. Afterwards, the measurements are evaluated. The evaluations and protocols correspond to the general industry standard for gearing technology. Gearings can thus be checked and recorded after the machining process in accordance with industry standards.

Ultrasonic measuring

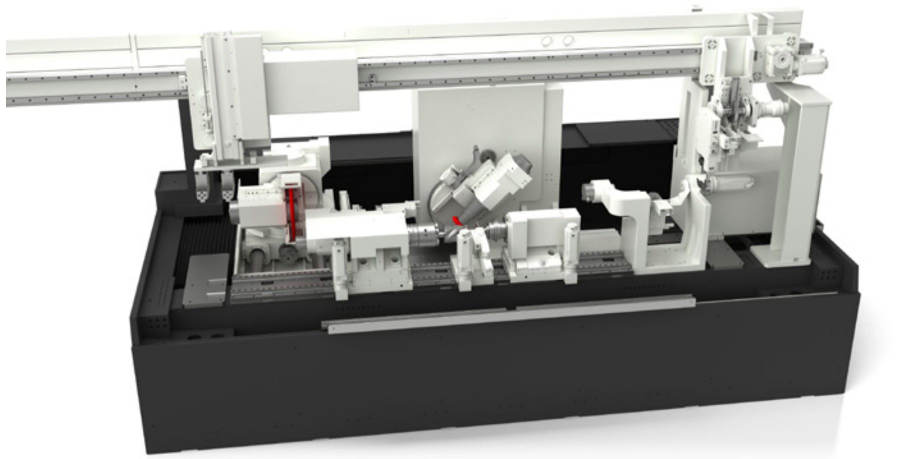
The ultrasonic measuring unit allows the measurement of the wall thickness of components. This method is used for long pipes or deep inner contours which can usually no longer be measured with a measuring probe. The wall thickness can be easily measured and evaluated by using WFL's measuring cycles. For example, the center error of an inner contour can be determined using the various evaluation algorithms.

"By implementing measurement methods, we are able to ensure and improve the quality of components. The automation of all measurement processes is an essential step to implement nearly or completely unmanned production processes," said Reinhard Koll, head of application and project engineering at WFL Millturn

www.wfl.at

Junker

DEVELOPS ALL-IN-ONE GRINDING MACHINE



Sullair LLC. located in Michigan City Indiana, a Junker customer since 2011 has changed their finishing process to eliminate the demand to pair shafts and achieve highest compressor efficiency. In the past, the process required multiple grinding machine setups to finish a shaft. Diameters and faces of the shaft were ground on the Junker QUICKPOINT prior to grinding the compressor flutes on form grinding machines.

Today with the JUMAT 6L all of this is done in one setup and one machine. In addition, for faster changeovers and to control process quality the machine in process measuring systems measures key features and automatically adjust the process to produce highest quality without operator intervention. Junker developed the capability to measure the complex compressor flute profile and correct the dressing path to dress the CBN wheels complete automatically.

Cost-effective complete grinding with optimum accuracy

The correction is essential as tool pressure varies depending on the contact zone of the shape. It is necessary to apply a wheel with an incorrect shape to make a perfect part. The Junker grinding machine masters this with ease and for an optimum accuracy, the machine produces parts with a total lead variation of ±3 microns and a profile accuracy of less than 6 microns.

Junker ensures productivity with intelligent processes

For the different flute shapes and for rough and finish grinding - the machine is equipped with a wheel changer. The machine programs call up the correct wheels and manage their life span. If a wheel has reached the end of its life, the controller requests a new wheel and alerts the production manager to purchase a new one. The parts are presented to the machine on a conveyor with an autonomy of a full shift. Parts are loaded into the machine by an internal gantry system. With that, the safety of the entire system is safeguard and grinding with straight oil possible.

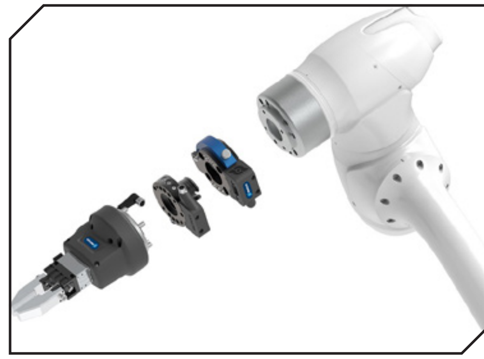
Economical, intelligent and highest dimensional precision Junker rotor shaft technology provides the capability to grind highest efficiency compressor shafts in one setup with controlled part quality by the grinding machine.

www.junker-group.com

Schunk

OFFERS MODULAR PLUG AND WORK GRIPPER SYSTEM FOR COBOTS

As more and more manufacturers discover cobots, including major players in industrial robotics as well as specialized cobot pioneers, Schunk has established its ready-to-use Plug & Work portfolios that radically simplify the equipment of the Cobot front-end.



The customized Plug & Work portfolios include pneumatic and electric grippers, co-act gripping modules for collaborative applications, and quick-change systems. Whereas the pneumatic grippers are easy to use, have a high-performance density and are attractive in price, they are especially predestined for conventional automated applications, where primarily its robustness is sought-after. Electric grippers are flexibly adjustable to force or stroke, are versatile in use, and offer many variants. Plugins simplify programming, particularly for those users who are new to automation, because they enable a fast and simple start into process automation.

Broad selection of components

The segment of pneumatically controlled actuators includes modular systems of the industry-proven, multi-tooth guided parallel gripper PGN-plus-P, the centric gripper PZN-plus, the universal gripper JGP with the best value for money, as well as the long-stroke grippers KGG, and PSH. Micro valves for control of the pneumatic modules are already integrated in the Plug & Work adapters. Moreover, the selection of components includes electric grippers for small components EGP, electric grippers type Co-act EGP-C, as well as the versatile Schunk EGH with a freely programable overall stroke of 80 mm, which is virtually the ideal gripper for starting cobot-supported automation. But the Plug & Work portfolio also includes the manual change system SHS with integrated air feed-through, electric feed-through and an optionally integrated lock monitoring. It allows flexible use of cobots and Schunk grippers. Other actuators can be exchanged in just a few working steps.

Diverse applications

Cobot applications can be easily adapted to different application cases because

every component is flexibly combinable and the whole offering of accessory products and options listed in the Schunk catalog are available. Solutions can be intuitively configured with the Schunk online configurator, based on the eCATALOG solutions technology of CADENAS. It takes just one click and all common CAD formats (optionally two- or three-dimensional ones) can be downloaded. Thereby a combinational logic ensures that only configurations can be implemented, which are feasible from a technical and mechanical point of view. The ready-to connect Plug & Work portfolios cover diverse fields of application: the ones of common automation but also of collaborative applications. They are equally suitable for people without any experience in automation and experts of the metal-cutting industry, automotive and electronics industry, logistics and of many other industries, who want to discover the potentials of robot-based automation by using cobots.

Schunk.com

Chiron Group

INTRODUCES MULTIFUNCTIONAL MACHINING CENTER

Chiron Group recently demonstrated for the first time its new 715 Series machining center. Designed for complete machining of all six sides of complex parts, the machine fits between the vertical Chiron FZ 08 S mill turn precision+ machining center and the STAMA MT 733 machining center. It includes part handling automation and storage.

Matthias Efinger, Chiron Systems Engineer R&D, says "the goal during development was to create a machining center designed for autonomous processing on all six sides, rounding off the Chiron Group bar machining portfolio and fully bridging the gap between the FZ 08 S mill turn precision+ **and MT 733.**"

The 715 Series is designed for fully automated, complete machining tasks in the medical technology, aviation and aerospace, energy, and automotive industries. Part size range is bars up to Ø 65 mm or chuck parts up to Ø 200 mm, with maximum workpiece weight of 20 kg.

Continuous machining process

Two versions of the machining center are available: Chiron MT 715 and Chiron MP 715 – MT is Mill Turn and MP is Multi Profile. The machines include a direct-drive 20,000 rpm milling head, a horizontal main spindle and a matched, opposing counter spindle to permit continuous multifunctional machining on all six sides of a part in a single setup. This capability is used to machine hip stems, turbine blades, and extrusions for chassis or battery storage.

Both machines accommodate 128 tools and include integrated workpiece handling and workpiece storage. This supports fully automated,

cost-reducing manufacturing of workpieces in small and medium batch sizes. Convenient loading and unloading of the tool magazine can occur during machining.

High levels of automation

The new machine platform is also set up to integrate digital systems from the Chiron SmartLine Portfolio, including automatic condition monitoring, integrated machine and process diagnostics, machining simulation, preventive machine protection in every mode of operation, remote diagnostics and remote maintenance, and intuitive operation.

Within the Chiron Group portfolio there are a range of options for machining workpieces with up to a 200 mm diameter and a length of up to 500 mm, for milling and turning off the bar, or milling off the bar or from profile.

CNC machining centers and “Made by Chiron” turnkey solutions guarantee high-speed manufacturing and CNC machining with maximum productivity and maximum precision. Whether with one, two or four spindle, machining centers from Chiron produce components of the highest quality at minimum unit costs. Economical turnkey solutions for CNC machining, high-speed cutting and high-speed manufacturing permit “seconds ahead” production.

www.chironamerica.us

KISSsoft

OFFERS CROSSED HELICAL GEAR CALCULATIONS

The gear calculation in *KISSsoft* covers all common gear types such as cylindrical, bevel, hypoid, worm, beveloid, crown and crossed helical gears.

In the *KISSsoft Release 2021*, new graphics for the crossed helical gear calculation are available: The evaluation graphic for specific sliding is calculated and displayed based on the geometry of a spur replacement cylindrical gear. A visual evaluation of the tooth meshing in 2D is now also possible for axis crossing angles not equal to 90°. For this purpose, parallel sections to the center axis plane of the worm are calculated and shown. This 2D geometry is visualized using the "Tooth meshing in slices" function. The option "Determine form diameter dFf and dFa from tooth form" is also selectable.

With the help of the fine sizing method in KISSsoft, you can also find the best variants for crossed helical gear stages with preset, definable boundary conditions. If you input the nominal ratio, normal module, pressure angle, helix angle, center distance and profile shift coefficient, the system calculates and displays all the possible suggestions.

All the variants the system finds are then output in a list, classified by the most varied criteria (accuracy of ratio, contact ratio, safety factors, weight, axial forces etc.). You can either expand or reduce the scope of the list, if you want to display more or fewer individual results for a specific solution.

www.kisssoft.com

Liebherr

PROVIDES CLAMPING SOLUTION FOR DIVERSE REQUIREMENTS

SECLA offers easy operation combined with maximum flexibility and short setup times. These are the clamping arbor features that Liebherr has been successfully using in its own gear cutting machines for many years. Anyone who buys a SECLA from Liebherr benefits from manufacturing to after-sales service, as the company offers everything from a single source.

Customer feedback was so positive that, in 2019, Liebherr decided to offer the clamping fixture as a separately available component. The clamping arbor manufactured by Liebherr offers modular construction, enabling a clamping fixture exchange in next to no time.

Short delivery times

As well as its diverse variety and its robustness, which make it suitable for different workpieces, the SECLA also impresses with its fast availability. A complete clamping device can be delivered within 10 weeks, while individual components such as the clamping arbor, clamping base and the mounting for the counter column are in stock and thus immediately available.

Liebherr even goes one step further and provides customers with the interface geometry of individual, workpiece-touching components – for example, the workpiece support, the centering tip or the clamping top – for their own production.

Work area and collision monitoring in advance

Liebherr offers a special peripheral service for the clamping fixture: in case of possible interfering contours, Liebherr conducts advance collision monitoring in the work area as an engineering service. This ensures that production can start immediately after installing the clamping device.

SECLA service help desk

Liebherr has set up a help desk for any questions concerning SECLA. The employees can be reached by telephone or email and will answer any questions about technology, delivery times or commercial handling, or will connect you with the right person.

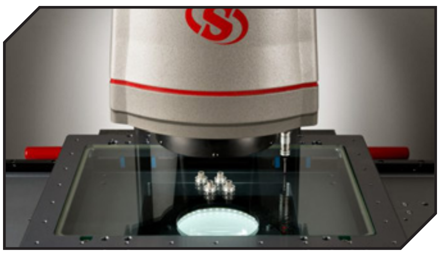
www.liebherr.com

Real-Time Results

Starrett Helps Produce Accurate and Repeatable Production Runs with Latest Metrology Equipment

Matthew Jaster, Senior Editor

Gear Technology recently caught up with CW Moran, marketing specialist at Starrett, to discuss gear metrology and inspection technologies.



GT: How have your measurement systems for gears evolved in recent years?

CWM: Gear measurement has evolved considerably in recent years to become a fully automated process. One of the main inspection objectives for gear manufacturing is to measure runout, or the variation in distance between successive tooth spaces on the gear and the articulate surface. Modern vision and optical measurement systems feature digital overlay comparisons to CAD files of a master template, replacing the traditional micrometer with pins or balls. This gives instantaneous results on runout for the entire gear in question, complete with tolerance zones. Wide ranges of lens options, such as the 0.14X lens on the Starrett AVR-FOV Vision System, can even enable multiple gears to be inspected simultaneously in the large field of view.

Also, the integration of multi-sensor measurement capabilities such as a touch probe, allow for more discreet or recessed areas to be accurately inspected. The software on the latest measurement systems has also become far more user friendly, allowing virtually anyone on the shop floor to initiate and run a part profile on the system. This is known as "walk up metrology." These advancements help produce accurate and repeatable production runs, while reducing lead times and QC bottlenecks.

GT: What are the latest capabilities to this equipment that give your customers a competitive edge?

CWM: Optics are one of the main areas of innovation providing a competitive edge in Starrett Optical Comparators and Vision Systems. Lens options on optical comparators range from 10× to 100×, all of which are interchangeable in seconds. Both zoom and telecentric optical video systems are available for the Starrett Optical Comparator line. In our Vision Systems, fixed or interchangeable zoom or telecentric camera lenses are available and easily changed out via the bayonet system. Multi-lens systems are offered on both Optical and Vision Systems, saving time by eliminating the need to recalibrate after switching lenses.

Large field of view lenses, up to 2.3" (X-axis) × 1.9" (Y-axis) are available on select models, such as the AVR-FOV, which allow for more of the work-stage or part to be viewed at once. Ideal for larger parts and multiple small parts, when combined with the "Super Image" software application function, a single large image can be stitched together to show the entire part. Such a large optical range reduces the amount of equipment required for QC, saving floor space and time. The software allows for auto-recognition part programs to be created. Once created, when the part in question is placed in the field of view and the program is initiated, the measurements are taken automatically. These automated features help facilitate "walk up metrology."

GT: How important is the collaboration between the manufacturer and the end user regarding the selection of the right inspection system?

CWM: When a customer decides to invest in a metrology product, they are also investing in a partnership with the metrology company. Collaboration between customer and supplier is key to ensuring the right system is chosen for the application requirements. The first step is a thorough application review for selecting the right system format, options, lenses, lighting, and applicable accessories. At Starrett, we provide support for the lifetime of the system by serving as a go-to resource that starts with working hand in hand on proper setup and initial training, in order to maximize the use of the system. Technical support is always available, either in person or digitally, for service and for troubleshooting any issues or questions that may arise over time. Annual calibrations are also available; ensuring that accurate and repeatable results can be relied on for years to come.

GT: What role is smart manufacturing (Industry 4.0) solutions playing in your metrology equipment for gears in 2021?

CWM: Industry 4.0 solutions are being incorporated into our metrology products at every level of production. For gear inspection, the traditional method of inspection is with a micrometer utilizing pins or balls. The rollout of DataSure 4.0 wireless data collection technology this year from Starrett brings micrometer measurement into the digitalization world by allowing micrometers to communicate instantly and wirelessly with a central computer. This means that multiple individuals can be performing quality checks on the shop floor and the information can be analyzed in real time.

In the Starrett Optical Comparator lines, new technology in select models for readout will allow for instant wireless upload to a central computer via Bluetooth connection. Digitalization can also help identify developing issues such as excessive wear on manufacturing tools. Features like "Go/No-Go" tolerance zones can be viewed in real time to identify if a machine on the floor is still within specifications, allowing manufacturers to prevent issues such as excessive backlash before they arise.

GT: What other technology advancements are vital to inspection/metrology today?

CWM: The sheer adaptability and flexibility of today's inspection systems. Modern systems have wide arrays of lens configurations that are easy to interchange. Lighting options are also customizable and easy to control. New systems, such as the Starrett AVX550, even have the ability to utilize multiple lenses that can be used sequentially, eliminating the need to recalibrate which saves time. System options come in floor standing, tabletop, and large format, depending on customer needs, and many systems are available with multiple stage travel options.

Systems such as the Starrett HVR100 Flip can change (flip!) between a horizontal and vertical orientation as well. Users can also select from manual or CNC control for most systems and have options such as touch probe capability. A wide range of accessories such as rotary indexers, part holding fixtures, and touch probe changing racks, further enhance the inspection capability of any single inspection system.

The end result of this wide range of products and configurations is that one single system has the ability to perform many, if not all, tasks that a manufacturer might require, allowing them to save floor space, time and money.

GT: How has training/technical support changed post-COVID?

CWM: At Starrett, we have always been a big proponent of having a digital presence for technical support and training. In a post-COVID world, this need for quality virtual engagement has only been accelerated. We have developed an in-house demo facility where we can shoot and produce high quality demos, as well as go live to interact with the end user. Manufacturers can send in sample pieces, or can select from our sample collection. They can see first-hand the benefits of a system or receive training on their new system without ever having someone enter the building. Our use of multiple cameras allows for the system as a whole, the stage, and the control software to be viewed simultaneously, providing the same level of detail as an in-person visit. With this live digital engagement platform, we can interact with more customers faster than before, reducing lead times while addressing technical support issues, training, and product demonstrations.

GT: How much of your quality/inspection solutions are customizable?

CWM: Virtually all of our quality and inspection solutions are customizable. While we offer a wide range of both horizontal and vertical systems in both tabletop and floor standing models, we also offer a large range of compatible lighting options, accessories, indexers, fixtures and more. Almost every system can be custom configured to have fixed or interchangeable lenses of the users' selection. Stage size, travels, and lighting options can also be adjusted accordingly. For situations where customization of an in-line solution is not sufficient, Starrett prides itself on developing truly customized designs as one-offs, engineered and developed in-house. In this way, we have the ability to address the needs of almost any customer regardless of how challenging or unique.

GT: How will gear inspection change in the coming years and what role will Starrett play in these changes?

CWM: Advancement in the modern manufacturing environment is dependent on delivering quality products faster that are machined to the highest degree of accuracy. Starrett Metrology is dedicated to providing the measurement and inspection tools necessary to accomplish these goals.

In the coming years, look for more comprehensive 3D model based inspection, especially in prototype and short-run situations. Production lead times will continue to be reduced as the user interface becomes increasingly more user friendly, allowing more employees to be able to run quality checks or inspections in real time. Full integration and automation will continue to develop, helping to identify quality issues before they arise, such as premature cutting tool wear. Ultimately, end users will be able to refine their processes and deliver faster, more precise inspection results to manufacture gears with a higher level confidence than ever before.

www.starrett.com

For Related Articles Search
optical metrology
at www.geartechnology.com

A Shifting Status Quo

What's New and What's Next at Motion+Power Technology Expo?

Matthew Jaster, Senior Editor

Manufacturing is getting a makeover. This might be why you've signed up for the Motion+Power Technology Expo. The gear shop is evolving right before our eyes. New material, software and additive technologies are in the headlines while machine tools get smarter, faster, and more energy efficient.

Forecasts are buzzing with news on automation, IIoT, robotics and augmented reality. In order to meet the stringent demands in aerospace or e-Mobility, you'll need the appropriate grinding wheels, hobbing machines, closed loop solutions or skiving technologies to stay competitive.

It's all here in St Louis—hints of the future gear shop. Markets are picking up, power transmission is moving in the right direction and commercial and industrial growth may provide real opportunity post-pandemic. It's time to roll up the sleeves and focus on the future.

Bourn & Koch Touts Hobbing and Remanufacture Packages

While Bourn & Koch is well known in the gear manufacturing industry for their expert support of Barber-Colman and Fellows machine tools, the machines they are bringing to M+PT will showcase the solutions they can provide for new and remanufactured gear manufacturing machine tools.

Bourn & Koch will feature their flagship horizontal gear hobbing machine, the 400H. Capable of producing large diameter, high quality gears in a compact footprint, the 400H allows for a highly efficient way to hob long spline shafts and gears on large shafts for a variety of industries, including aerospace, agriculture, heavy equipment, and defense. The 400H's predecessor is the Barber-Colman 16-16, a machine still used to this day by many gear manufacturers. The Bourn & Koch 400H provides a way to upgrade your Barber-Colman to today's technology with standard single and multiple cut cycles, a Fanuc 0i-F CNC control with easy to learn conversational programming, a power-programmable CNC hob swivel, automatic hob shift, along with crown and taper hobbing cycles. Additionally, the machine will feature an integrated probe arm assembly, designed to be used in carbide re-hobbing applications to measure tooth to tooth spacing and for automatically detecting profile length.

Also, on display in Bourn & Koch's booth, is their new Fellows 10-4 CNC remanufacture package. While remanufactured gear shapers have been provided by Bourn & Koch for decades, this new package provides a direct drive work-spindle and infeed axis along with numerous mechanical improvements over a typical retrofit. Bourn & Koch has long provided quality OEM remanufactures of Fellows 10-4 gear shapers, but this new package, featuring a Fanuc 35i, provides an economical CNC gear shaping machine with the quality and support that Bourn & Koch is known for. Loyd Koch, co-founder of Bourn & Koch, was integral in bringing this "new product" to market with the engineering team, so its pedigree is based in a practical approach to providing a quality machine for job shops and large manufacturers alike.

Bourn & Koch, Inc. – Booth #3721
www.bourn-koch.com

Euro-Tech Offers Frenco and Mytec Hydraclamp Workholding Solutions

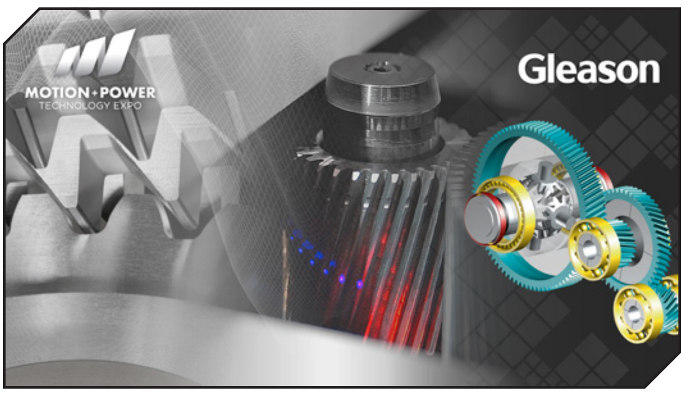
Euro-Tech Corporation offers workholding solutions for gear industry challenges with the Frenco and Mytec Hydraclamp product lines. Today's solutions for efficiency and power density are often a combination of mechanical, fluid power, electric, and hybrid technologies. Today's gears and splines are precision items produced through special tools with very tight tolerances. When you need to inspect manufactured workpieces you need even more accurate measuring and inspection equipment. For over 40 years, Frenco has committed itself to the challenge of providing customized solutions for individual gear and spline inspection requirements. MyTec Hydraclamp expansion elements provide the optimal connecting link between workpiece and machine. Mytec recently added a line of mechanical arbors

and chucks with repeat accuracies of ≤ 0.005 mm (≤ 0.0002"). These are excellent for workholding where high forces are incurred or auto load applications where high clearance is required.

Euro-Tech Corporation – Booth #2312
www.eurotechcorp.com

Gleason Showcases Latest in Closed Loop Manufacturing and In-Process Quality Control

Gleason Corporation will showcase the latest technologies in design, manufacturing and inspection of cylindrical and bevel gears. Special focus will be given to the new KISSsoft Gear and Transmission Design Capabilities, 100%-In-Process Control, Gear Noise Analysis and live manufacturing demonstrations from Gleason operations around the globe.



KISSsoft: Intuitive Gear and Transmission Design at System Level

KISSsoft will demonstrate its *KISSsoft 2021* release with numerous new features, including: *KISSsys*, the intuitive concept design software at system level; the new interface with SKF bearing technology to simplify transmission development; the interface with Gleason's GEMS to exchange gear and system information for bevel gear manufacture; the Closed Loop system to exchange data with metrology and production machines, and much more.

Up to 100% In-Process Quality Control with Integrated Gear Noise Analysis Tool

The new GRSL Gear Rolling System with laser technology revolutionizes in-process gear inspection and sets a new standard for high-speed, high-volume quality control. This compact gear inspection unit combines double flank roll testing with index and involute measurement as well as lead measurement on all teeth for full analytical and functional in-process gear inspection. Measurement data and process trend analysis are displayed in real time throughout the production run, with automatic Closed Loop corrections. In addition, Gleason's Advanced Waviness Analysis allows the detection of potentially conspicuous gears in real time regarding noise problems.

Live Product Demos and Complementary Virtual Show

Gleason will present several new products with live webcasts directly from its global operations including a world

premiere, the 280HCD Genesis Gear Hobbing Machine with integrated Chamfer Hobbing, Threaded Wheel Gear Grinding, Power Skiving, and the new Phoenix 500C Bevel Gear Cutting Machine with Pentac Ecoblade Cutter System for mid-size bevel gears. Experts will be available to answer questions and demonstrate specific features of products. For customers not able to participate in MPT2021, Gleason's "**e**motions" virtual showrooms will be available to experience all exhibits remotely. For more details, please refer to Gleason's website and social media channels.

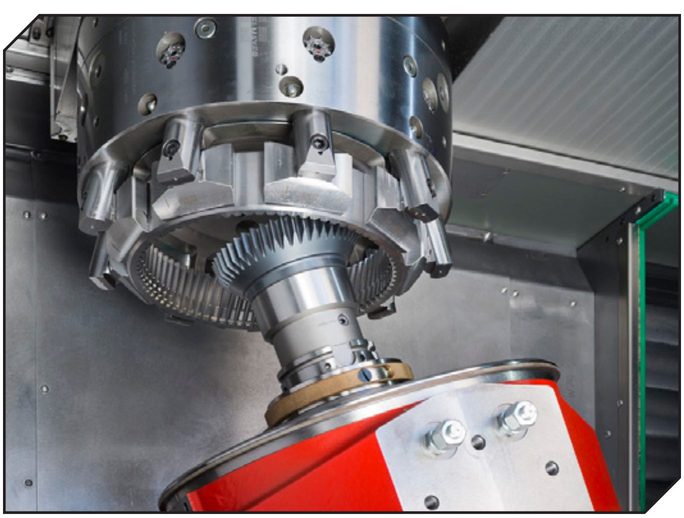
Gleason Corporation – Booth #2607
www.gleason.com/mpt2021

GMTA Presents Machine Tools and Metal Fabricating Equipment

German Machine Tools of America (GMTA) in Ann Arbor, Michigan, will showcase several of its machine tools and metal fabricating equipment at the Motion + Power Technology Expo. The show will take place September 14-16, 2021 in St. Louis, Missouri and is produced by AGMA. It connects top manufacturers, suppliers, buyers and experts in the mechanical and gear power, electric power and fluid industries.

The company represents several high quality, high performance lines including Arnold, BvL, K+G, Profilator, Rasoma, Samag and its latest addition, Stiefelmayer. Arnold laser technology provides a complete line of laser welding machines for the automotive, aerospace and other markets. BvL offers parts washing systems, equally suited as a one-off station for large castings/forged products or as a continuous washing and drying line. K+G are high-tech machine tools for internal or external grooving, turning and milling.

Profilator is a world-renowned brand of machines for gear pointing, cutting, rounding, deburring, polygon slot facing and the Scudding process. Rasoma is a builder of vertical turning centers and inverted spindle turning machines for milling, drill-



ing and special machining. Samag machining centers and deep hole drilling machines are used in the automotive, off-highway and moldmaking industries. Stiefelmayer lasers cut products such as motor laminations, as well as laser hardening, fiber and diode types. Lastly, GMTA offers its own line of baskets, trolleys and lift tables.

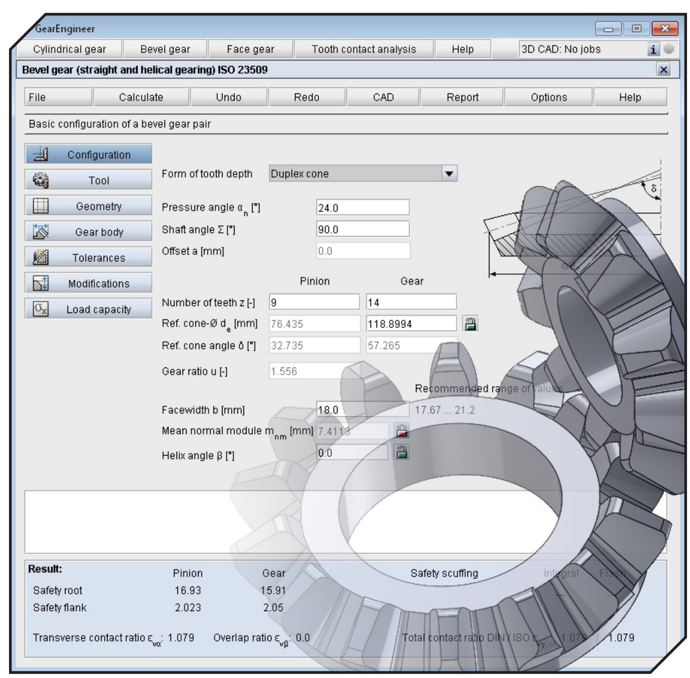
German Machine Tools of America (GMTA) – Booth #3513
www.gmtamerica.com

GWJ Technology Offers GearEngineer Software for 5-Axis Milling

GearEngineer is a special gear software that calculates the exact and real 3D tooth form geometries of cylindrical and bevel gears. The 3D tooth forms are generated using mathematical simulations of the manufacturing process. Micro geometries, i.e. profile and flank modifications, are also taken into account when generating the 3D data. This makes GearEngineer the ideal starting point for 5-axis milling of gears.

With the new version, the GearEngineer is now 64bit and adapted for WIN 10. At the same time, the internal CAD core has been updated and, in addition to the surface and curve output, provides even more stable 3D solid models for special functionalities such as the circumferential chamfer for cylindrical gears. The definition of the tool basic rack tooth profile for hobs has been supplemented by the new tip form "Full radius" in addition to the tip form "Radius with straight line". This means that cylindrical gears with a full root fillet can be calculated and manufactured.

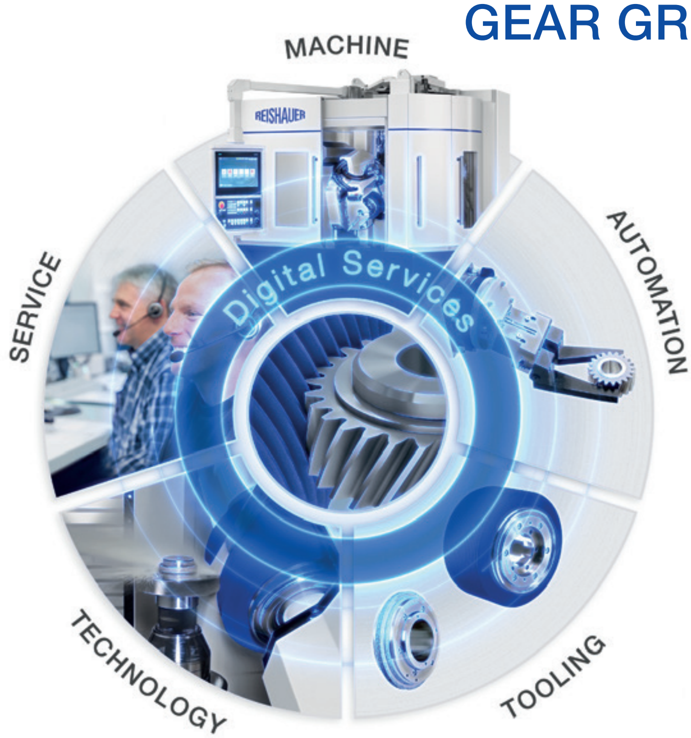
For cylindrical gears, the VDI 2736 standard for plastic gears was added to the load capacity methods according to DIN 3990, ISO 6336 and ANSI/AGMA 2001. In addition, plastics have also been included in the material database. Another new feature is the possibility to calculate with a "wrong" center distance for cylindrical gear pairs. A corresponding function has been



integrated for this purpose when designing the profile shift coefficients.

Furthermore, the module for straight and helical bevel gears has been extended by profile modifications in addition to the already existing flank modifications. Thus, profile crowning and tip relief as well as pressure angle modifications are now


REISHAUER
RZ x60 4.0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available for each flank.

The new "duplex" bevel shape is now supported, which results in a constant tooth root along the facewidth. This enhancement, together with the profile modifications, was added in response to user requests from the differential bevel gear forging sector.

In addition to the output options of CAD data in STEP and IGES format, so-called nominal measurement data, are also possible. An updated version of the Klingelnberg´s KIMoS software format has been integrated here, which allows the measurement of the flank topography on corresponding gear measuring centers or 3D coordinate measuring machines.

GWJ Technology – Booth #2810
www.gwj.de

Hainbuch Presents Maxxos T211

A mandrel with hexagonal pyramid shape instead of a round taper, designed with stringent manufacturing requirements and process reliability in mind. Hainbuch has acted in response to demand from specific areas that has been growing year by year. Users are requesting mandrels that deliver higher performance as well as process reliability. The result is called Maxxos. The segmented clamping bushing with hexagon inside shape fits perfectly onto the clamping pyramid and enables maximum cutting performance. The lubrication, combined with its tightness ensures a very constant production flow and as a result, achieves maximum reliability. Customers that value process reliability and maximum torque transmission will be delighted with the Maxxos T211.

The best for heavy I.D. clamping

Thanks to the hexagonal pyramid clamp, maximum torque transmission can be achieved. Up to 155 percent more transmissible torque and up to 57 percent higher bending stiffness compared to the classic Mando T211 mandrel. This makes it possible to achieve higher process parameters and consequently improve the yield of finished parts. Greater process reliability is facilitated by the spacious layout between the clamping bushing and the clamping pyramid. Even during the clamping process, this design prevents virtually any dirt getting onto the surfaces.

This significantly cuts down the frequency of maintenance times for cleaning and lubrication. Overall, the mandrel has a clamping diameter range of 18 to 100 mm. The clamping areas of each size are designed to overlap. This has the advantage that users can choose from up to three mandrel sizes depending on the clamping diameter. The larger the mandrel is, the greater its stability and rigidity. Smaller mandrels may be able to handle more of the customers smaller workpieces. The aligned, segmented clamping bushings have a minimum concentricity of 0.01 mm and can even be supplied in a high precision version.

Advantages include I.D. clamping mandrel for clamping diameters of 18 to 100 mm, ideal for stringent manufacturing demands and process reliability, unique rigidity due to spacious layout of the clamping segments, high transmissible torque and holding forces, contamination resistant due to hexagonal pyramid shape, and concentricity < 0.01 mm also available in high precision version.

Hainbuch America – Booth #3425
www.hainbuch.com

Helios Features Latest Hobbing, Shaping, Skiving and Grinding Technologies

In the Helios show booth, manufacturers will see a Hera 90 CNC gear hobbing and thread (worm) milling machine with unified gantry automation. This machine offers a single platform for automatically hobbing and milling parts up to approximately 3.5" outside diameter. With its 6,000 rpm cutter spindle, the machine productively handles small parts with small hobs by maximizing surface speeds. This high-speed spindle also enables productive milling of worms. Moreover, this machine will demonstrate its versatile, easy-to-set-up automation system to prove its place as the industry-leading workhorse at an unbeatable price for fine-pitch gear manufacturing.

Also in the Hera series of hobbing machines, show attendees will learn about the model 350, which empowers manufacturers as a robust vertical hobbing platform for parts up to approximately 15" outside diameter. As with other Hera hobbers, the 350 is surprisingly affordable and offers several options for an optimized solution, such as 2- or 4-station ring loaders, re-hobbing abilities, automation systems, and more. Similarly, Helios offers the Hera models 500 and 750 for parts up to approximately 30" outside diameter. Additionally, manufacturers of fine- and ultra-fine-pitch gears will want to learn about the Hera 30, which features dual direct-drive work spindles, and a 10,000 rpm hob spindle for productive hobbing of parts up to approximately 1.6" outside diameter.

For productive manufacturing of internal gears, Helios will feature the Neo Power Skiving ("NEOPS") line. This series of machines, which includes the models 100, 200, and 400, produces internal or external gears for parts up to approximately 16.5" outside diameter. Compared to traditional shaping, a NEOPS can produce precision gears in a fraction of the time.

"Show attendees will really want to stop by and learn about the Neo power skiving machine, which offers this cutting-edge technology at a fraction of the price compared to competitors in the market," said David Harroun, Helios vice-president.

Helios will also feature the 2021 CNC upgrades to its line of Tecnomacchine ("TM") gear deburring machines. The TM series now offers manufacturers complete CNC programming of the chamfer-deburring process. This includes tool position (radial, axial, tangential, and inclination), tool pressure, tool rotation speed, tool rotation direction, workpiece rotation direction, and workpiece rotation speed. This allows manufacturers to store a complete application to later be recalled by the CNC with just a few software steps. Consequently, changeover time reduces to a few minutes rather than the traditional 30-45 minutes. Moreover, it significantly lowers the bar for personnel training, altogether making the machine investment more flexible and productive for high-mix gear manufacturing.

Helios also offers manufacturers cutting and abrasive tools, including hobs, milling cutters, shaper cutters, continuous generating grinding wheels, form (single-profile) grinding wheels, bevel gear grinding cups, diamond dressing gears, and more. Manufacturers will want to establish their communication channel with Helios engineers at the show to empower their manufacturing teams with valuable guidance on tool specifications and machining parameters. These in-person connections will pay dividends well into the future.

Manufacturers who attend the Motion + Power Technology Expo will discover the latest solutions for hobbing, deburring, inspection, and grinding by seeing demonstrated CNC equipment and a variety of cutting and abrasive tools at the Helios Gear Products booth. Show attendees can ask questions and learn from Helios experts on-the-spot while viewing machines and tools that enable globally competitive production of gears.

Helios Gear Products – Booth #3521
Heliosgearproducts.com

KAPP NILES

KAPP NILES will be displaying the latest technology in gear finishing and metrology solutions at this year's Motion Power Technology Show. At Booth #3303, gear manufacturing professionals will be able to see the proven ZE 400 gear profile grinding machine - a versatile, highly flexible solution with unparalleled KAPP NILES quality. Precision grinding requires even more precise measuring where the newly launched X series

analytical inspection machines from KAPP NILES Metrology are necessitated. The KNM 2X and KNM 5X will be on display featuring granite measuring columns, air bearings, and linear motors. The Penta Gear Metrology division will showcase new DFT and DOB gauging to support in process and final inspection requirements.

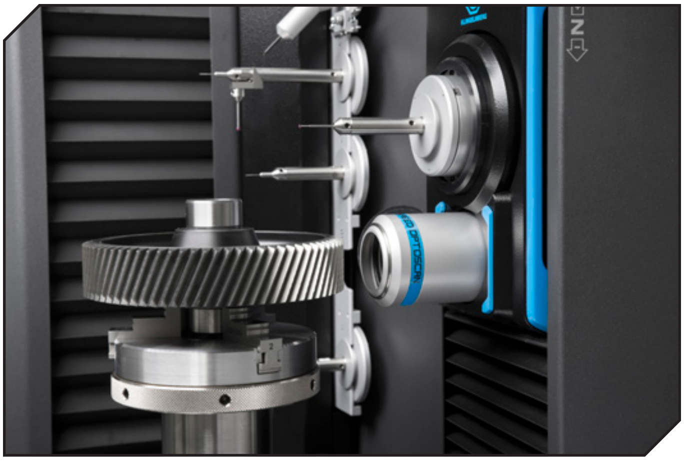
KAPP NILES – Booth #3303
www.kapp-niles.com

Klingelnberg Looks at Optical Measuring Technology and Bevel Gear Grinding

Reducing measurement times in series measurement thanks to hybrid solution

Klingelnberg precision measuring centers can be optionally equipped or retrofitted with an optical solution. Klingelnberg has worked very intensively on the entire signal chain of optical measuring technology and, together with several development partners, has developed a measuring system specially tailored to the requirements of gear measurement.

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

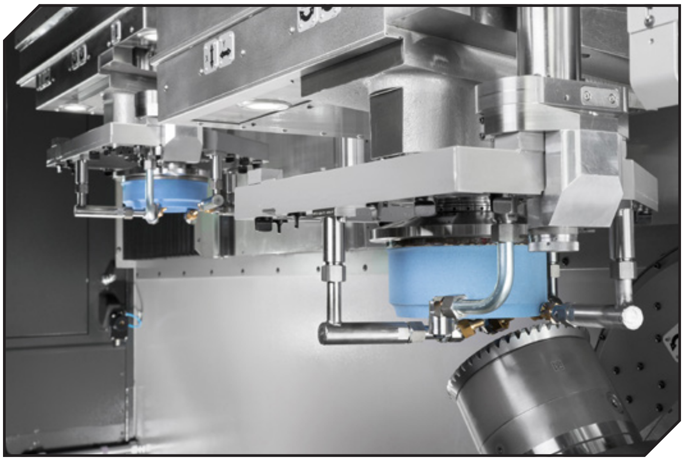


continuous, uninterrupted rotation of the component, the measurement time advantage increases with large numbers of teeth to up to 80 percent. It is not necessary to scan a large area of the gear with multiple revolutions.

This optical pitch measurement is combined with the tactile measurement of Precision Measuring Centers 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.

G 35 – Optimal and maximum productivity in the aviation industry

Just as innovative and inspiring is another innovation from Klingelnberg: with the Oerlikon Bevel Gear Grinding Machine G 35, the gearing specialist has implemented a new machine design for the 5-cut method. As a result, the manufacture of aviation gearing as regards efficiency is really taking off. To achieve this, the system provider has combined proven technology with new ideas. Background: bevel gears manufactured using the 5-cut method with a fixed setting are used in the avia-



tion industry. This entails the consecutive machining of convex and concave pinion flanks, with different tools and different machine settings. Due to complex certification procedures for aerospace applications, changing to another gearing is not an option. However, the newly developed Oerlikon Bevel Gear Grinding Machine G 35 makes the production of aerospace gearings much more efficient thanks to its technology: with its two vertically arranged grinding spindles, it is specially tailored to these requirements. In contrast to older dual-spindle concepts with fixed grinding spindles, the G 35 is equipped with two grinding heads that are positionable independently of each other, thus enabling maximum flexibility. The high rigidity and thermal stability ensure optimum machining results and, thanks to the advanced vertical concept, grinding sludge deposits in the working chamber can be avoided. Its name, "Clean Cabin", is thereby justified. The machine's operating concept is based on the forward-looking KOP-G software interface, which is operated intuitively via a high-resolution touch screen. Function keys on the control panel thus provide direct access to frequently used setup functions.

Klingelnberg GmbH – Booth #3629
www.klingelnberg.com

Norton | Saint-Gobain Abrasives Focus on Grinding Efficiency

Saint-Gobain Abrasives has announced it will be featuring new Norton Quantum Prime Grinding Wheels. The new wheels have new, proprietary nano-crystalline ceramic grain which offers unprecedented productivity gains across a wide range of applications. The new Quantum Prime grain delivers exceptionally high grinding efficiency and part quality, as well as significantly longer wheel life than traditional ceramic grains.

"We are excited to offer our customers with a superior grinding solution which is producing substantial productivity increases," said Rama Vedantham, director of product management, bonded and superabrasives, Norton | Saint-Gobain Abrasives "In an Outer Diameter (OD) Bearing Grinding application, the Quantum Prime Wheel resulted in 150% more parts per dress than a previous generation ceramic wheel, and also resulted in 300% faster rough/ finish infeed for a plunge face grinding application compared with a competitive ceramic OD wheel."

Norton Quantum Prime Wheels have several important advantages including a new micro-fracturing grain that has unparalleled sharpness and cutting efficiency which reduces power draw and cycle times, while increasing material removal rates. The unique grain is free cutting, which combined with advanced bond technologies such as Norton Vitrium3, allows Quantum Prime to wear more consistently, improving part quality, geometry and finish even at high material removal rates. Also, Quantum Prime has a more friable self-sharpening grain technology so grinding wheels stay sharper longer, reducing dress requirements and drastically improving wheel life.

Applications for new Norton Quantum Prime are diverse including OD, Centerless, Internal Diameter (ID), Gear, Toolroom, Disc, Surface, Flute and Creepfeed Grinding and Mounted Wheels. Also, newly introduced Norton IDeal-Prime ID Wheels for precision applications feature Quantum Prime grain embedded in an optimized matrix of Norton Vitrium3 bond. The combination of the micro-fracture properties of the new ceramic grain and the retention capability of the bond, ensures long wheel life, excellent grinding efficiency and consistent part quality which results in substantial cost savings.

Key industries for Norton Quantum Prime include Automotive, Aerospace, Energy, Primary Steel, Gear, Bearing, Cutting Tools, and Metalworking/ Engineering. Quantum Prime Grinding Wheels are made-to-order to meet customer requirements. The grain blends are available in all standard grain combinations, and bonds are organic or Vitrium3 vitrified.

Norton | Saint-Gobain Abrasives – Booth #2307
www.nortonabrasives.com/en-us/newsroom/news/revolutionary-new-norton-quantum-prime-grain

Reishauer Offers a Variety of Advancements to Gear Generation

Generating Skiving

Every automatic transmission features several planetary gear sets with internal gearing that could be hard-finished if an adequate process were available. For this reason, Reishauer designed a very stiff generating skiving machine and concurrently developed cutting tools that feature superhard material for their cutting edges. This combination enables the generating skiving process to be economical and successful for the hard-finishing of internal gear components.

Reishauer Software Platform (RSP)

The scarcity of skilled operators demanded a rethinking of the machine's operating design. Hence, the key design criteria of the new RZControl was its user-friendliness. Easily understandable icons guide the user through the set-up process. These visual aids apply both to generating skiving and generating grinding. The Reishauer Software Platform RSP simplifies operation and process design considerably, reduces potential errors, and increases efficiency with modern database technologies encompassing tooling, workpieces, and processes. During data input, the control automatically generates machining proposals based on sophisticated calculation models.

RZx60 4.0

Over 1000 RZx60 machines in the market have proven themselves as a successful concept. Building on this experience, the machine concept has been revised and adapted to the requirements of Industry 4.0 applications. The 4.0 series still features all the proven technologies including the double spindle feature. However, this has been complemented with the latest control technology and modern interfaces for Industry 4.0 applications.

ARGUS Monitoring System

The ARGUS process monitoring system controls the dressing and grinding intensities by applying real-time data processing and tested algorithms. "Grinding and dressing intensities" are process-based force models to calibrate the grinding and dressing forces to interpret and control the process. The force models encompass the characteristics of the cutting zone, the cutting kinematics over the changing grinding wheel diameter, the variation of the wheel's RPM, and the variable lever ratios depending on the wheel's position to the axial location of the bearing.

Reishauer – Booth #2526
www.reishauer.com

Star SU Offers Full Line of Machine and Cutting Tool Solutions

At the Motion + Power Technology Expo, STAR SU will be showcasing its full offering of machine tool and cutting tool solutions for producing gears and other fluid power components. Star SU's comprehensive line of products and services enables the company to customize each cutting and tool grinding operation from cutting speeds and feeds to automation and tool coatings. The company will be presenting interactive demonstrations and displays of the following:

Machine Tools for a variety of processes including:

Vertical Gear Hobbing for workpieces from 80mm to 2300mm diameter; FFG Werke GmbH Modul H80 – H2300 machines

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Education Highlight: Materials Selection and Heat Treatment of Gears

New developments in gear technology, particularly from the materials and heat treatment perspectives, have improved gear performance. This course, development jointly by the ASM Heat Treating Society and AGMA, will provide an overview of materials selection and heat treatment of gears. The course takes place Thursday September 16 from 8:00 am – 5:00 pm.

Don't Miss These Events:

"Opportunities in the Electric Vehicle World," joint keynote address with IMAT takes place Tuesday, September 14th from 2:30 to 4:00 pm.

Keynote Speaker: Kathy L. Hayrynen, Ph.D., FASM, Applied Process Inc., takes place Wednesday, September 15th, from 8:00 – 8:45 am.

Heat Treat Session Chair Briefing takes place Thursday, September 16th, from 7:00 – 8:00 am.

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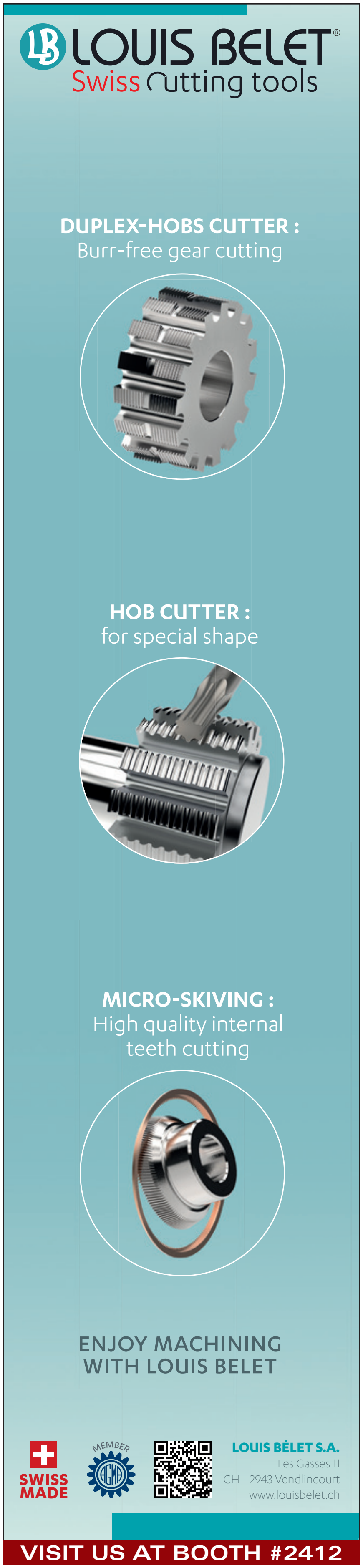

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Hard Finishing of Cylindrical Gears

Power Skiving with Integrated Cutter Resharpening

Edgar Weppelmann, Gleason-Pfauter

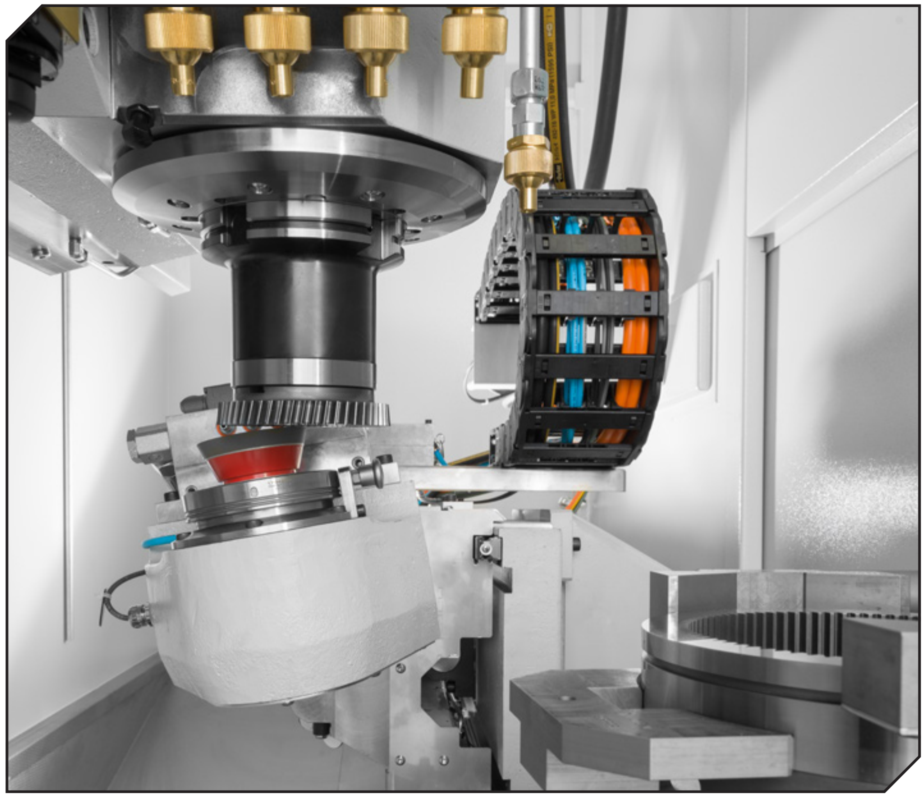
For the past decade Gleason has been building Power Skiving machines at its Gleason-Pfauter facilities in Ludwigsburg, Germany. As the many benefits of this technology have become widely recognized, Gleason Power Skiving machines have been at the forefront, and the series has grown to include models for internal and external cutting and finishing of gears as large as 800 mm in workpiece diameter. Now, with the demands for gear quality reaching new levels and hard finishing becoming increasingly common, Gleason is again pushing the Power Skiving envelope to meet these requirements.

Hard Finishing Requires a New Approach

Manufacturing carburized and hardened gears with Power Skiving has always taken the traditional approach: after a cutter has reached its wear or quality limit, the operator changes the cutter, adjusts the cutter data, cuts the next workpiece, transfers it to the inspection room, waits for the first part inspection and, if necessary, corrects the process by adjusting the machine parameters before proceeding with serial production.

This traditional approach to cutter refurbishing, which usually takes anywhere from 45 to 60 minutes, is time consuming and laborious, but vital to ensure that the cutting tools produce high quality parts throughout their useful life. Of critical importance is the amount of edge roundness, which is difficult to produce and control, and has a great impact on the hard finishing process requiring precise removal of very thin chips.

The non-productive time needed for cutter refurbishment is particularly evident in Power Skiving, a very fast process that requires frequent cutter changes and first part cycles. The required procedure increases tool cost, inventory and, most significantly, non-productive time and resources needed for cutter management, handling and



As compared to the typical cutter resharpening process, the new on-board unit is remarkably fast and simple. The machine's axes position the cutter to a grinding wheel. The integrated cutter sharpening unit then executes the necessary grinding strokes while the cutter performs the infeed and the indexing from tooth to tooth, all performed automatically and based on the new cutter geometry that exists after a certain number of gears has been cut (Courtesy Gleason).

sending used cutters to refurbishing (resharpening and recoating) and returning cutters into production.

Revolutionary Concept: On-Board Cutter Sharpening for Hard Finishing

By adding the capability of resharpening carbide cutters directly on the Power Skiving machine, Gleason has taken a revolutionary step forward in raising the economy and quality for hard finishing carburized and hardened gears. This new development enhances the benefits of Power Skiving in virtually every significant area.

Today, a fully-integrated, on-board sharpening unit is available for the vertical series of Gleason Power Skiving Machines up to 600 mm in diameter. The cutter face can now be resharpened fully automatically in the machine after it has cut a certain number of gears, without any operator involvement. The cutter geometry is continuously adjusted automatically to compensate for stock removal, and serial production is continued without interruption. Recoating the cutting face is not required because the original coating on the flanks sufficiently protects the cutter teeth.

The frequency of cutter changes is greatly reduced: a single cutter can stay on the machine for several days or even weeks before it is completely used up. The time used in the past by the operator for a cutter change is instead used for a certain number of automatic cutter grinding cycles with a reduced stock removal per grinding cycle to keep the cutter constantly sharp for a high and constant gear quality.

Additional non-productive time is saved since first-part inspection and machine corrections after cutter change are no longer necessary because the same cutter stays in production, also minimizing cost and required capacity in the inspection room.

Cutter management and handling logistics are greatly reduced to just ordering new cutters in time to ensure a continuous production. The required cutter inventory is much less as well, because there is no longer the need to circulate cutters through an external refurbishing cycle.

Overall tool costs are very much reduced because the high cost for the frequent external refurbishing cycles of the carbide cutters is eliminated—which is typically the most significant factor in tool cost per gear.

Applications

Power Skiving of carburized and hardened gears with integrated cutter resharpening is ideally applicable for internal ring gears and for external cluster gears where the small cross axis angle of the cutter allows for cutting the smaller gear without collision with the larger gear. A high gear quality can easily be achieved with this method by grinding the cutter more frequently but faster with less stock removal.

Integrated cutter resharpening can be applied to spur and helical step sharpened carbide cutters. The resharpening process employs inexpensive standard grinding wheel technology with no need for dressing grinding wheels, as they remain sharp due to a self-sharpening effect from the grinding process.

The danger of damaging expensive carbide cutters by manual handling is greatly reduced as the cutters stay much longer in the process without being touched. The productivity of the hard skiving process is not jeopardized by having no coating on the cutter face because the required sharpness of the cutting edge is now being guaranteed by the chosen resharpening frequency.

Entering New Frontiers

With the integration of the cutter sharpening process into the machine Power Skiving becomes very desirable for the hard finishing of higher quality gears in electro-mobility and robotic applications. Gleason Power Skiving machines ideally support these requirements for quieter and more precise gears, with lower direct and indirect tool cost.

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Dr.-Ing. Edgar Weppelmann is manager application engineering at Gleason-Pfauter Maschinenfabrik GmbH.

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The Digital Maturity Index

A categorization of digital activities and a perspective from Klingelnberg

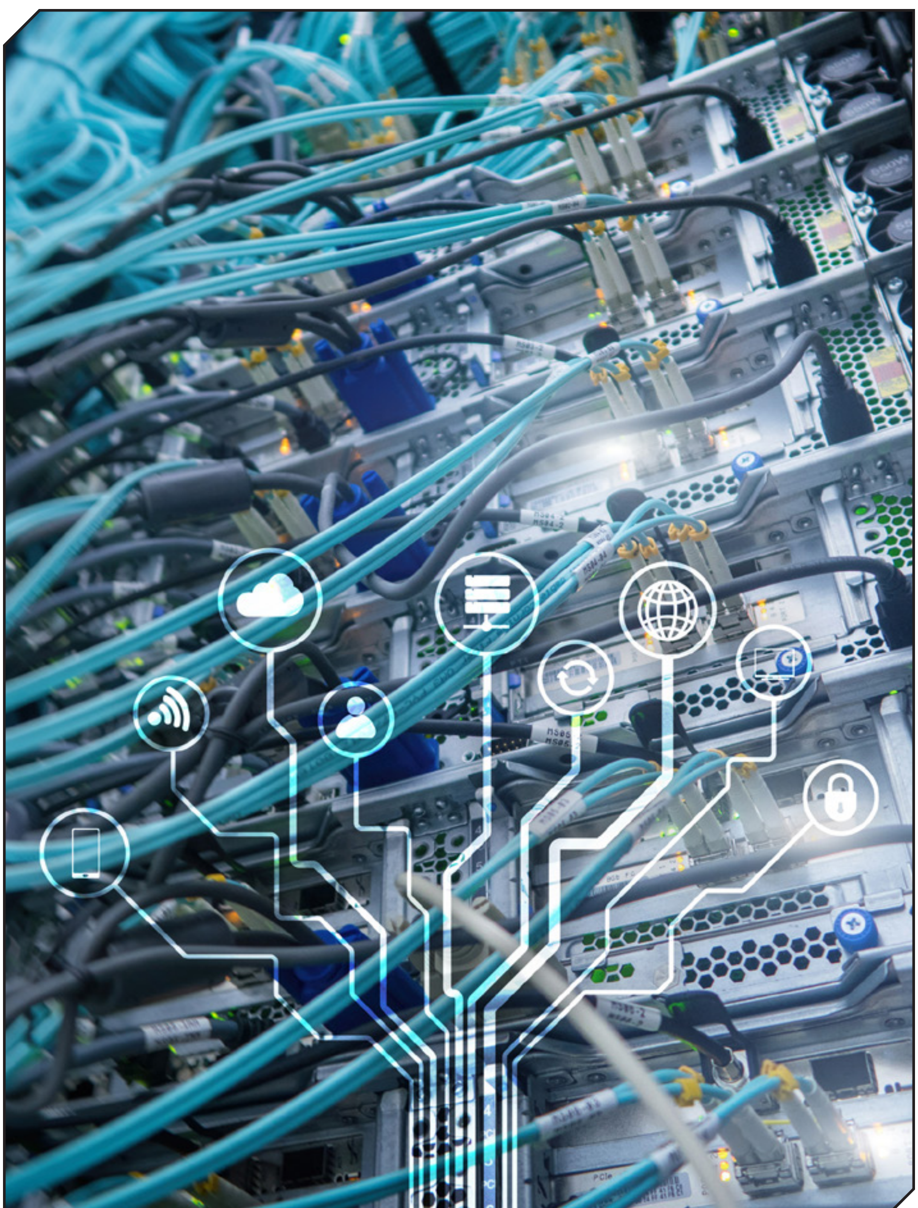
Daniel Meuris, Klingelnberg

Introduction

The industrial internet of things (IIoT) as a promising approach towards higher efficiency is well known and extremely fashionable. Klingelnberg provides a broad portfolio of services and software solutions to address different topics of gear production digitally (from sensors to the cloud).

The benefit for customers lies in bundling gear and machine knowledge into sophisticated software solutions. This is an important component in order to achieve great production results and a reason for a partnership with Klingelnberg.

However, the development of tangible software solutions in the context of IIoT that deliver concrete value beside a core machine business has just begun. New IT technologies emerge regularly and widen the corridor for feasible solutions. In order to create promising product roadmaps for digital solutions the German science association acatech released a digital maturity index.



In the following, this maturity index is used to classify the cornerstones of Klingelnberg's digital solutions in its current state. Furthermore, a projection of these solutions to the future of the maturity index is outlined. One should see that only an intensive cooperation between machine providers and producers can lead to a mature digital shop floor for gear manufacturing.

The digital maturity index

Figure 1 depicts the digital maturity index adapted by Klingelnberg. Of course, there is a perspective on single machine systems. At the very least, they need a computer which is common for all CNC machines. Connectivity is also a basis requirement for machines when talking about digitization. The final goal is to make decisions based on predictive analysis and have automatically adaptive production systems or processes. But before you can go there, it is necessary to create a "visibility of information" by collection and aggregating these processes. Many solutions are available here in the context of MES, but solutions are missing that take the specialties of gear production into account. That is why Klingelnberg is very active in this field of information visibility and transparency for gear production.

Computerization and Connectivity

There is no doubt that modern CNC based gear production machines do not lack computerization and connectivity technologies. A modern Höfler Generating Grinding Machine Speed Viper by Klingelnberg holds an industry PC with a 19" touch panel and the operator's fingertips can access every function of the machine. Also, advanced connectivity scenarios do not pose a challenge since Klingelnberg machines commonly

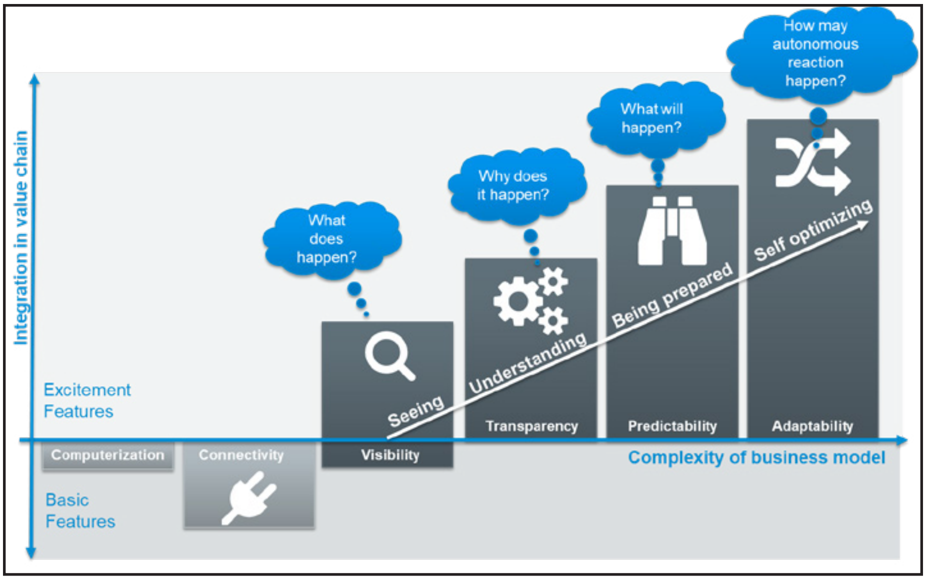


Figure 1 Klingelnberg's interpretation of the digital maturity index by acatech.

interplay within a network of different IT systems (the Closed Loop).

Gear design, compensations, measurement results and machine parameters are shared across the network and can be manipulated via web applications from everywhere. The newest member of Klingelnberg's product family addressing connectivity concerns is the **OPC UA umati** interface. OPC UA represents a modern standard for data exchange. This standard is characterized above all by the fact that not only the individual data but entire information models (including the semantic description of data) are transported. Umati is a special extension of the OPC UA server and describes a universal interface to machine tools and systems.

The detailed contents are regulated in the VDMA specification **VDMA 40501-1 (OPC UA for Machine Tools – Part 1: Machine Monitoring and Overview of Processing Orders)**. Currently, the following status data of the machine is standardized with an update rate of around one second: Uniform identification of the machine, operating status of the machine, information about production order, program progress and finally error messages and warnings. With this software customers may easily integrate Klingelnberg machines into existing MES systems by using generic interfaces.

Information visibility and transparency

The next steps on the maturity index address the act of creating information visibility and transparent processes. The leading question here tries to solve what happens in the process and why it happens. A perfect example is the Smart Process Control solution for gear cutting machines. Here, a special software on the machine is transferring process information and machine tool utilization like spindle loads to a database. Deciders and process designers access this database with a web tool as shown in Figure 2.

This dashboards gives a complete overview on produced parts, process parameters and machine behavior and therefore it can be used perfectly to identify causalities between single process changes and their consequences on tool life, machine utilization or quality problems. There is a deep integration of machine signals and process settings which do not need any further post processing. Experts can directly jump in after a quick installation.

Another example for increasing visibility and transparency of production processes is the SmartTooling system. All production equipment like cutter heads and fixtures get a data matrix code and the machine gets equipped with a scanner. Yesterday, operators typed in geometrical information of fixtures manually. But today, with SmartTooling, it is just a scan and data is transferred from a central database to the machine. Utilization data is transferred vice versa. Consequently, manual information input is not required anymore because all the information about the usage of equipment is stored and can be used to identify critical equipment that may be exceeding its usage limits.

Prediction and adaptability

The highest degree of maturity foresees solutions that allow to predict processes and make automatic adaptions to it, if required. Today, there are no real solutions which address the whole manufacturing process or at least crucial parts of it (like grinding for final quality). Of course, Klingelnberg is working on this topic in different customer projects but a real "out of the box" solution is not in sight. These projects are always very individual and depended on concrete process variations.

An exciting technology that is required for predictive maintenance or for a prediction of resulting part quality is edge computing. Here, an additional PC is integrated in the machine. This device can write up to 100 signals of the CNC during the machining process. With this amount of data and the correlation to data of end of line tests the future trend goes to big data analytics. Klingelnberg provides knowledge for data analytics and edge computing, but there is still a long way to go. The success of a roadmap to predictive analytics is the joint operation of customers and machine providers.

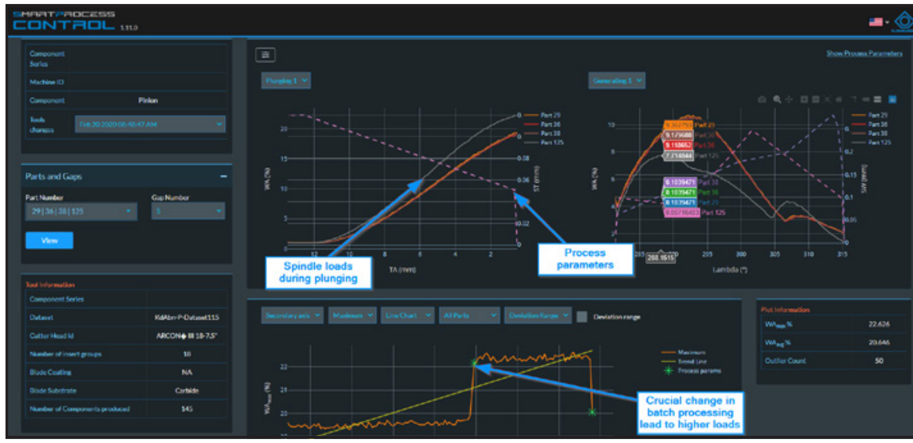


Figure 2 **Smart Process Control for information visibility and process transparency.**

Conclusion

The maturity index by acatech is a profound tool to align digital solutions along a roadmap. Here, a small categorization of current Klingelnberg solutions, according to different stages of this index, were done. The first steps of "computerization and connectivity" as well as "visibility and transparency" are covered well. Future activities occur in the "prediction and adaptivity" field where Klingelnberg is focusing its efforts.

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Daniel Meuris is responsible for the development of digital products at Klingelnberg. This includes controller software of the machine tools, calculation tools and Industry 4.0 solutions.

The development of tangible IIoT software solutions in the gear industry has just begun.

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Understanding and Controlling the Source of Gear Noise

Mark Malburg and Mike Zecchino

There is an irony in the automotive industry: as vehicles are becoming quieter, noise control is becoming more important. Electrification has reduced engine noise, which means other noise sources are now much more prominent. Specifically, one of the most talked about noise sources is gears.

Gear surfaces have always received attention from the friction and durability standpoints, and there has certainly been some level of attention paid to deviations in gear geometry. Much less attention, however, has been paid to waviness along a gear tooth. This "middle wavelength" texture—on the order of perhaps 2 or 3 undulations between the root and tip of a gear tooth—has been found to directly correlate to gear noise [Refs. 1-2].

Middle frequency waviness on gear teeth has been correlated to gear noise, similar to the way chatter in a bearing race has been shown to cause bearing noise. Surface waviness along a gear flank causes cyclic variations in tooth stresses and meshing. These cyclic variations can

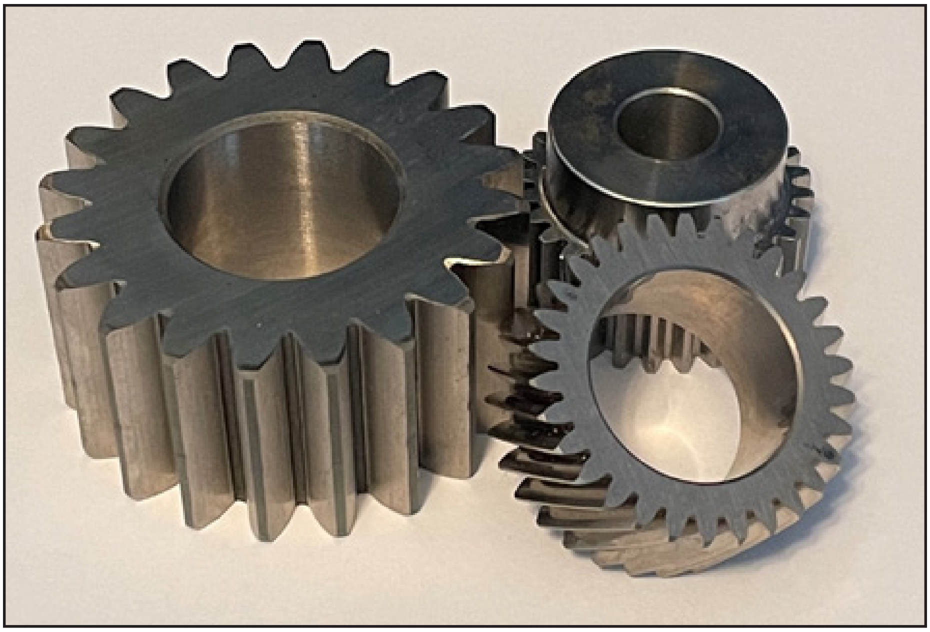

Figure 1 **Gear tooth noise can be a prominent source of noise, especially in cars, as engines have become quieter.**

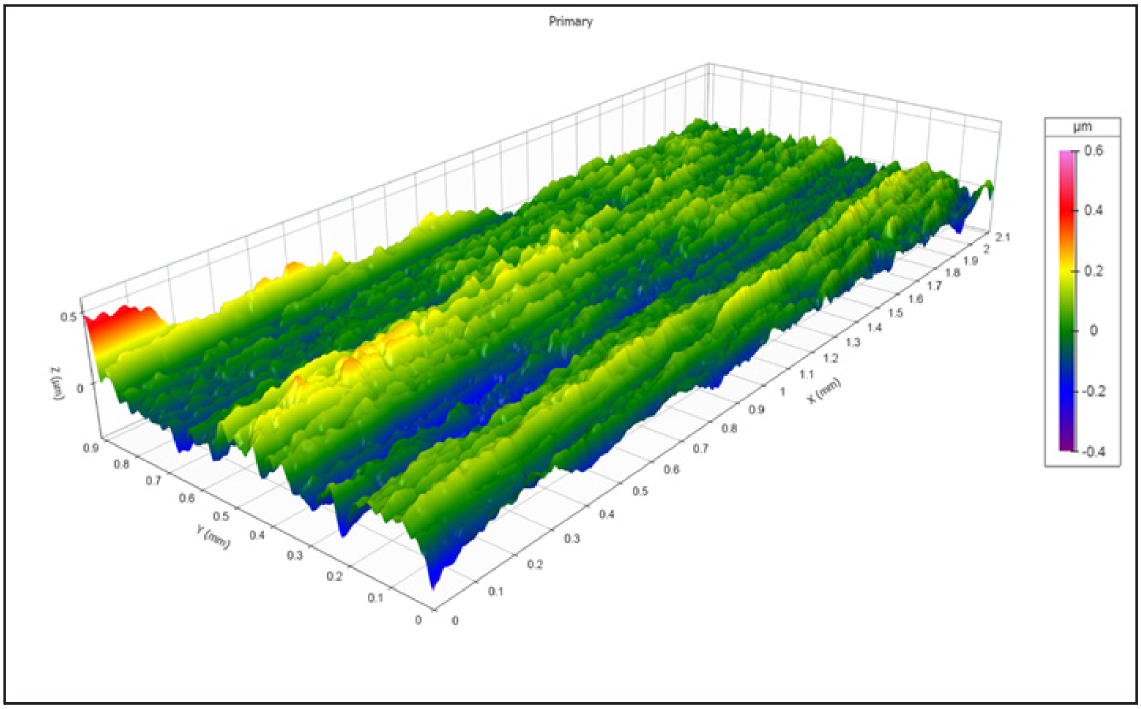

Figure 2 **An areal (3D) measurement of a gear tooth after removing the involute shape.**

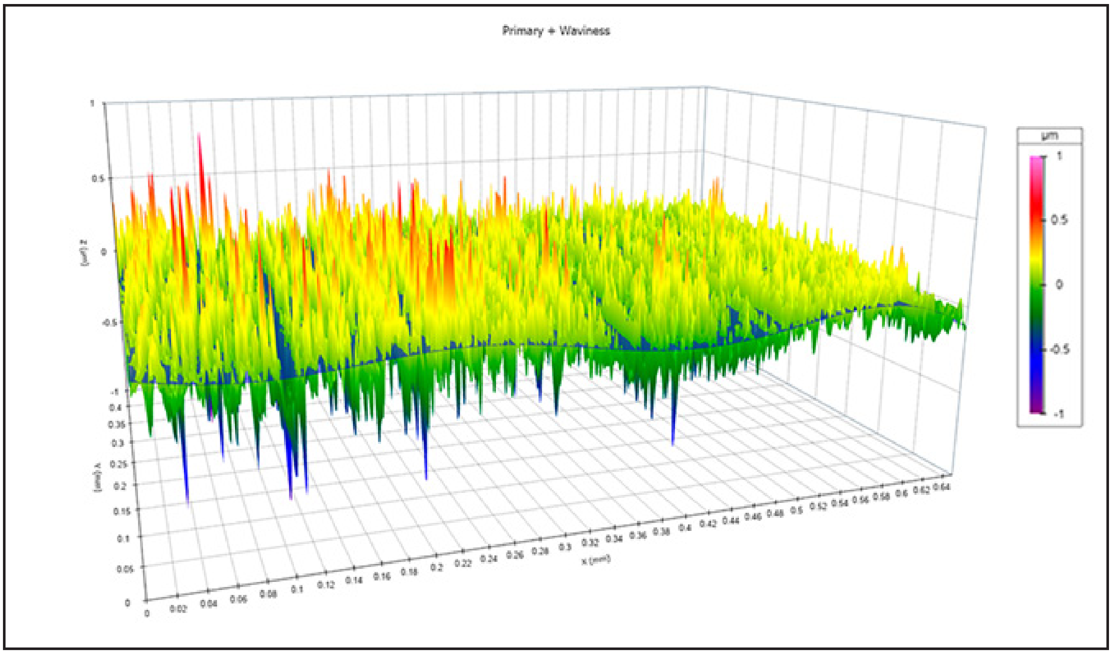

Figure 3 **Filtering can isolate the waviness (blue surface) from the overall surface texture.**

ultimately lead to vibrations and noise in the audible range [Ref. 3].

Unfortunately, these waviness features often go undetected as they are typically much smaller than the overall form tolerance limits for the gear profile. Nevertheless, this waviness can cause noise and therefore needs to be controlled—which is why this aspect of gear surface texture is getting a lot more attention.

Measuring Gear Texture

Gear tooth waviness can be measured using a 2-dimensional measurement system such as a stylus profiler. However, the configuration and range of a stylus often limits how much of the gear tooth can actually be measured. Larger shapes such as waviness can easily go undetected when the profile length is of a similar length scale as the space between waviness peaks.

To better understand gear waviness, many companies are turning to areal (3D) surface analysis. The resulting data can be far more impactful than a simple profile graph, providing a visual map of the surface features that may be causing noise (Fig. 2).

The ability to see and interact with texture helps connect texture to function. Nevertheless, to address the noise issue we ultimately need to produce an analysis method (geometry removal and filtering) and numerical values (parameters) that can be used to tolerance and control the waviness.

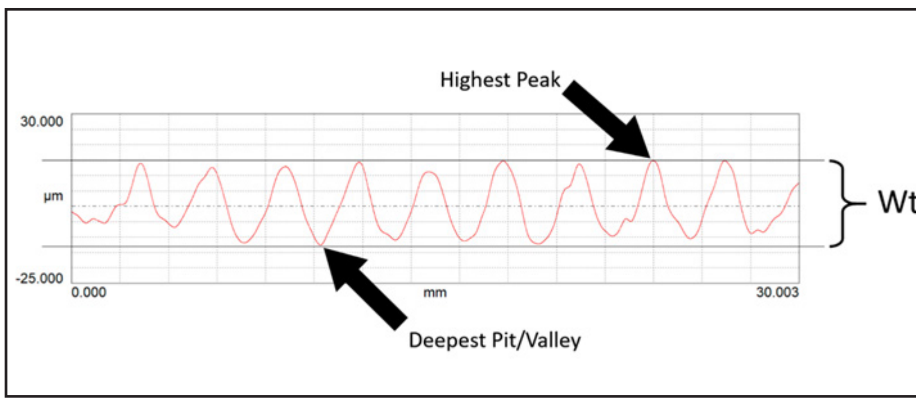

Figure 4 **The Wt parameter is based on the highest and lowest points in a 2-dimensional profile.**

Filtering for Waviness

To isolate the waviness "shape" in a 3-D dataset, we first remove the overall geometry, or form, of the gear tooth itself. Multiple options are available for removing the tooth geometry. A 4^{th} order polynomial fit is typically the best choice for this operation as it adapts to various positions along an involute. Once the geometry has been removed, we see the surface texture as shown in Figure 2.

Texture consists of multiple "wavelengths" of features, ranging from short-wavelength roughness through longer wavelength waviness. The process of filtering separates the waviness from roughness at a particular cutoff wavelength (Fig. 3). The filter type and cutoff both greatly affect the results and should be specified for a measurement. A 2^{nd} order Gaussian or spline filter type typically provides an accurate fit. The cutoff wavelength will depend on the size of the features of interest, which will vary with the size of the gear.

In Figure 3 the waviness (shown in blue) has been isolated and can now be analyzed separately from the remaining surface texture.

Typical Parameters Used to Describe Gear Waviness

Once the waviness profile/surface is established via filtering, we can then describe the height of the waviness with numbers. Waviness has traditionally been measured in 2-dimensional data, using the Wt (Waviness – total) parameter. Wt reports the largest peak-to-valley height for the waviness profile (Figure 4).

Similarly, in areal (3D) analysis the St parameter gives the total peak-to-valley height over a surface, as in Figure 5.

The challenge with Wt and St is that both parameters measure the extreme highest and lowest points in the dataset. Since gear tooth measurements extend from the root to the tip of the tooth, the extreme points are almost always at the ends/edges of the data where the tooth blends into the hub or rounds over at the tip (Fig. 6). These extreme heights tend to dwarf the mid-wavelength waviness at the center of the tooth, which is the actual noise source. Wt or St values, therefore, are reporting peaks and valleys that are not associated with gear noise.

Better Parameters to Control Gear Waviness

To get reliable numbers that describe this noise-causing waviness, we must exclude the points at the extreme ends/edges of the data and focus on the peaks and valleys that are fully "contained" within the tooth data. However, as we mentioned earlier, the end points are required in order to ensure that measurements occur in the same location each time.

To address the issue, the parameter Wtc was developed and appears in the *OmniSurf* software package (Digital Metrology Solutions). Wtc measures the total waviness for "contained" peaks and valleys in a profile (Fig. 7). Similarly, the 3-D parameter Stc measures the height of contained peaks and valleys for a surface (Fig. 8). Stc is available in the *OmniSurf3D* software package (Digital Metrology).

Wtc and Stc target the actual noise-causing features in a measured gear surface. These parameters also produce much more stable values since they ignore edge points. For example, if the highest peak is at the edge of a measurement and the measurement location is moved slightly, a different highest peak will be detected. However, the "contained" peaks and valleys are more likely to remain consistent.

Working with areal (3-D) data we can also analyze the Stc parameter in the particular direction that matters most for a given application (Fig. 9). For example, noise in a spur gear will be more sensitive to waviness in the root-to-tip axis. The Stc-x and Stc-y parameters enable analysis of all profiles in each direction, reporting the average contained peak-to-valley value for the respective profiles/surfaces.

The ability to distinguish waviness features and report the magnitude in each direction along the tooth can be very powerful for diagnosing functional issues like noise and for controlling process variables in manufacturing.

Summary

As measurement and analysis techniques have improved, it has become increasingly possible to measure the aspects of surface shape and texture that influence a part's function. In the case of gear noise, the traditional toolset has proven unreliable. However, the custom parameters, Wtc (2-D), and Stc/Stc-x/Stc-y (3-D) can directly track the gear tooth waviness features that can cause gear noise.

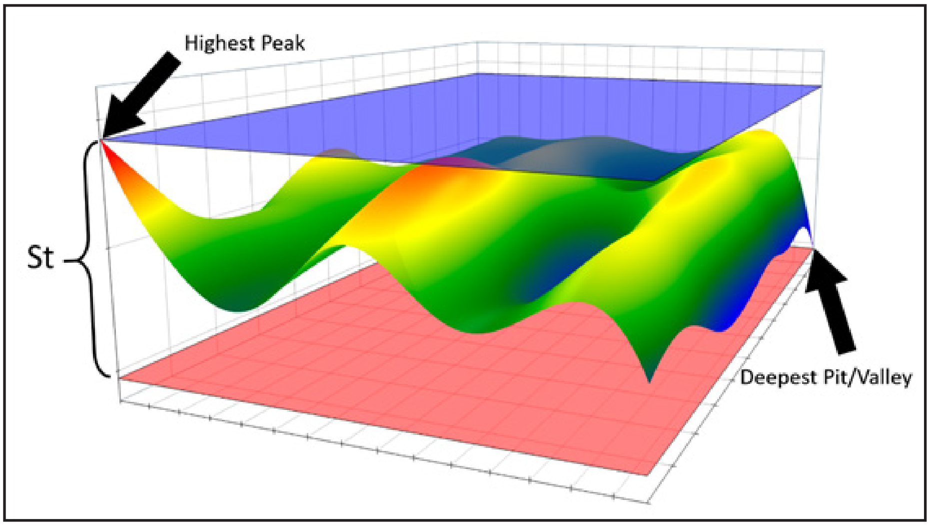

Figure 5 The St parameter is the 3-dimensional counterpart to Wt.

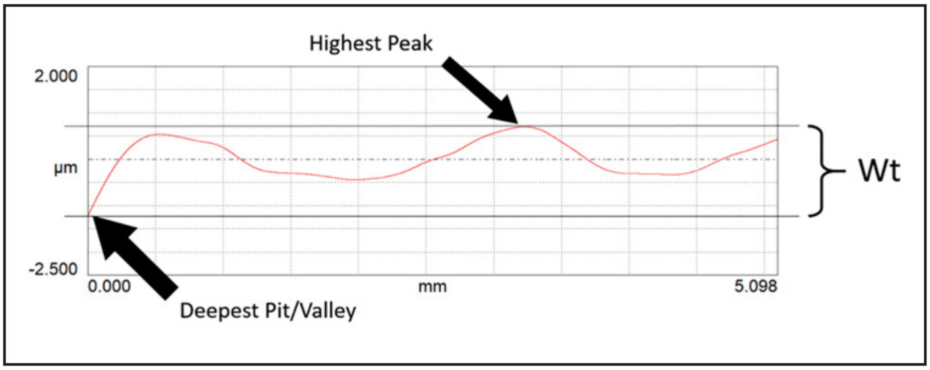

Figure 6 In a gear measurement the extreme points are almost always at the ends of the measurement—at the root and tip—eclipsing the waviness in the middle of the tooth which is typically responsible for gear noise.

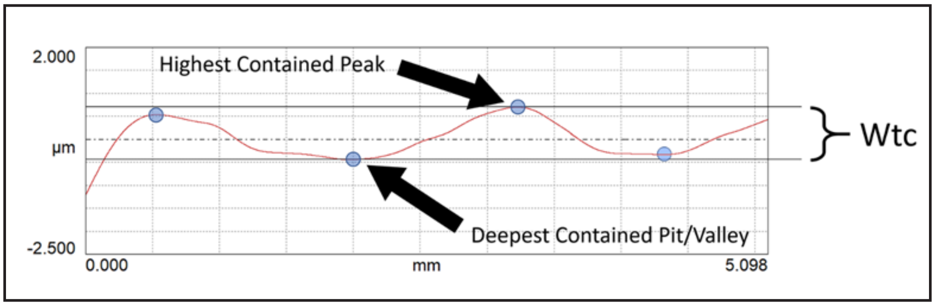

Figure 7 Wtc measures waviness in the middle of the tooth, where noise may occur.

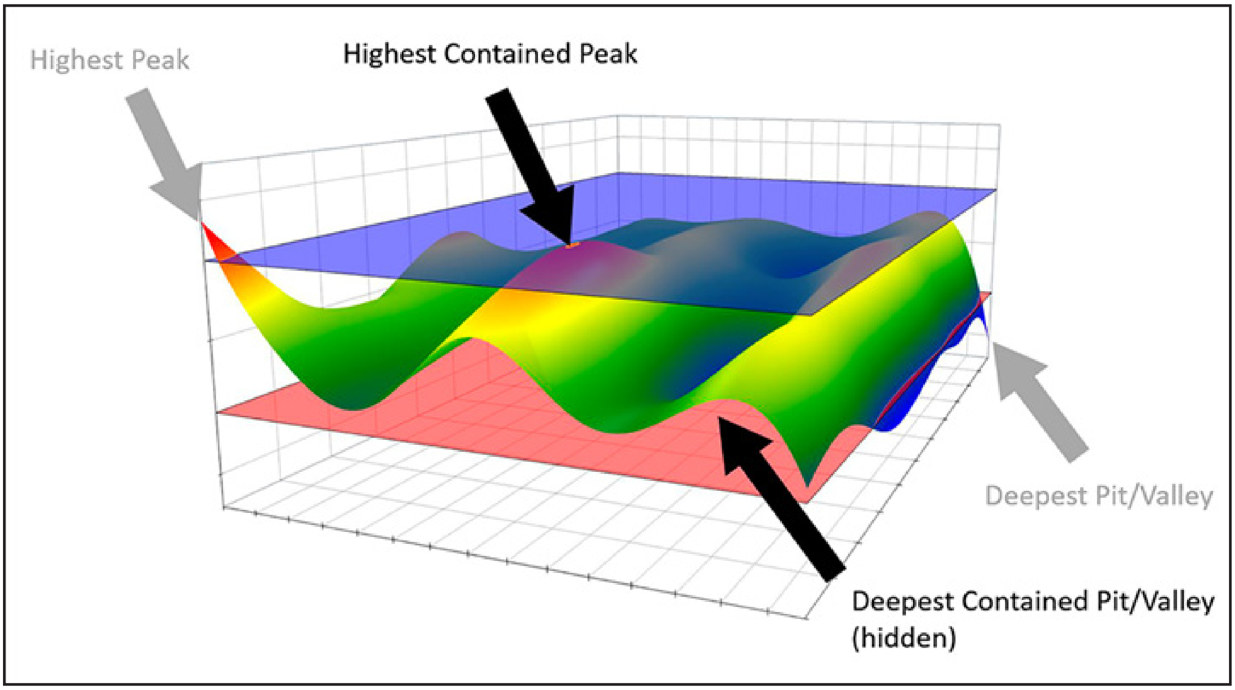

Figure 8 By excluding the edge peaks/valleys and focusing on contained pits/valleys, Stc correlates better to the gear tooth waviness that may lead to noise.

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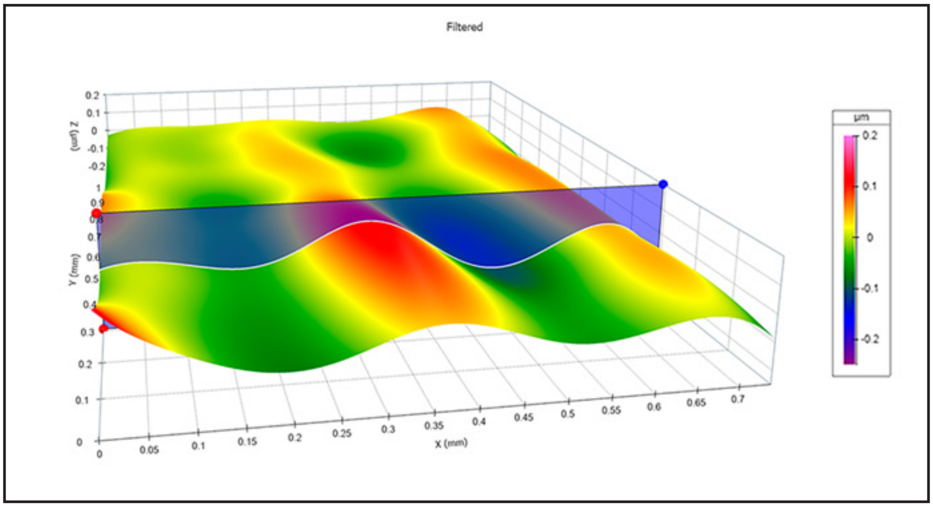

Figure 9 The Stc parameter can be analyzed in the particular direction that matters for a given application.

Dr. Mark Malburg is the president of Digital Metrology Solutions. With over 30 years in surface metrology, he is the chief architect of a range of standard and custom software for surface texture and shape analysis. Dr. Malburg has consulted in numerous industries ranging from optics to aerospace. He is a frequent participant in standards committees and has helped shape many of the standards that govern surface specification and control.

Mike Zecchino has been creating technical content and resources related to metrology and many other industries for over 20 years. His articles have appeared in dozens of publications, and his training materials and videos support numerous measurement instruments and technologies.

Psychoacoustic Flank Form Optimizations Higher Order Flank Form Optimizations and Motion Transmission Characteristic

Dr. Hermann J. Stadtfeld

Bevel and hypoid gears commonly have a parabolic motion error which is the result of circular crowning on the surface of the teeth in tooth profile and length direction. The crowning is required in order to allow for load affected deflections in the gearbox housing, the bearings and shafts and the gears themselves. Those deflections are a magnitude larger than in cylindrical gear transmissions which is related to the angular shaft orientation and the often cantilever style pinion support.

Bevel gear sets without crowning are conjugate, which means they transmit the rotation of a driving pinion precisely with the ratio given by the division of the number of gear teeth by the number of pinion teeth. Traditional flank form corrections in bevel and hypoid gears and today also in cylindrical gears use dominating second order modifications. A combination of circular length and profile crowning is shown in the Ease-Off in Figure 1. In bevel and hypoid gears, the crowning is partially applied to the pinion and partially to the gear. In cylindrical gears it is common practice to manufacture one of the two members without any modification and apply the entire crowning in the second member (Ref. 1).

The Ease-Off in Figure 1 is cut in path of contact direction with a plane, which traces the crowning along the path of contact. This path of contact crowning is shown in the midsection of Figure 1. By dividing the ordinate values in direction S by the relevant radius of the gear, the bottom graphic in Figure 1, which represents the motion error, can be produced.

The motion error graphic is only drawn from entrance to exit transfer point. Only this section is of interest for the following Fourier analysis because it is the area of transmission contact.

The parabolic motion error as shown on top in Figure 2 ($\Delta\varphi$ over time) is caused by the crowning and leads to

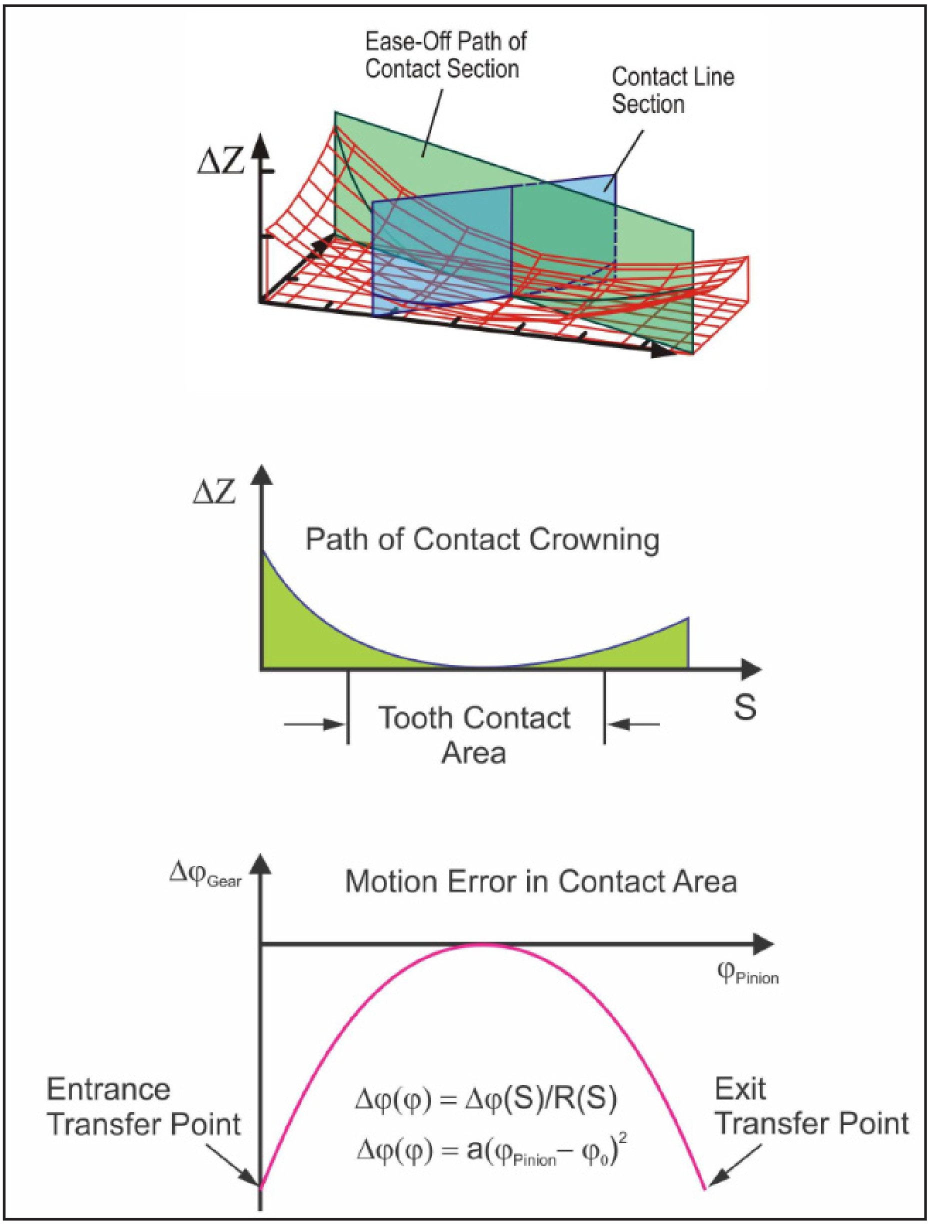

Figure 1 **Ease-Off with path of contact section, path of contact crowning and motion error.**

changes in angular velocity Δω as shown in the first derivative of the motion error in the middle graphic of Figure 2. At the moment of engagement of every new pair of teeth (during the rotation), the initial velocity level has to be re-established. The second derivative of the motion error at the bottom of Figure 2 shows the angular acceleration graph Δα. At the point of tooth engagement the graph shows a peak which is the result of the abrupt velocity step in the Δω graphic above. The acceleration peak is considered an impulse which is the major source of gear noise.

Significant reductions in transmission noise have been established with a double wave form shown in Figure 3 (UMC-Ultima). The development of the "Ultimate Motion Graph" in Figure 3 is targeted to noise reductions in ground bevel gear sets. Here for the first time, motion transmission graphs with non-parabolic shapes are proposed (Ref. 2). The overall transmission error will not be the result of a single pair of teeth (like the green graph in the center),but will be the result of the interaction of three consecutive tooth pairs. At the entrance point, the measured motion error follows the green solid line from 1st to 2nd transfer and then the red solid line from 2nd to 3rd. After that, the motion error follows the green solid graph from 3rd to 4th, then the blue solid graph from 4th to 5th, and finally from 5th to the exit point it follows the green solid line. The result is a graph with four unequally spaced waves which shows lower amplitudes of motion error, but also lower amplitudes in the FFT results. It should be noted that although a higher fifth harmonic FFT amplitude is expected compared to the parabolic graph, the FFT result of the Ultimate Motion Graph delivers a similar fourth order and a lower first order harmonic amplitude, but shows additional side bands between first and fourth harmonic amplitudes. Also, the Ultimate Motion Graph is not sinusoidal, but consists of parabolic elements that will cause certain residual amounts which are not captured and evaluated in the course of an FFT. This wave form was possible with non-linear kinematics of the bevel gear generating machine. The double wave leads to overlapping consecutive motion graphs. The motion graph in Figure 3 will produce five

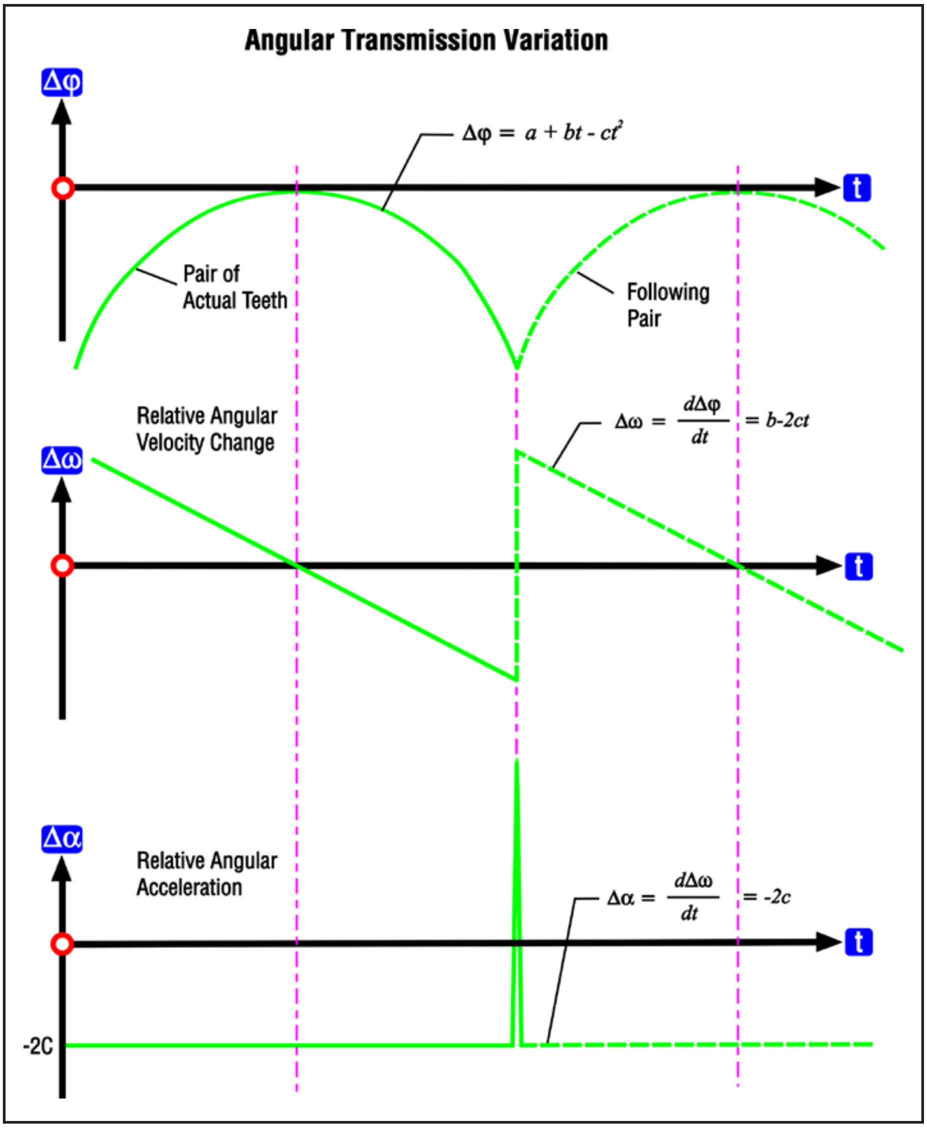

Figure 2 Parabolic motion graph and its first two derivatives.

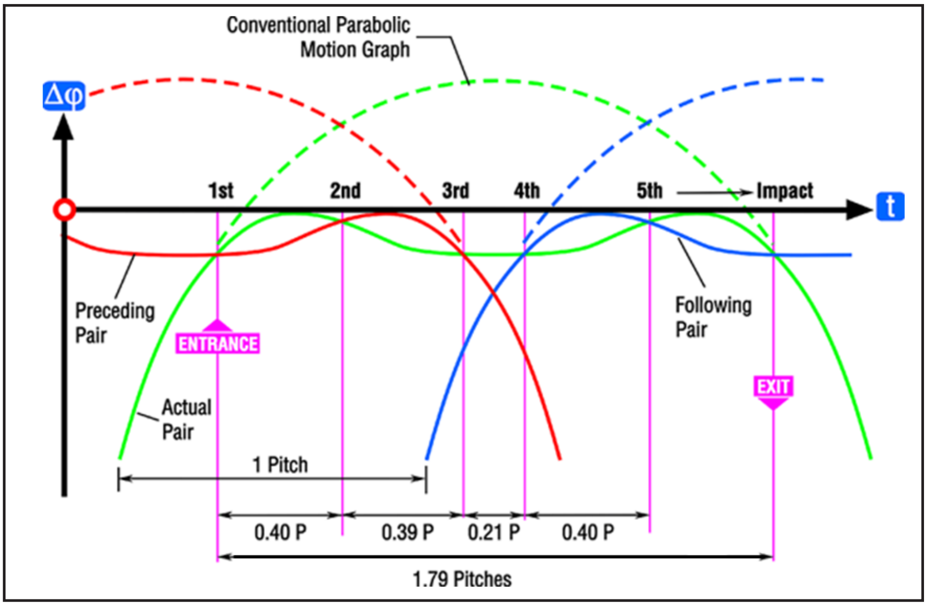

Figure 3 Alternative motion graph with overlapping double wave.

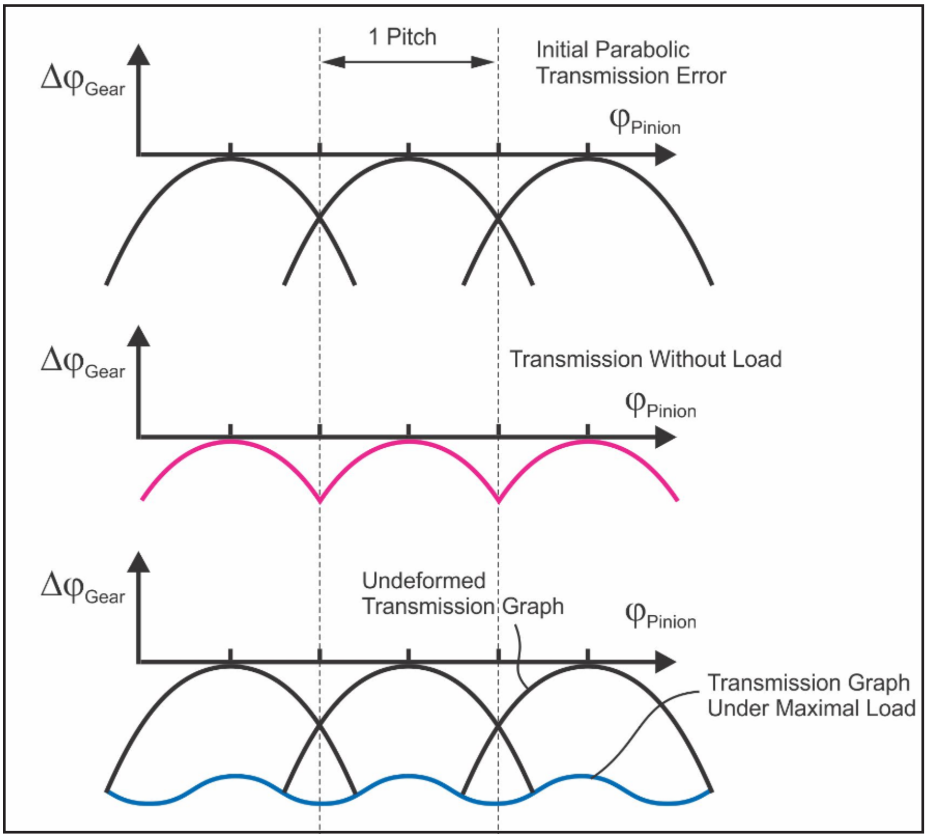

Figure 4 **Parabolic transmission error without and with load-inflicted deflection.**

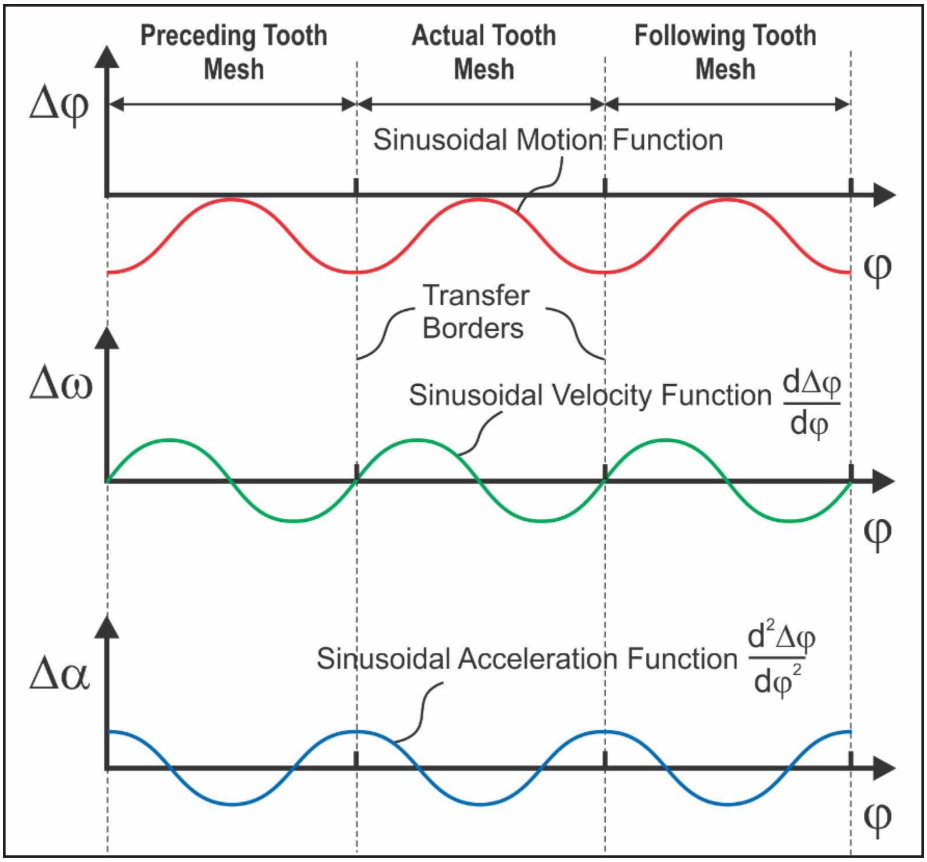

Figure 5 **Sinusoidal motion graph, angular velocity and angular acceleration.**

micro-impulses-per-tooth-mesh rather than one great impulse. The problem of gear noise caused by tooth impacts can be reduced with the motion graph in Figure 3, but it cannot be eliminated.

The Conclusion for a Hybrid Motion Graph

It appears conclusive that the parabolic motion transmission in Figure 2 and its first two derivatives show the most significant source of gear noise. The alternative motion transmission graph in Figure 3 reduces the physical sources of gear noise, but does not eliminate them. In the search for a more suitable transmission function, the following theses have been derived from the previous installments of this series:

- Many higher-order harmonics found in a FFT are not really present as disturbances on the tooth surfaces but are the result of the Fourier approximation.
- There are considerable residuals after a FFT of the motion error.
- The residuals stay undetected; their influence to the recognized noise is unclear.
- The air transmits sound pressure in sinusoidal waves.
- The human ear with its discrete frequency recognition of the tectorial membrane mirrors the basic FFT function and only recognizes sinusoidal sound pressure waves.

A further interesting observation is presented in Figure 4. The top graphic shows the parabola-shaped transmission error graphs of three consecutive pairs of teeth. Two adjacent parabolas always intersect at a point and continue below this point. In case of no load, the motion transmission follows the red graph in the center drawing of Figure 4. In case of the maximum load, the undeformed transmission error in the lower graphic of Figure 4 changes to the deformed transmission error under load, drawn in blue. It can be noticed that the transmission error under load has a nearly harmonic characteristic.

An acoustic signal consisting of a single fundamental sine function with a certain amplitude sounds smooth and quiet, where an acoustic square wave signal with the same amplitude sounds harsh and loud. If a transmission graph with sinusoidal form was realized, then in fact the first and second derivative are also sine waves which are simply phase shifted as shown in the three sequences in Figure 5.

This acknowledgement in connection with the formulated theses would allow the conclusion that a gear set with a true sinusoidal transmission error within the one pitch of single mesh (equal to the length of the tooth contact without load), like that shown on top in Figure 6, would sound extremely quiet under light or no load.

The sinusoidal transmission error on top in Figure 6 creates the conflict of the missing ability to adjust to increasing loads. Load increases above zero or light load (light load is less the 10% of the maximal load) would immediately cause edge contact due to the misalignment of the transfer points (center graphic in Fig. 6), which in turn will make the gear set operation noisy with a high risk of tooth damages.

The solution proposed in this chapter is the parabolic continuation below the intersecting points of the transmission graph, as shown in the center graphic in Figure 7. Below the intersecting points also means outside of the one pitch long active tooth contact. This hybrid between a sinusoidal and a parabolic transmission function will under zero or light load provide ideal sinusoidal excitation for a quiet gear set operation and will be equally suitable for all loads up to the maximal load the gear set is rated. The hybrid transmission error will change its shape under maximal load to a graph with reduced amplitude which still has a dominating sinusoidal characteristic as shown in the bottom graphic of Figures 4 and 7 (Ref. 3).

The Realization of Hybrid Motion Graphs

The combination of a trigonometric function (sinusoidal portion) with an analytic function (parabolic portion), superimposed to involute or octoide-shaped flank surfaces might appear complicated and unrealistic for an implementation in a production environment. Only tooth surface modifications which allow a robust reproduction on manufacturing machines are acceptable for most industries. The "double wave" modulation in Figure 3 has been realized with the *Gleason Universal Motion Concept* (UMC) in the grinding production of many automotive hypoid axle manufacturers. Grinding is today the only process where a given theoretical master surface

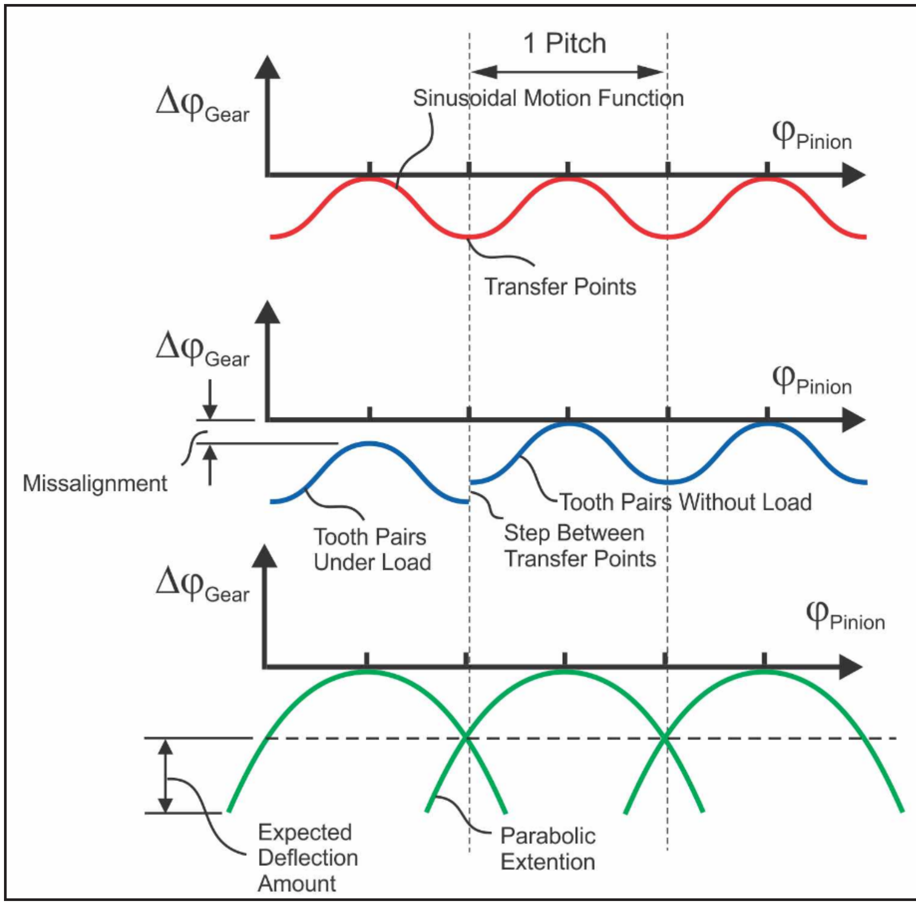

Figure 6 Sinusoidal motion graph without and with load and parabolic motion graph.

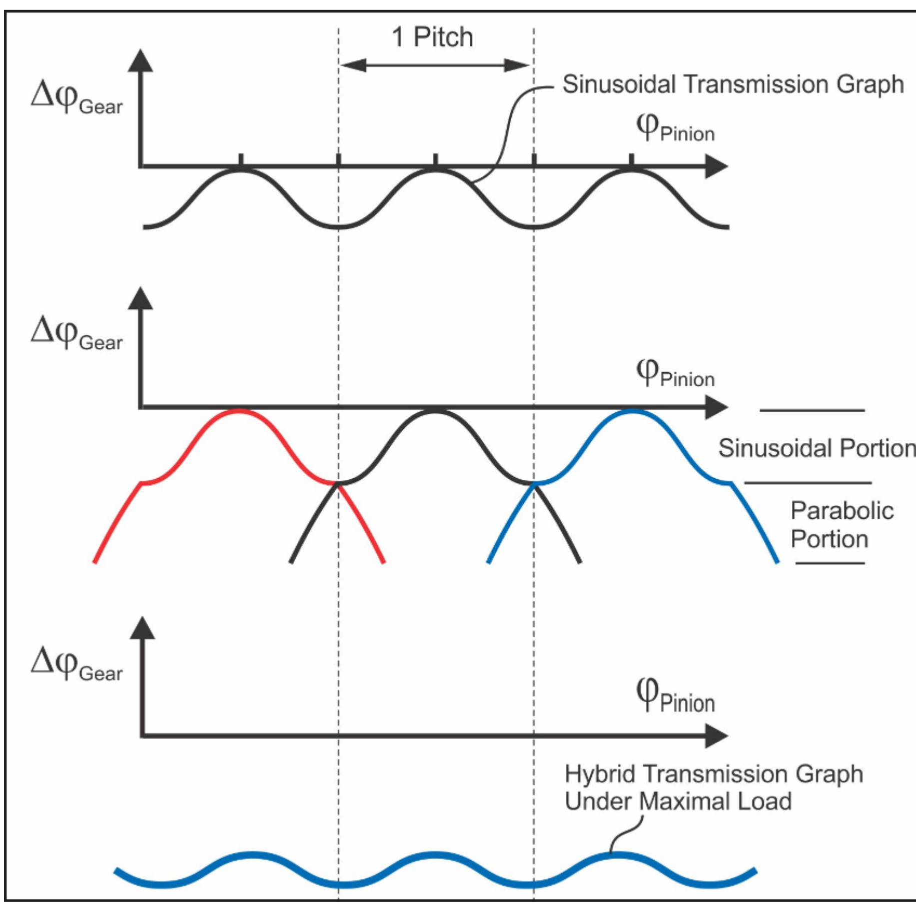

Figure 7 Synthesis of sinusoidal and parabolic motion transmission function.

can be reproduced very precisely in mass production. Future developments and trials have to show if the same applies to the hybrid motion graph, which is a more complex function than the double wave in Figure 3.

The freedoms and control parameters of the *UMC* motions allow defining a center section as well as a heel and toe section, directed along the path of contact. As the tooth contact moves along the path of contact, it creates the motion transmission function. As such, the *UMC* motion seems to be a suitable tool for the required modifications. Figure 8 shows on top the *UMC* center section and the toe and heel section to the left and right of the displayed tooth. The *UMC* parameters allow deactivating the toe and heel motion before reaching the exit (and entrance) point which allows for a parabolic entrance and exit section. The possible result of the *UMC* modification is shown in the lower graphic in Figure 8.

If the direction of the path of contact is profile-oriented, grinding wheel profile modifications can also be a suitable feature in order to achieve a sinusoidal transmission function within the tooth contact area which is active under light load.

Several development trials have been performed applying both *UMC* motions and grinding wheel profile modifications. The best results have been achieved with a combination of a conventional center section, a *UMC* toe section and blended Toprem on the grinding wheel profile.

A typical tooth contact (TCA) development result is shown in Figure 9. The magnitude of the modifications which are superimposed to the conventional Ease-Off is in the range of 10 to 12 microns, which is not very noticable in the Ease-Off in Figure 9. The tooth contact has a typical bias-in pattern and also here the sinusoidal surface modulation cannot be recognized. The motion graph at the bottom of Figure 9 has along the crest a nearly sinusoidal characteristic. The access motion graph below the crossing points of adjacent pitches is parabolic and will become active in case of increasing load. The TCA analysis results in Figure 9 are a good example for the realization of a hybrid motion graph, which consists of a combination between a sine function and a second order function.

The results from single flank testing of a hypoid gear set which has been ground according to the theoretical development in Figure 9 are shown in Figure 10 below the results of the conventionally ground baseline. The single flank working variation in the bottom graphic reflects well an approximated sinusoidal motion transmission. The Fourier analysis of baseline and sinusoidal transmission graph both have a first harmonic level of 18 microradians, which matches the amplitude of the designed motion transmission in Figure 9.

Although the lower motion graph in Figure 10 approximates a sinusoidal shape, the transfer section at the bottom of the graphic indicates that the transition from one tooth pair to the next is still problematic. Manufacturing tolerances and even the smallest deflections shift the motion graph vertically like that shown in the center graphic of Figure 6. It is assumed this is the major reason why the theoretically based assumption that the sinusoidal motion graph would not produce any amplitudes at the higher harmonic frequencies was too optimistic. However, the Fourier analysis comparison between baseline and sinusoidal motion graph version allows a remarkable solution as shown in Figure 11.

The lower graphic in Figure 11 is a plot of the Fourier analysis result from the gear set which was developed with the sinusoidal motion graph. The amplitudes of all frequencies above the mesh harmonic are lower than the baseline reference. The average lines of the multiple mesh frequencies indicate four micro radiant of the baseline gear set and only 2.5 micro radiant of the sinusoidal optimized gear set.

An audible comparison of this development to the conventional baseline gear set was performed on a CNC roll tester using

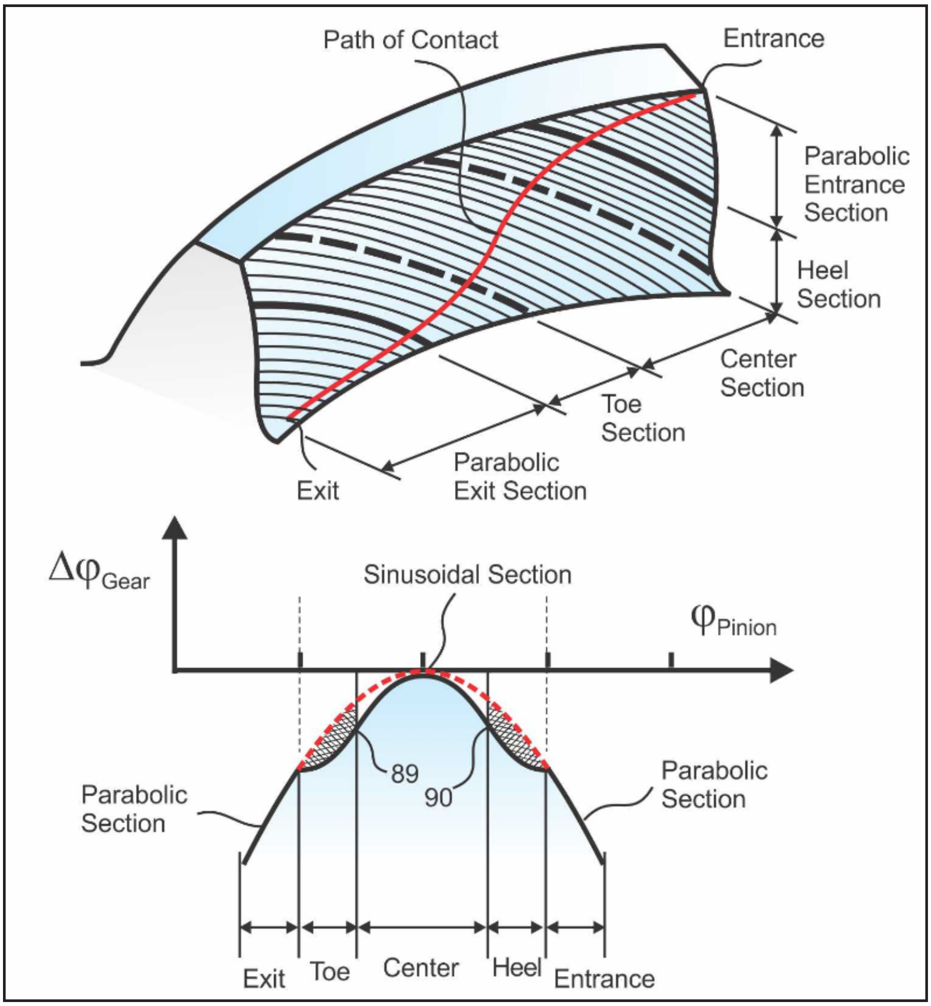

Figure 8 Universal motion tooth sections for hybrid motion graph or sinusoidal grinding wheel profile modification.

a microphone recording and a sound pressure analysis. Both gear sets had been run from 200 RPM to 1,000 RPM in 200 RPM increments, for five seconds at each RPM. The two side-by-side graphics in Figure 12 show the graphical sound pressure recording. The comparison clearly favors the right-side recording for the optimized gear set. Sound pressure amplitudes are lower for most speeds of the right-side graphic, which was confirmed by the audible impression of the sound play back.

Summary

The traditional bevel and hypoid gear design utilizes length and profile crowning. This crowning is required for bevel gears more than for cylindrical gears. The crowning accounts for manufacturing and gear set assembly tolerances, as well as load- affected deflections of the gearbox, the bearings and shafts, as well as the teeth. The length and profile crowning of traditional bevel gears is generated with geometric effects of the machine tool settings and the tool form. The resulting Ease-Offs and motion graphs are second order, which also means that the motion graphs are parabolic. The acknowledgement that the differences of the first and second derivative

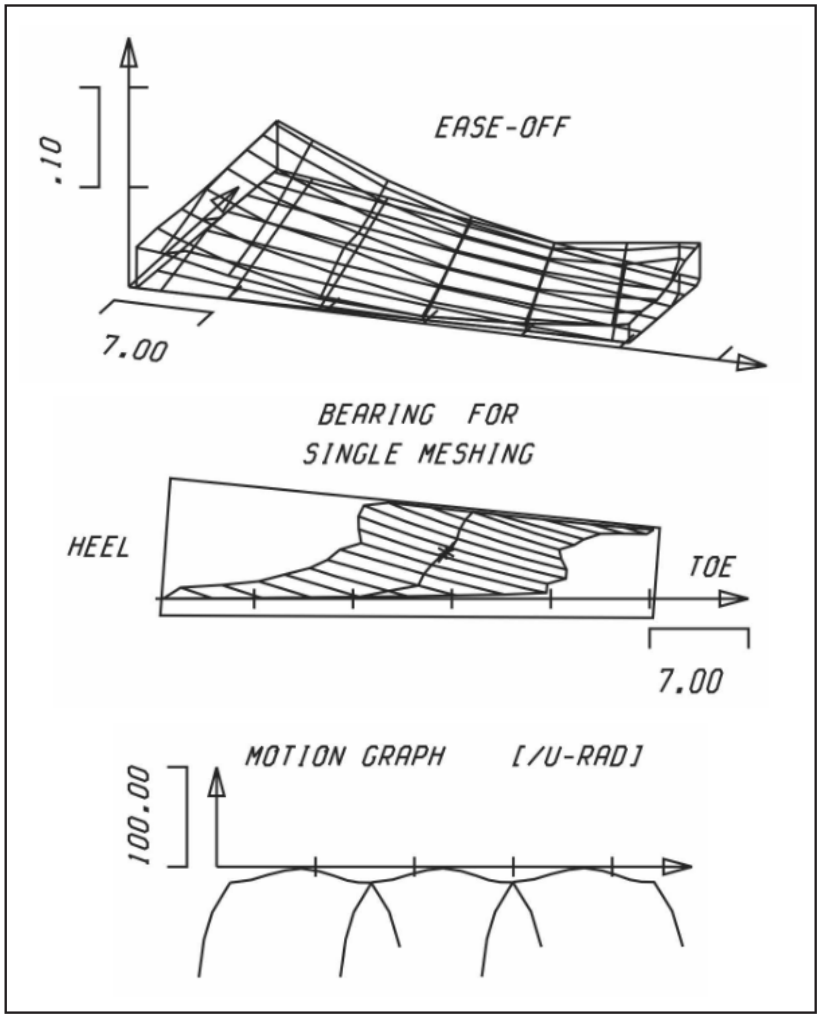

Figure 9 Tooth contact analysis of bevel gear set with hybrid motion graph.

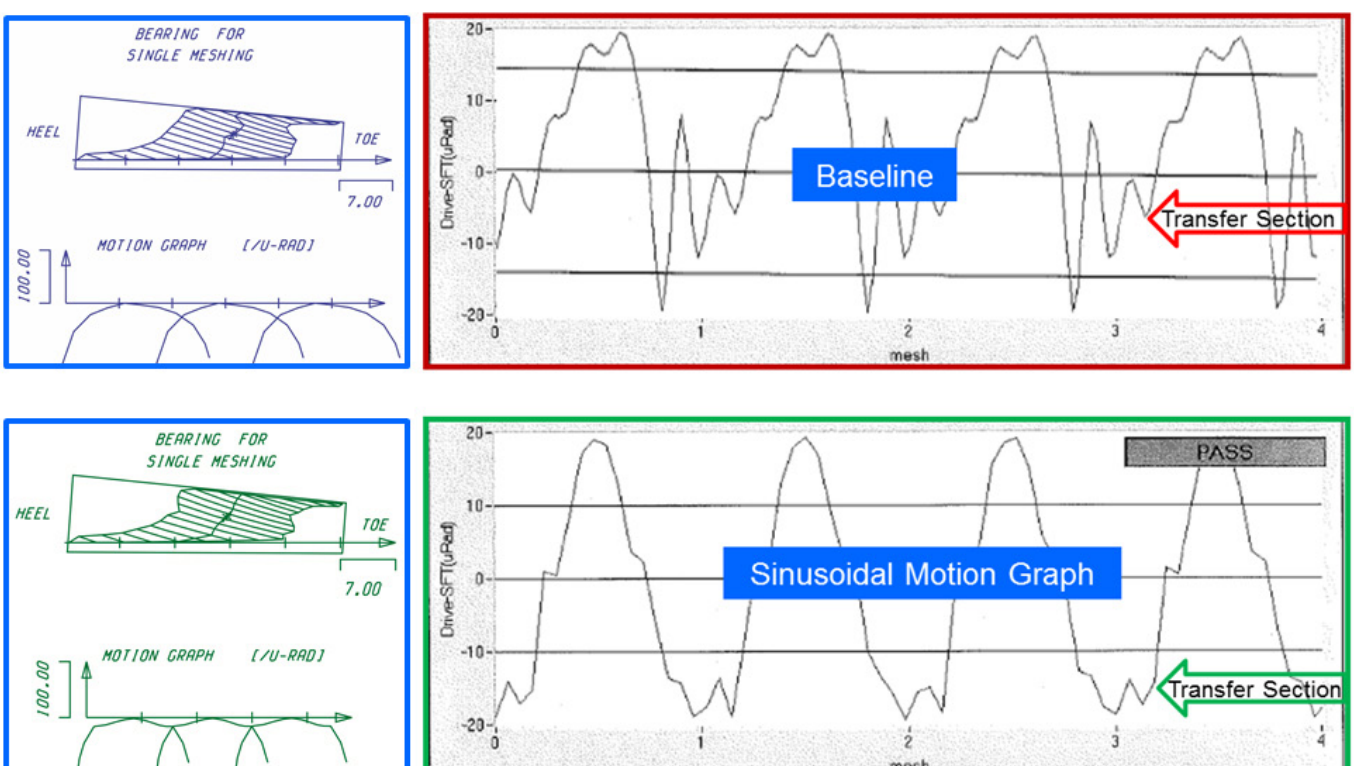

Figure 10 Theoretical tooth contact and single flank variation of baseline hypoid gear set and version with hybrid motion graph.

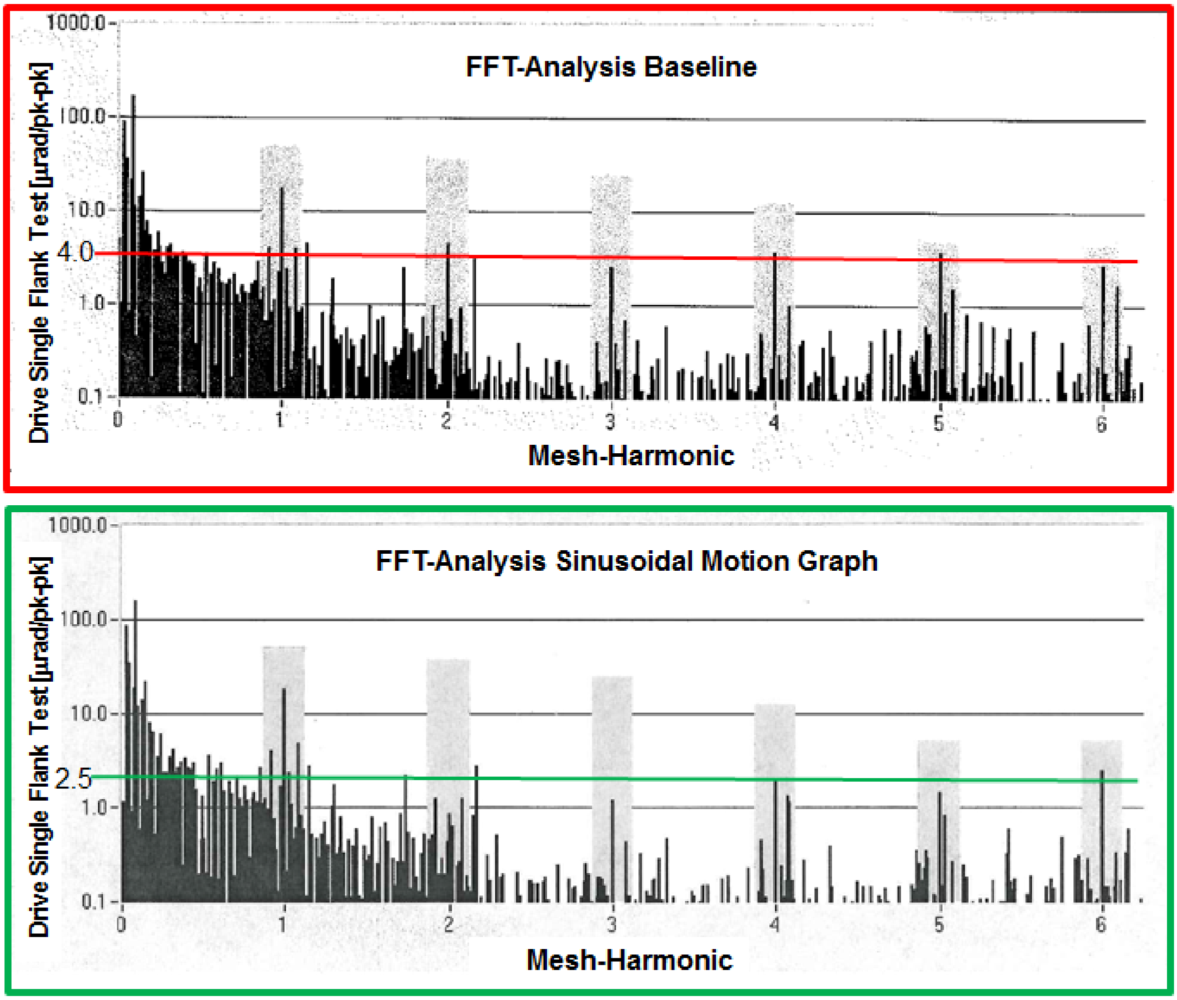

Figure 11 Fourier analysis of baseline hypoid gear set and version with hybrid motion graph.

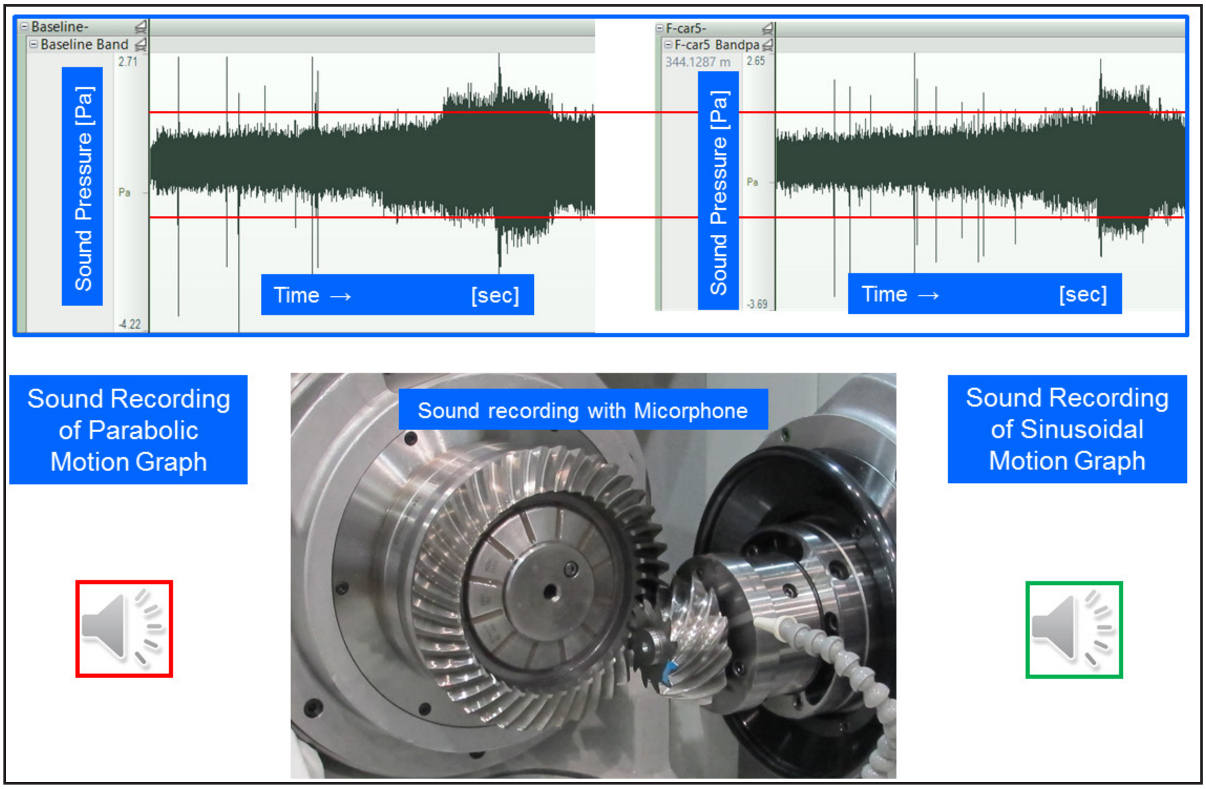

Figure 12 Comparison of sound amplitudes in time domain.

of the motion graph at the transfer points between adjacent motion graphs are the reason for a meshing impact causing a structure-borne disturbance of the motion transmission has often been discussed in the technical literature (Ref. 2).

A rather exciting conclusion from the psychoacoustic phenomenon is the proposal of a gear transmission graph which is a pure sinusoidal function at the very light load condition. Such a motion graph could only be transmitted as single sine function and would therefore also be received by a listener as a simple, low-frequency sine wave. In order to account for medium and high loads, the proposed hybrid motion graph connects different mathematical functions within the one-pitch-long contact area and outside of this area. A first surface development of a hypoid gear set has been realized by applying a *UMC* center section in connection with toe and heel sections which are second-order parabolas. The results are very promising, which seem to confirm that the hybrid transmission function can dramatically change the way bevel and hypoid gear sets will be optimized in the future for silent operation.

It has been noticed that the development of the hybrid motion transmission graph on real hypoid gear sets was rather time-consuming. Achieving the combination of a sine function in the flank center and parabolic-shaped extensions from the transfer points to the heel entrance point in the one direction, and the toe exit point in the other direction, required a painstaking effort. At this stage of development, therefore, it appears practical to develop an algorithm which will automate the conversion of a conventional motion graph into the hybrid combination of a sine function with a parabola.

The ongoing development work and testing will make this technology available soon for the application by gear engineers in the bevel and hypoid gear manufacturing industry. The positive results during the first practical developments indicate that even small modifications which aim to achieve a smooth contact transition area under light load will make a noticeable difference in noise emission. Those small modifications which could capture the major effect of the described method are easy to realize by most gear engineers with the tools that are already available today.

For more information.
Questions or comments regarding this paper? Contact Hermann Stadtfeld at *hstadtfeld@gleason.com.*

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Dr. Hermann J. Stadtfeld is the Vice President of Bevel Gear Technology and R&D at the Gleason Corporation and Professor of the Technical University of Ilmenau, Germany. As one of the world's most respected experts in bevel gear technology, he has published more than 300 technical papers and 10 books in this field. Likewise, he has filed international patent applications for more than 60 inventions based upon new gearing systems and gear manufacturing methods, as well as cutting tools and gear manufacturing machines. Under his leadership the world of bevel gear cutting has converted to environmentally friendly, dry machining of gears with significantly increased power density due to non-linear machine motions and new processes. Those developments also lower noise emission level and reduce energy consumption.

For 35 years, Dr. Stadtfeld has had a remarkable career within the field of bevel gear technology. Having received his Ph.D. with summa cum laude in 1987 at the Technical University in Aachen, Germany, he became the Head of Development & Engineering at Oerlikon-Bührle in Switzerland. He held a professor position at the Rochester Institute of Technology in Rochester, New York From 1992 to 1994. In 2000 as Vice President R&D he received in the name of The Gleason Works two Automotive Pace Awards—one for his high-speed dry cutting development and one for the successful development and implementation of the Universal Motion Concept (UMC). The UMC brought the conventional bevel gear geometry and its physical properties to a new level. In 2015, the Rochester Intellectual property Law Association elected Dr. Stadtfeld the "Distinguished Inventor of the Year." Between 2015–2016 CNN featured him as "Tech Hero" on a Website dedicated to technical innovators for his accomplishments regarding environmentally friendly gear manufacturing and technical advancements in gear efficiency.

Stadtfeld continues, along with his senior management position at Gleason Corporation, to mentor and advise graduate level Gleason employees, and he supervises Gleason-sponsored Master Thesis programs as professor of the Technical University of Ilmenau—thus helping to shape and ensure the future of gear technology.

Simulative and Experimental Determination of the Tooth Flank Fracture Load Capacity of Large Modulus Gears

Christian Brecher, Christoph Löpenhaus and Fabian Goergen

1. Introduction and Motivation

Because of continuously increasing power density in modern transmissions, the damage pattern tooth flank fracture (TFF) is becoming a limiting factor in terms of gearbox lifetime. Tooth flank fractures depend on numerous influencing parameters. On the one hand contact pressure influences as well as influences of bending, shearing and compression downstream of the Hertzian contact exist. In addition, residual stresses are superimposed on the time-variable load stresses, which can even manifest themselves in the form of tensile residual stresses in the volume critical for tooth flank fracture. On the other hand, the local material properties have a significant influence on the development of tooth flank fractures, since the crack initiation under the surface takes place in the area of low local hardness and preferably at material inhomogeneities (e.g. voids, non-metallic inclusions, carbides). In recent years, numerous calculation methods have been developed to estimate the tooth flank fracture load capacity and been validated on several gear geometries. However, discrepancies frequently occur in the calculation of the tooth flank fracture load capacity, especially for large-modulus helical gears from industrial practice. One possible reason is that the validation is usually based on experimental results from research environment. The experimental investigation of large-modulus helical gears from industrial practice is not economically feasible, which is why smaller gears are used. For this reason, there is currently no generally applicable calculation approach for determining the tooth flank fracture load capacity.

Two research motivations result from the current deficits. On the one hand, a generally valid calculation approach has to be developed for the determination of the tooth flank fracture load capacity, which has been validated both on gears from the research environment and on large-modulus gears from industrial practice. The validation requires statistically verified experimental results which cannot be determined economically for large-modulus helical gears from industrial practice. For this reason, an analogy test has to be developed which enables the economic determination of the tooth flank fracture load capacity of gears from industrial practice on the other hand.

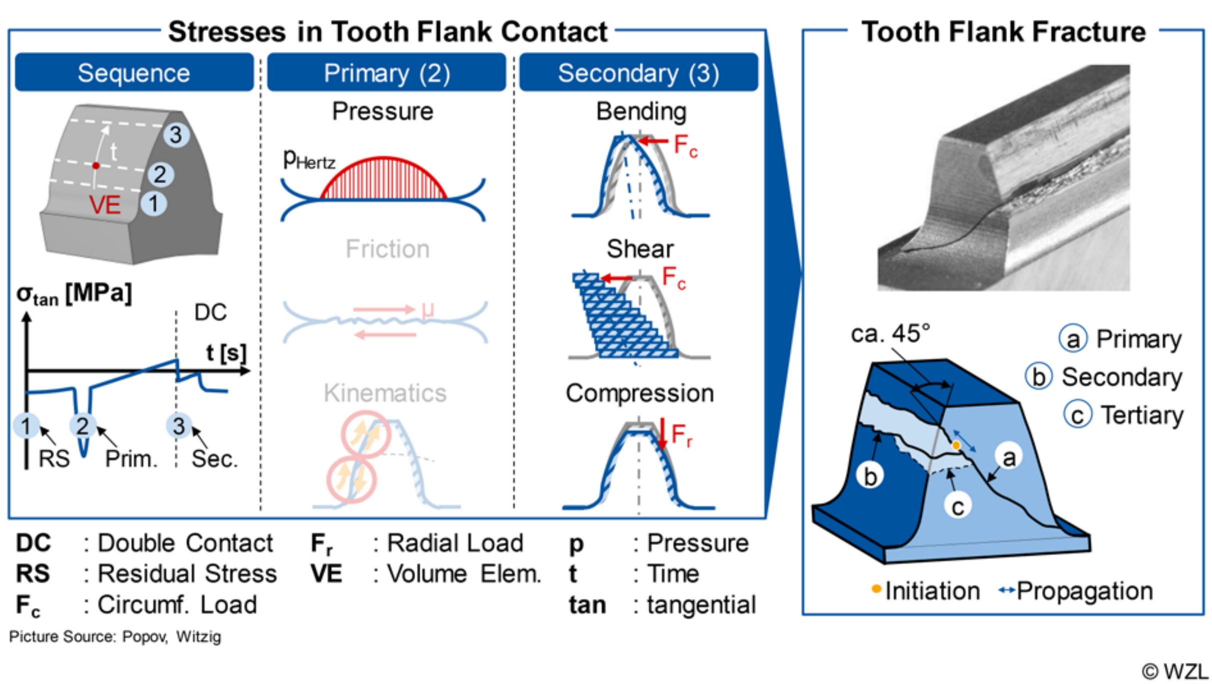

Figure 1 Stresses in Tooth Flank Contact and Tooth Flank Fracture [Ref. POPO 10, Ref. WITZ, Ref.12].

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2. Tooth Flank Fracture in the State of the Art

The processing of the damage type tooth flank fracture in the state of the art takes place in three steps. In the first step, the stresses in tooth flank contact are explained and their relevance for the development of tooth flank fractures is evaluated. Subsequently, the method for the TFF load capacity calculation according to KONOWALCZYK is presented [Ref. KONO18]. Finally, the concept developed by KONOWALCZYK for the investigation of tooth flank fractures is presented in an analogy test [Ref. KONO18].

2.1 Stresses in Tooth Flank Contact

The loading of a volume element which is located on or below the tooth flank surface can be characterized in three steps, Figure 1. If no external load is present, then a constant residual stress-state, step 1, prevails in the volume element. In the active tooth flank contact, as a result of the HERTZIAN contact flattening, mechanical compressive stresses predominantly build up in the volume element which are superimposed on the residual stress-state, Figure 1 [Ref. LOEP15]. The stress state immediately below the HERTZIAN contact zone is determined by normal, tangential and temperature stresses due to friction, slippage, micro and macro HERTZIAN contact [Ref. LOEP15]. In higher material depths, the influence of the macro HERTZIAN contact is dominant and the tribological influencing factors are assumed to be negligibly small [Ref. ANNA03].

After the HERTZIAN contact the volume element is stressed as a consequence of tooth deformation. Tensile normal and shear stresses build up, which increase until the change to multiple tooth meshing due to the increasing lever arm, Figure 1 [Ref. LOEP15]. The tooth flank fracture has its initial crack location under the surface at a depth of $t \approx 2 \cdot CHD_{550}$, preferably at a material inhomogeneity (e.g. void, non-metallic inclusion, carbide). According to the current state of knowledge, the cause of the crack initiation is assumed to be a stress increase due to the modulus of elasticity difference between the inhomogeneity and the microstructure as well as the notch effect of the inhomogeneity [Ref. WITZ12].

The damage type tooth flank fracture is therefore significantly influenced by HERTZIAN contact pressure in combination with secondary mechanical stresses (bending, shear, compression) [Ref. BRUC06, Ref.WITZ12, Ref. KONO18]. Compared to the stress condition of the tooth flank near the surface ($0\,mm \leq t \leq t_{vonMises,max}$), the stresses in the tooth flank fracture critical area are low and the influence of the low material strength predominates [BRUC06]. The low local strength is a result of the transition between hardened surface layer and unhardened core structure, which results in a locally low hardness in combination with low compressive residual stresses or even tensile residual stresses [Ref. KONO18].

2.2 Calculation of Tooth Flank Fracture Load Capacity

In recent years, numerous calculation methods have been developed to determine the tooth flank fracture load capacity [Ref. WEBE15, Ref. PATE16, Ref. WICK17, Ref. OCTR18, Ref. LEIM19, Ref. MEIS19]. The calculation methods have in common that the local safety or material strain is determined in the form of a comparison between local stress and stress resistance, whereby the determination of stress and stress resistance differs in all methods. Especially for large-modulus helical gears all approaches have deficits in order to take all important influencing parameters into account. [Ref. WITZ12, Ref. WICK17, Ref. OCTR18, Ref. LEIM19, Ref. ISO19] use an analytical approach based on the half space theory to calculate the stress sequence which results from the HERTZIAN contact. This approach is not considering tensile stresses which appear before and after the compressive stress peak in high material depth and lead to an alternating load. Furthermore tensile residual stresses in high material depth due to the case hardening process are not considered in [Ref. WITZ12, Ref. WICK17, Ref. LEIM19,

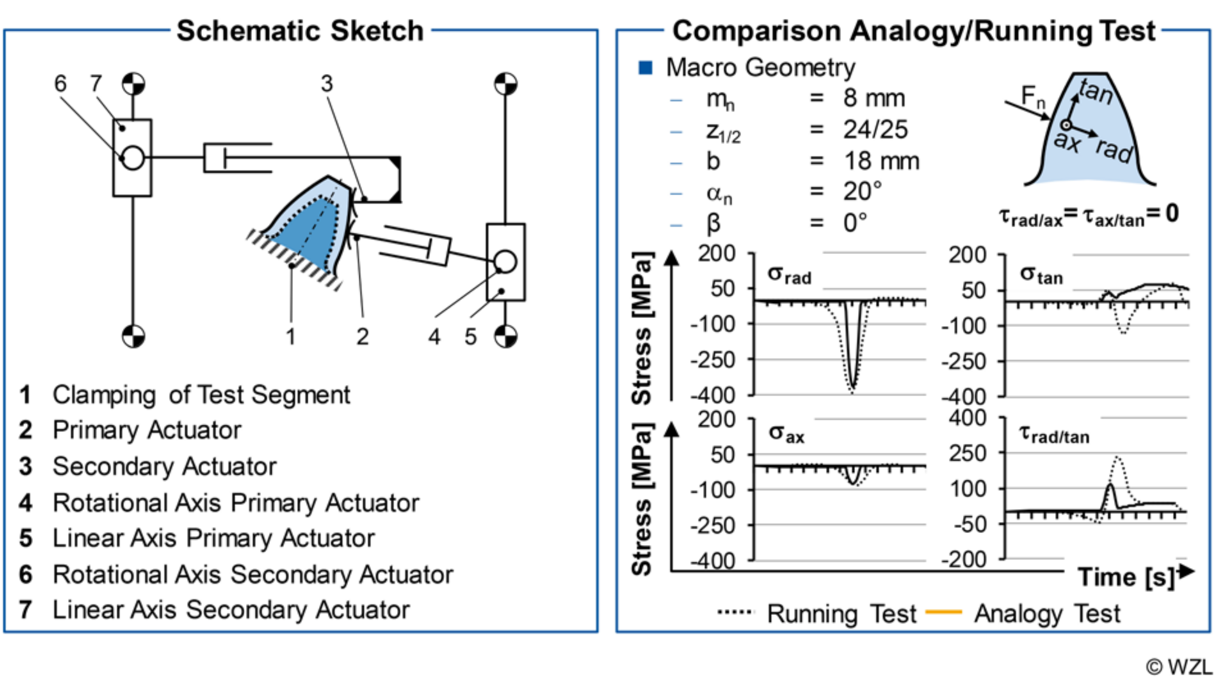

Figure 2 Analogy Concept to Investigate the Tooth Flank Fracture Load Capacity.

Ref. ISO19]. Secondary stresses after the HERTZIAN contact flattening in the form of bending, shear and compression are not considered in [Ref. OCTR18, Ref. ISO19]. Other approaches such as [Ref. WITZ12, (Ref. [Ref. WEBE15, Ref. WICK17] use an analytical approach based on the bending beam theory or elastic wedge theory to determine secondary stresses. In this case the analyzed gear is cut into several parts in lead direction and the stress sequence after the HERTZIAN contact flattening is calculated for each segment. In this case cross influences in lead direction are assumed to be negligible small which results in deviations especially for helical gears. Regarding the stress resistance calculation several approaches use empirical factors or nominal strength values from literature or experimental experience which are not considering material inhomogeneities and their statistical distribution [Ref. WITZ12, Ref. PATE16, Ref. OCTR18].

2.3 Experimental Investigation of Tooth Flank Fractures in Analogy Tests

KONOWALCZYK shows by simulation of a large-modulus spur gear from research environment that the local material strain in the TFF critical volume can be approximated using a pulsator with two actuators. For this purpose, an analogy concept is developed in which a tooth segment of the test gear is separated by means of electrical discharge machining (EDM) and clamped in a test setup, Figure 2 [Ref. KONO18].

The primary stress is applied by an actuator, which is fixed on the tooth flank above the expected crack origin. To apply the secondary stress, an additional actuator is positioned in the area of the tooth tip. By using two actuators, the new test rig concept differs fundamentally from pulsators for the investigation of tooth root load capacity. The results of the contact simulations carried out in running and analogy tests show the suitability of the test rig concept for the investigation of tooth flank fractures in analogy tests. In particular, the maximum compressive stresses in radial and axial direction (Fig. 2: σ_{rad}, σ_{ax}) as a result of the HERTZIAN contact flattening can be accurately mapped by the primary actuator. The tensile stress in tangential direction can also be accurately reproduced by applying the load to the secondary actuator with a time delay to the primary actuator (Fig. 2: $\sigma_{tan} \geq 0$). In this way, the bending stress downstream of the rolling-sliding contact due to tooth deformation is applied. Nevertheless the developed methodology for determining the required pulsator loads only reproduces the maximum amplitudes of the normal stresses sufficiently, but not the stress tensor sequences. Furthermore, the compressive stress in the tangential direction as well as the shear stress in the radial/tangential plane cannot be reproduced sufficiently (Fig. 2: $\sigma_{tan} < 0, \tau_{rad/tan}$). With the procedure shown KONOWALCZYK can achieve a correlation of the equivalent stress in the tooth flank fracture critical volume between analogy and running test for the analyzed gear. The investigated gear is an established large-modulus spur gear from the research environment ($m_n = 8$ mm, $z_{1/2} = 24/25$). [Ref. KONO18]

3. Research Aim

The state of the art shows that there is currently no suitable method to determine the tooth flank fracture load capacity by taking all relevant influencing parameters into account. When developing a suitable method for the calculation of the tooth flank fracture load capacity, the following aspects have to be considered in particular:

- FE calculation of the load stresses for the sufficient evaluation of the stress state
- Consideration of possible tensile residual stresses in higher material depth
- Consideration of material inhomogeneities in the microstructure

For the experimental validation of the method on large-modulus helical gears from industrial practice, a suitable analogy

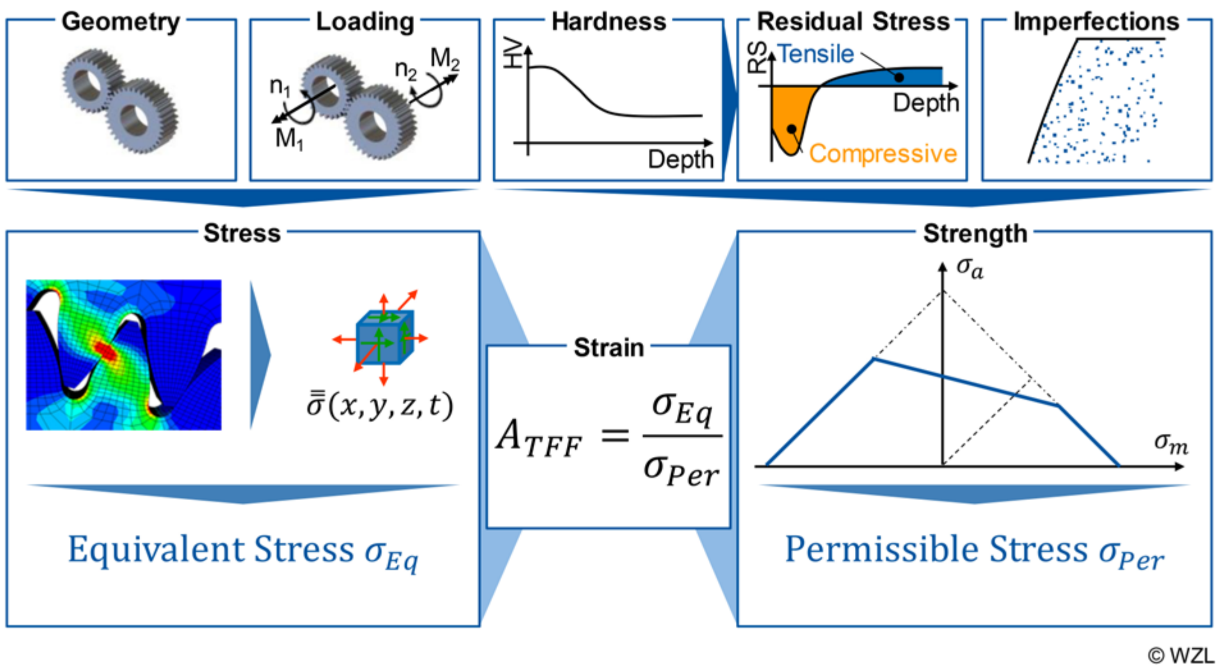

Figure 3 Calculation of TFF Load Capacity according to KONOWALCZYK [Ref. KONO18].

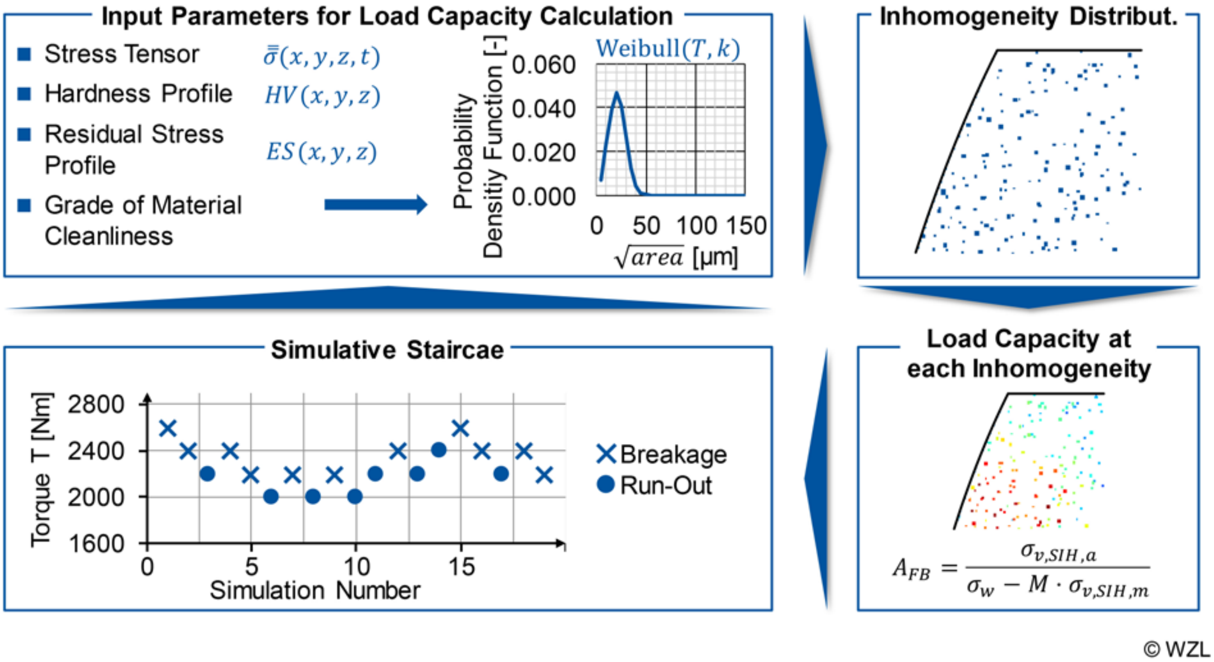

Figure 4 Calculation of TFF Load Capacity according to KONOWALCZYK [Ref. KONO18].

concept is also required, as such gears cannot be investigated economically with regard to load capacity in the running test.

The following objective is derived from the existing deficits: *Method for the calculation of the tooth flank fracture load capacity as well as an economic analogy test concept for the experimental investigation of the tooth flank fracture load capacity of large-modulus spur and helical gears.*

In order to achieve the objective, a three-step procedure is chosen. In the first step, the method development taking into account all relevant influencing parameters is done. The method for the calculation of the tooth flank fracture load capacity presented in chapter 4 was developed at WZL and is based on the work of KONOWALCZYK [Ref. KONO18]. Subsequently, the validation of the method takes place based on experimental investigations of a large-modulus spur gear from the research environment. The experimental investigations presented in this report were carried out within the framework of the research project FVA 695 [Ref. KLOC18] and are also based on the work of KONOWALCZYK [Ref. KONO18]. Furthermore, a validation is carried out on the basis of a tooth flank fracture critical large-modulus helical gear from the gearbox of a wind turbine. In the last step, a concept is developed which allows to test the tooth flank fracture load capacity of large modulus helical gears economically in an analogy test as well as a calculation approach to determine the pulsator load-sequences in order to get the same stress-state in the tooth flank fracture critical volume.

4. Calculation Method to Determine the TFF Load Capacity

methods because the stress calculation is 3D-FE-based over the entire mesh cycle, tensile residual stresses in the transition area between surface layer and core hardness can be taken into account and a material inhomogeneity-based, statistical approach serves as a basis for the local strength calculation. The calculation approach is based on the principle of local endurance strength by The The calculation method described in this report was developed at WZL by KONOWALCZYK and serves as a basis to investigate the tooth flank fracture load capacity at WZL and the current DFG research project BR 2905/90 1 for the reproduction of the damage type tooth flank fracture in an analogy test [Ref. KONO18]. The methodology differs from existing determining the local material strain in every discrete tooth volume element, cf. Figure 3 [Ref. KONO18].

To calculate the equivalent stress, time-dependent stress tensors are determined by a quasistatic simulation of the tooth contact in FEA. The combination to an equivalent stress σEq, which considers the time dependency and the rotation of the main stress coordinate system in the rolling-sliding contact, is carried out using a modified variant of the stress intensity hypothesis (SIH) according to LIU [Ref. LIUJ91, Ref. KONO18]. The determination of the local strength σPer is based on the calculation of the local alternating strength at material inhomogeneities in the interior of the component according to MURAKAMI [Ref. MURA02]. The statistical distribution of the material inhomogeneities in the tooth volume is carried out according to HENSER [Ref. HENS15]. To determine the local residual stress-state, an optimization algorithm is developed on the basis of a stress equilibrium between compressive and tensile residual stresses. The calculation of compressive residual stresses up to $t = 0.5 \cdot CHD_{550}$ is realized according to LANG [Ref. LANG79]. Afterwards a continuous transition (equal residual stress value and equal slope) is defined as a first and second boundary condition. The third and fourth boundary conditions are defined by the maximum depth in the tooth center, where the residual stress has to reach a constant value ($\sigma_{RS,t(max)} \geq 0$ MPa, $\sigma'_{RS,t(max)} = 0$). The calculated local residual stress value is taken into account by using the mean-stress sensitivity according to the FKM guideline [Ref. FKM03]. The statistical distribution of inhomogeneities leads to different results for each individual calculation and thus enables the implementation of a simulative staircase method which can be evaluated according to the IABG method, Figure 4 [Ref. HÜCK83]. A statistical distribution of inhomogeneities in the tooth volume is generated in successive calculation steps. The distribution follows a density function, which results from the cleanliness of the material and is described by the scale parameter T and shape parameter k of a Weibull distribution as well as a reference number of the inhomogeneities present in the volume. According to HENSER, this density function is derived from existing fracture surfaces and the inhomogeneities detected by SEM [Ref. HENS15]. On the basis of the locally available data regarding stress, hardness and residual stress condition, it is possible to calculate whether the local strength is exceeded at each inhomogeneity.

The alternating strength σ_w of an inhomogeneity is calculated according to Equation (4-1), whereby no influence of the local mean stresses on the tolerable amplitude is taken into account initially.

$$\sigma_w = 1.56 \frac{HV + 120}{\sqrt[12]{area}} \qquad (4\text{-}1)$$

σ_w	Alternating Strength
$\sqrt{area}$	Murakami Factor
HV	Vickers Hardness

This is done in a second step according to MURAKAMI'S recommendation by calculating a mean stress sensitivity M [Ref. MURA02]. In this report the procedure according to FKM is applied for the calculation of the mean stress sensitivity M [Ref. FKM03]. Both load and residual stress induced mean stress components are taken into account. On the basis of the local strain calculation at each inhomogeneity in the tooth volume, the result of a calculation step is evaluated either as a breakage or as a run-out and classified in a simulative staircase procedure (Fig. 4, bottom left). Based on the result, the load for the next calculation step is defined and the calculation of the load capacity is repeated. The described procedure is repeated a total of 30 to 50 times, so that a high statistical assurance of the result regarding mean value and scatter is available.

5. Validation of TFF Calculation Approach

Chapter 5 deals with the experimental validation of the calculation approach described in Chapter 4. The validation is carried out in two steps. First, a large-modulus tooth flank fracture critical spur gear is tested in a back-to-back test rig by means of endurance limit derivation regarding tooth flank fracture in a staircase method. In a second step, a large-modulus helical gear from a wind turbine, which showed several tooth flank fractures in field, is analyzed simulatively and compared to the nominal torque during operation.

5.1 Experimental Investigation on Back-to-Back Test Rig

The investigations carried out in the present work were carried out on a back-to-back test rig with center distance a = 200 mm. In chapter 5.1.1 the test geometry, the test rig and the test conditions are presented. Chapter 5.1.2 shows the results of the experimental investigations and the comparison to the results of the tooth flank fracture load capacity calculation.

5.1.1. Test Parts, Test Rig and Test Conditions

The test gear geometry was determined based on the test variant EHTA out of TOBIE'S work, Figure 5 [Ref. TOBI01]. The geometry was designed for a center distance a = 200 mm. The main features of the spur gears are a normal module m_n = 8 mm, number of teeth on pinion and gear $z_{1/2}$ = 24/25, pressure angle α_n = 20° and profile shift coefficients $x_{1/2}$ = 0.27/0.266. To avoid premature tooth meshing, a short tip relief with C_α = 75 µm is applied. The tip relief definition is based on a FE-based penetration calculation [Ref. KONO18]. To minimize edge effects, a low

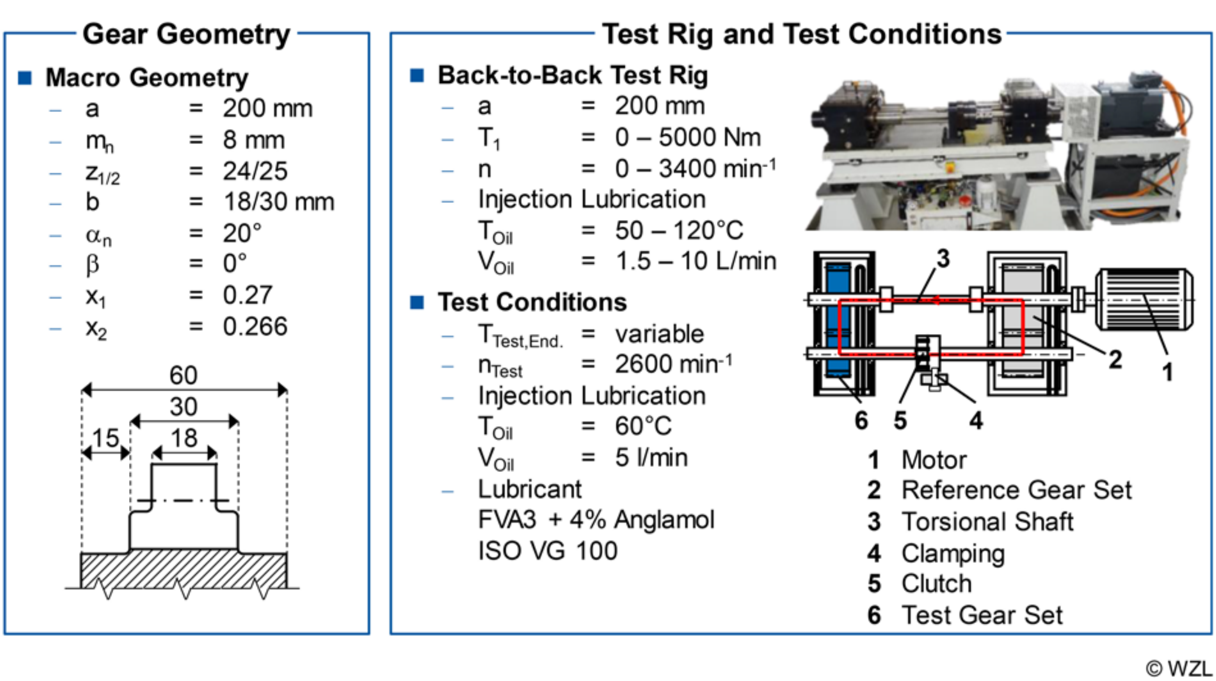

Figure 5 Gear Geometry, Test Rig and Test Conditions.

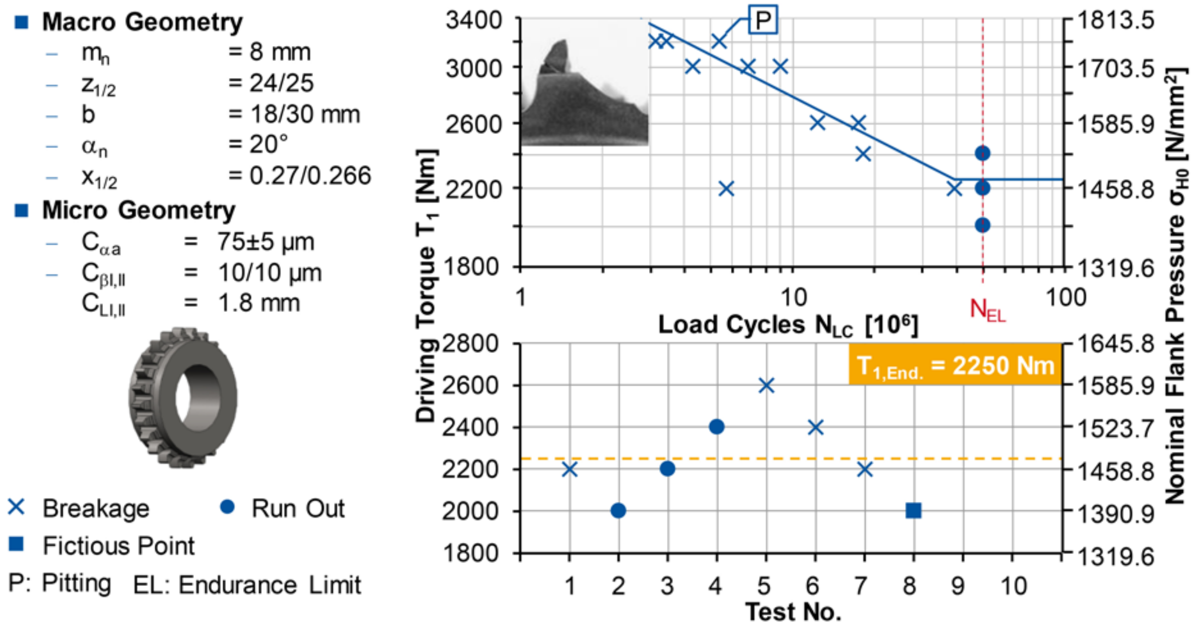

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Figure 6 Experimental Endurance Limit (EL), SN-Curve [Ref. KLOC18].

lead crowning of $C_\beta = 2$ µm is applied. The distribution of material inhomogeneities was determined according to the method of BRECHER ET AL. [Ref. BREC17]. Therefore single tooth segments were cut in an angle of 45° to the flank surface and the cross section view was captured by light microscopy. To evaluate the defect distribution the automatic algorithm creates cluster of black pixel, which represent material inhomogeneities, in the microscopic pic ture and evaluates the size of each defect.

The principle of the test rig used corresponds to a standard back-to-back test rig consisting of a motor, a reference gear set and a test gear set, a torsional shaft, a coupling and a clamping, Fig. 5. The performance data of the test rig enables the experimental determination of the load capacity up to a maximum torque $T_{max} = 5{,}000$ Nm at a maximum rotational speed $Nm_{ax} = 3{,}400$ min^{-1}. Therefore, an injection lubrication is recommended for the experiments. In order to enable a classification to the state of the art, the investigations were carried out at a rotational speed of $n_{Test} = 2{,}600$ min^{-1}. The lubricant used is the common oil for load capacity investigations FVA3 +4% Anglamol. The oil temperature was defined to $T_{Oil} = 60$°C with a flow rate of $V_{Oil} = 5$ l/min. The direction of rotation of the motor and the direction of torque applied were selected in a way that the pinion drives the counter gear. According to the state of the art, an estimated maximum torque of $T_{max} \approx 3{,}500$ Nm

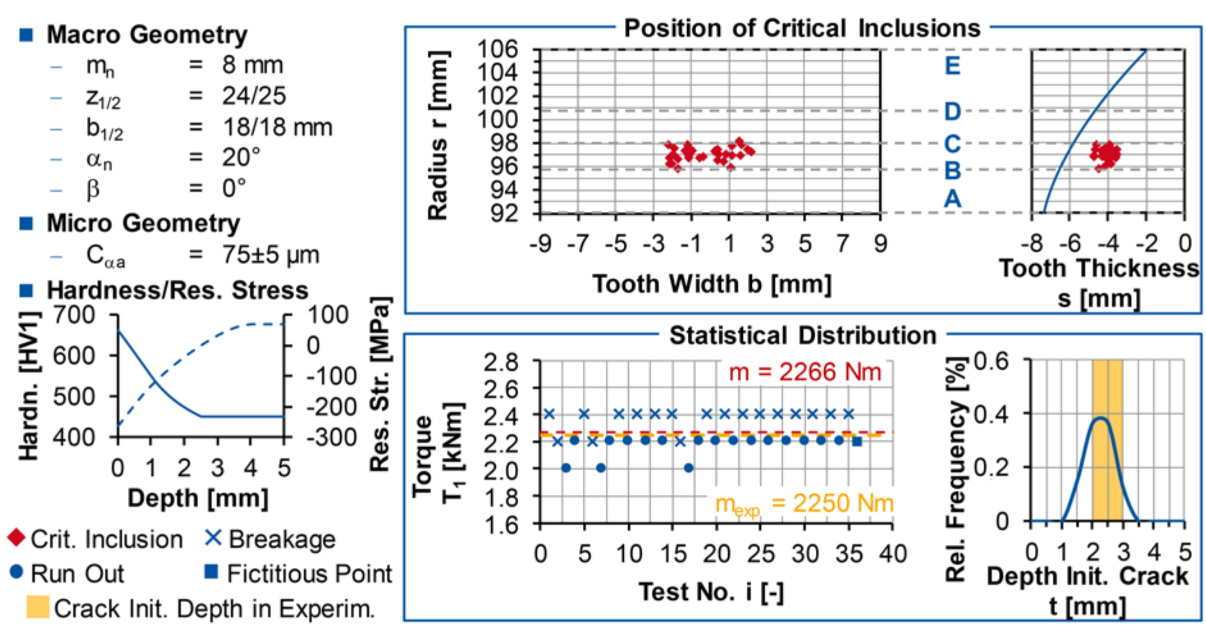

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Figure 7 Comparison TFF Endurance Limit between Experiment and Simulation.

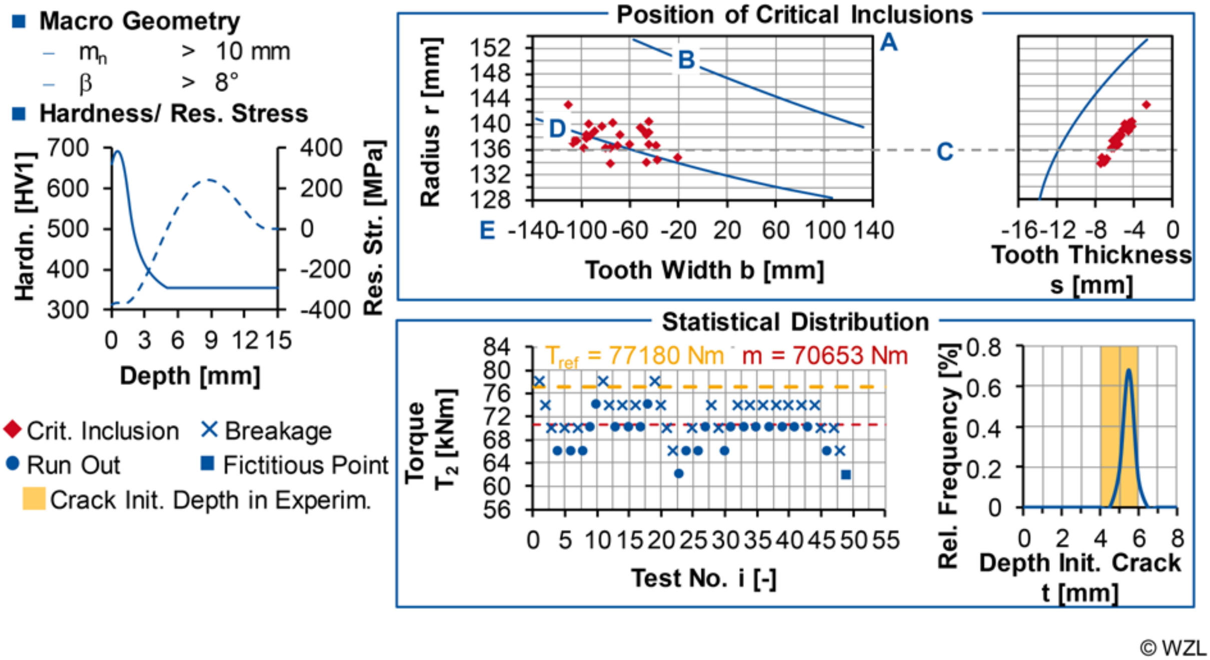

Figure 8 Comparison TFF Endurance Limit between Operation Torque and Simulation.

is applicable for the test gear geometry. The test rig therefore has enough power reserve to react to unexpected test results in order to enable tests at higher torques. [Ref. KONO18]

5.1.2. Results

The endurance strength is determined using the staircase method and extended IABG evaluation method according to HÜCK [Ref. HÜCK83]. The results are illustrated in Figure 6. In the lower part of Figure 6, the tests to determine the endurance strength are supplemented by the fictitious point and evaluated using the staircase method. In total, 8 test points (including the fictitious point) could be evaluated. The result is an endurance strength torque limit of $T_{1,End.} = 2{,}250$ Nm at a failure probability of $P_A = 50\%$.

The teeth fail in the range of finite life due to tooth flank fractures. This damage mechanism also limits the previously determined endurance strength, as it can be seen in the upper part of Figure 6 in the SN-Curve. However, one test with a driving torque of $T_1 = 3{,}200$ Nm was stopped with a pitting damage. Consequently, the load capacity limits for pitting and tooth flank fracture damage are close. The tests carried out show a low scatter, which is visible in the SN-Curve. Only one test with driving torque $T_1 = 2{,}200$ Nm has a reduced number of load cycles. Since the test was used to evaluate the endurance strength, for which the number of load cycles is irrelevant, the result can be classified as valid.

Figure 7 illustrates the results of the tooth flank fracture load capacity calculation as well as the comparison between simulative and experimental determined endurance strength. The damage causing material inhomogeneities are located in the area of the single tooth contact close to the diameter of the lower transition point B. Due to the symmetric load on the spur gear, all critical inhomogeneities are in the center of the tooth in lead direction. With regard to the depth of crack initiation, the maximum relative frequency is in the range of $t = 2…2.5$ mm. This corresponds to the depth of the crack initiation points discovered in the metallographic analysis [Ref. KONO18].

The evaluation of the simulative staircase procedure is carried out based on 35 simulation points. The mean value of the endurance torque is determined to $T_{1,End.} = 2{,}266$ Nm. The tests spread over three load values between $T_1 = 2{,}000$ Nm and $T_1 = 2400$ Nm, resulting in a standard deviation of $s = 126.5$ Nm respectively $s = 5.6\%$. In comparison to the experimentally determined endurance strength, the difference is $\Delta T_{1,End.} = 1\%$, which is lower than the stand ard deviation.

5.2 Simulation of Gear Set from Industrial Application (Wind Turbine)

In addition to the experimental validation on the back-to-back test rig, a large-modulus helical gear from a wind turbine which showed tooth flank fractures during operation, was recalculated using the developed calculation approach by KONOWALCZYK [Ref. KONO18]. The shared geometry data is subject to confidentiality and cannot be published in this report. The normal module is $m_n > 10$ mm and the helix angle is $\beta > 8°$. The material is case-hardened 18CrNiMo7-6 with a surface hardness $HV_S = 660$ HV1, a case hardening depth $CHD_{550} = 1.64$ mm and a core hardness $HV_C = 355$ HV1. In application the counter gear drives and the pinion is driven.

The calculation results are shown in Figure 8. The critical inhomogeneities leading to tooth flank fracture are mainly located on the left gear side in the transition between the double and triple tooth contact. In this area of the tooth flank there is a high stress due to contact pressure on the one hand and a high bending stress due to high loads on higher diameters on the other hand. The statistical evaluation shows that the majority of critical inhomogeneities are in a depth between $t = 4…6$ mm. This corresponds to observations made in industrial practice. The evaluation of the simulative staircase procedure results in an endurance strength torque of $T_2 = 70{,}653$ kNm.

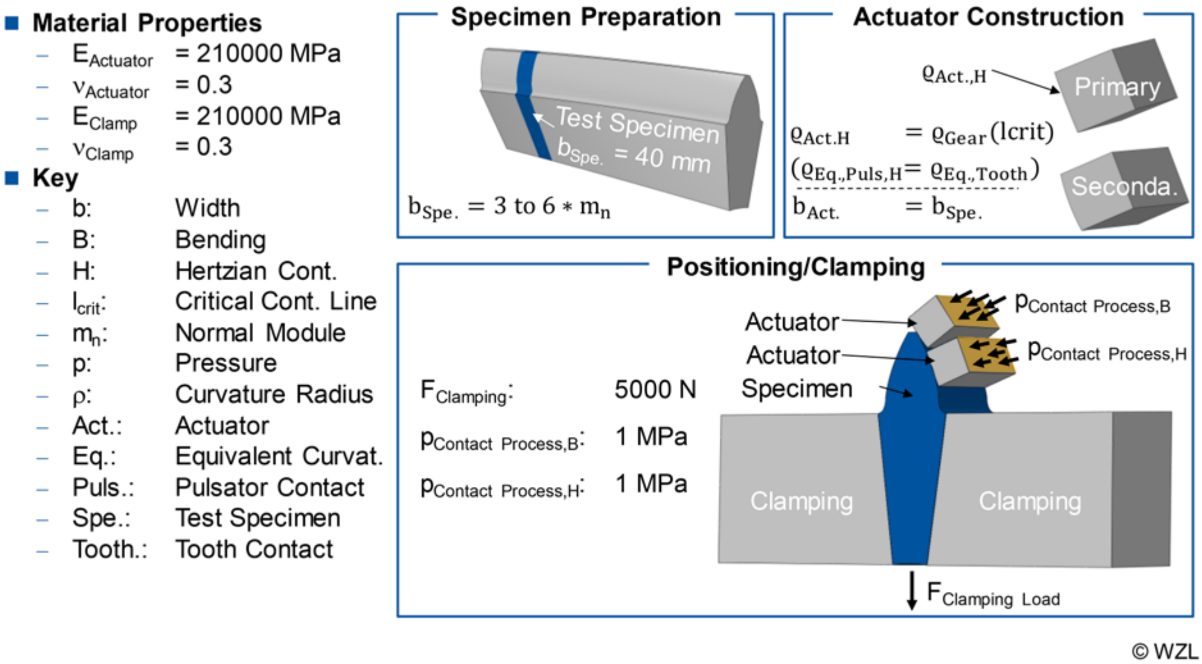

Figure 9 Construction of Simulation Model.

The tests spread over a torque range between $T_2 = 62$ kNm and $T_2 = 78$ kNm. A total of 48 simulations could be evaluated, which results in a standard deviation of s = 3.8 kNm or s = 5.4%. [Ref. KONO18].

Compared to the nominal operating torque ($T_2 = 77{,}180$ kNm), the calculated endurance torque is $\Delta T_2 = 8.5\%$ lower, which corresponds to the observations made in operation, where several tooth flank fractures occurred. The calculated crack initiation depth and position is also correlating to the observations, where the crack origin was located in $t \approx 5$ mm depth in the transition point between triple and double tooth contact shifted to the left of the tooth center in lead direction. [Ref. KONO18].

6/ Analogy Test Concept

In order to economically test the tooth flank fracture load capacity of large-modulus gears in an analogy test rig, KONOWALCZYK developed a double pulsator concept which is able to apply stresses caused by HERTZIAN contact and bending, cf. Figure 2 [Ref. KONO18]. In Chapter 6, a method to determine the load sequences of the actuators is presented which allows to induce equal stresses in the point of interest (POI) as in the running test. The newly developed method is applicable for spur and helical gears. The simulated test gear in Chapter 6 is the tooth flank fracture critical pinion which is also analyzed in Chapter 5.2. The point of interest defined is the center of all calculated crack initiation points according to the calculation approach presented in Chapter 4, Figure 8.

6.1 Simulation Model and Pulsator-Load Definition

The simulations presented in this report were performed in the software *Abaqus/CAE* 6.14-6. The simulation model was set up in three steps, Figure 9. In the first step, a tooth of the test gear was extracted from the gear mesh which was implemented in the tooth contact simulation software "*FE-Stirnradkette*" (STIRAK).

In order to enable an analogy study using the pulsator principle, the TFF critical part of the tooth in lead direction determined from field observations and according to the calculation by KONOWALCZYK was virtually separated, Figure 9 [Ref. KONO18]. In accordance with STAHL ET AL. a width of the test specimen in the range $3 \cdot m_n \leq b \leq 6 \cdot m_n$ was defined [Ref. Ref. STAH12]. In the second step, the two actuators were designed. To achieve a line contact between the two actuators and the test specimen over the entire width, the width of the actuators correspond at least to the width of the test specimen. In order to obtain an equal local material strain in the TFF critical volume, the equivalent curvature radius in the line contact between primary actuator and test specimen has to be analogous to the equivalent radius of curvature in the contact pinion/ counter gear. Consequently, the radius of curvature of the primary actuator has to correspond to the radius of curvature of the counter gear at the TFF critical contact line ($\rho_{act.,H} = \rho_{rad}(lcrit)$), Figure 9.

The aim of the load-sequence optimization is an analogue local material strain in the evaluation point (point of interest, POI) between running and analogy test. The running test respectively the real tooth contact is realized by a quasi-static rolling-sliding simulation over three base-pitches. The target value is the stress tensor sequence of the simulated tooth contact in the POI. The procedure of the method is shown in Figure 10.

The first step is the optimization of the HERTZIAN contact, which is imitated by the primary actuator. The contact between the primary actuator and the tooth flank is initially loaded with a load ramp within the limits of the actuator's performance, Fig. 10. The secondary actuator is load-free during the optimization of the HERTZIAN contact. The results of the initial load ramp are stress tensors in the POI as a function of the simulated load levels. Based on the digressive relationship between pulsator load and resulting stress tensor at the POI, all stresses at the

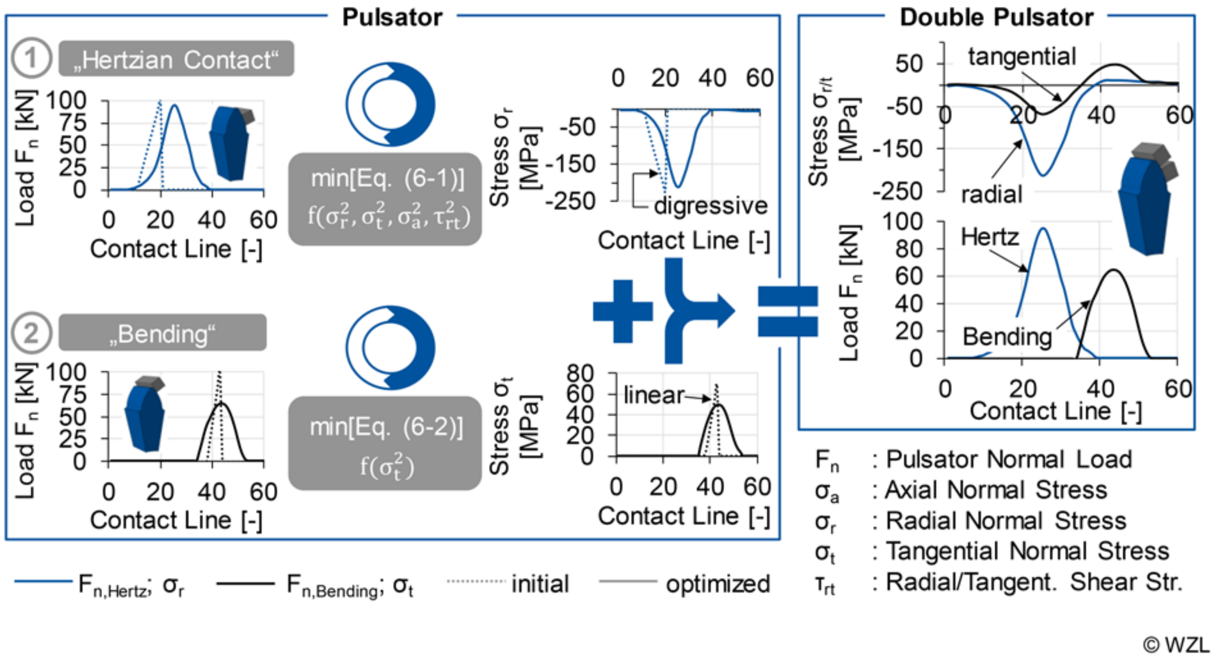

Figure 10 **Method for the Optimization of the Pulsator Load.**

POI can be interpolated to any load within the load ramp out of the initial load.

In order to optimize the load sequence, the quadratic minimization function is defined according to Equation (6-1). The function is based on the difference of all relevant stress components between analogy test and running test. The relevant stress components are all normal stresses and the shear stress in the radial/tangential plane. The two remaining shear stresses are not considered in the optimization function due to their low stress value. The relevant stress components are set in relation to the highest occurring stress (usually radial compressive normal stress). Additionally, weighting constants (A-C) are introduced to be able to weight individual stress components more strongly. The weighting constants are the result of a variation calculation and can be adapted to the specific gear set. Whether the selected weighting constants can be transferred to other gear geometries has to be checked in future work. The optimization algorithm uses the determined interpolation functions and iterates the pulsator load until the quadratic minimization function reaches the smallest possible value.

$$F = (\sigma_{t,real} - \sigma_{t,puls,Bending} - \sigma_{t,puls,Hertz})^2 + \left(A \times \frac{\max|\sigma_{r,real}|}{\max|\sigma_{t,real}|}\right)^2 (\sigma_{t,real} - \sigma_{t,puls,Hertz})^2 + \left(B \times \frac{\max|\sigma_{r,real}|}{\max|\sigma_{a,real}|}\right)^2 (\sigma_{a,real} - \sigma_{a,puls,Hertz})^2 + \left(C \times \frac{\max|\sigma_{r,real}|}{\max|\tau_{rt,real}|}\right)^2 (\tau_{rt,real} - \tau_{rt,puls,Hertz})^2$$

A-C	[-]	Weighting Constants
F	[-]	Target Function
σ	[MPa]	Normal Stress
τ	[MPa]	Shear Stress
a:	Axial	
r:	Radial	
t:	Tangential	
Hertz:	Hertzian Contact/ Primary Actuator	
puls:	Pulsator	
real:	Tooth Contact	

The first optimization algorithm provides pulsator load-sequences and their associated stress tensors for the primary actuator (Pulsator 1, HERTZIAN Contact). The procedure for optimizing the pulsator loads of the secondary actuator is analogous to the optimization of the primary actuator, whereby a different minimization function is used as a basis, Fig. 10. Since there is a linear relationship between the pulsator load at the secondary actuator and the stress at the POI (bending beam theory), a simulation at maximum load at the secondary actuator with subsequent linear interpolation is sufficient. The function only considers the normal stress in the tangential direction, since this stress component is the largest driver of the secondary stress mainly caused by bending, Equation (6-2). With the analogy test rig, it is intended that both actuators can apply load simultaneously in order to enable a smooth transition between primary and secondary stress. This is also considered in the simulation by superposition of the stresses from the optimization of the HERTZIAN contact in the downstream minimization function. In the last step, the pulsator load and stress tensor sequences of both optimization steps are merged. The validation of the determined stress tensor sequence is carried out by a final FE simulation with the calculated pulsator load sequences and subsequent comparison with the quasi-static rolling-sliding simulation.

$$F = (\sigma_{t,real} - \sigma_{t,puls,Bending} - \sigma_{t,puls,Hertz})^2 \qquad (6\text{-}2)$$

F	[-]	Target Function
σ	[MPa]	Normal Stress
t:	Tangential	
Bending:	Secondary Actuator	
Hertz:	Hertzian Contact/ Primary Actuator	
puls:	Pulsator	
real:	Tooth Contact	

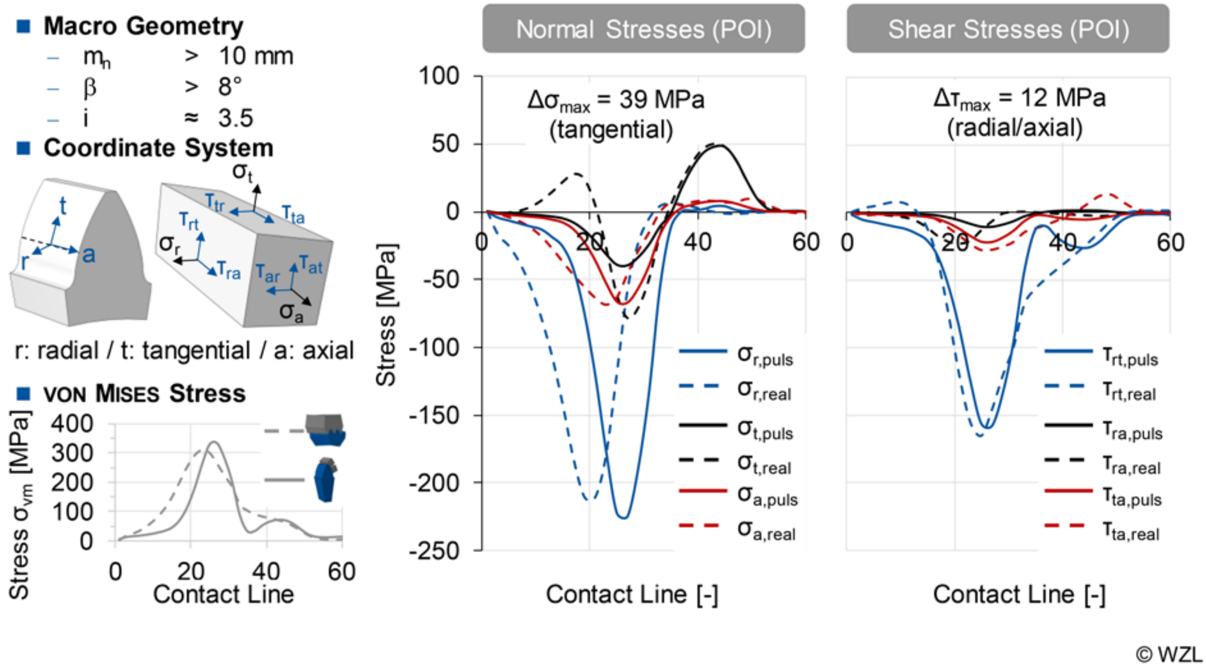

Figure 11 Stress Tensor Sequence, Comparison Real Tooth Contact/ Analogy Concept.

6.2 Stress Comparison between Analogy Concept and Real Tooth Contact

A detailed comparison of all stress components at the POI between the running test and the analogy test is shown in Figure 11. The comparison of the normal stress amplitudes at the POI shows that the maximum magnitude of all stress component amplitudes can be reproduced by the analogy test rig. In particular, the radial compressive stress σ_r due to the HERTZIAN contact, the axial compressive stress σ_a due to the HERTZIAN contact as well as the tangential tensile stress σ_t due to bending can be reproduced in the analogy test. However, there are also deficits due to the stationary positioning of the primary actuator. On the one hand, the tangential tensile stress upstream of the tangential compressive stress σ_t differs because it results from the rolling-sliding contact. An additional actuation of the secondary actuator would be conceivable at this point, but a tangential tensile stress with higher amplitude is induced at a later point in time by the secondary stress anyway. It can be assumed that the upstream tangential tensile stress has a negligible influence on the damage behavior.

On the other hand, the highest amplitudes of the stress components are present at the same time in the analogy test, while the highest amplitudes follow one another in the running test. For this reason, it will also not be possible with the analogy concept presented to exactly reproduce the maximum amplitudes of all normal stress components. By introducing weighting constants in Equation (6-1), an approximation of the tangential compressive stress σ_t to the running test can be achieved. On the other hand, it is visible in the normal stress sequences (Fig. 11) that a higher radial compressive stress σ_r is reached than in the running test. Accordingly, a stronger weighting of the tangential stress σ_t simultaneously leads to higher radial and axial compressive stresses than in the running test. The VON MISES equivalent stress (see Fig. 11, diagram bottom left) shows that there is no significant change in the equivalent stress between the analogy test and the running test despite the time displacement of the stress amplitudes. This is an indicator that no significant change in fatigue behavior is expected from the stationary load application. However, a precise check has to be carried out in experimental analogy investigations. The sequences of the shear stresses at the POI can also be reproduced in the analogy test (Fig. 11, right diagram.) The amounts of all shear stress components are lower in the analogy test than in the running test, whereby the difference for all three shear stress components is $\Delta\tau \leq 12$ MPa. In particular, the shear stress in the radial/tangential plane $\tau_{rad/tan}$, which KONOWALCZYK can only reproduce to a limited extent, shows a better correlation between the analogy test and the running test due to the adjusted primary actuator position and the developed optimization method.

7. Summary and Outlook

The present report deals with the development and validation of a calculation approach for tooth flank fracture load capacity of large-modulus spur and helical gears as well as the development of an analogy test rig for the economic investigation of tooth flank fractures. Currently existing calculation approaches do not sufficiently capture individual influencing parameters on the tooth flank fracture load capacity (possible residual tensile stresses in the core, exact local stress sequence caused by HERTZIAN contact and bending, crack causing material inhomogeneities). For this reason, a method was developed at WZL based on a statistically material inhomogeneity-based approach and the calculation of local material strains, which enables the calculation of a virtual staircase procedure with evaluation of an average endurance strength and a standard deviation [Ref. KONO18]. The method could be validated on the basis of experimental investigations on a large-modulus spur gear ($m_n = 8$ mm, $z_{1/2} = 24/25$, $\beta = 0°$) as well as on the basis of a tooth flank fracture-critical gear from a wind turbine ($m_n > 10$ mm, $\beta > 8°$). The calculated endurance strengths as well as the calculated initial crack locations correlate with the observations from the experiment and practice.

The concept of a double pulsator was developed for the economic investigation of the tooth flank fracture load capacity of large gears in an analogy test. With the developed concept it is possible to reproduce the stress sequence in the tooth flank fracture critical volume of the gear (point of interest). In this report, a method is presented which allows to determine the pulsator load sequences automatically in order to generate an equal stress state between analogy and running test. Thus, gears can efficiently been investigated with regard to tooth flank fracture load capacity, similar to the classical pulsator concept for the investigation of tooth root load capacity.

In future work, a validation of the method by means of recalculating several gear geometries will be focused. In addition, a sensitivity analysis of the calculation approach on the basis of different gear geometries will be carried out to analyze the influencing parameters on the tooth flank fracture load capacity. Within the framework of the DFG research project BR 2905/90 1 the developed analogy test rig is designed and put into operation. Subsequently, first tests with focus on tooth flank fracture generation are carried out on the gear geometries presented in this report.

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Prof. Dr.-Ing. Christian Brecher has since January 2004 been Ordinary Professor for Machine Tools at the Laboratory for Machine Tools and Production Engineering (WZL) of the RWTH Aachen, as well as Director of the Department for Production Machines at the Fraunhofer Institute for Production Technology IPT. Upon finishing his academic studies in mechanical engineering, Brecher started his professional career first as a research assistant and later as team leader in the department for machine investigation and evaluation at the WZL. From 1999 to April 2001, he was responsible for the department of machine tools in his capacity as a Senior Engineer. After a short spell as a consultant in the aviation industry, Professor Brecher was appointed in August 2001 as the Director for Development at the DS Technologie Werkzeugmaschinenbau GmbH, Mönchengladbach, where he was responsible for construction and development until December 2003. Brecher has received numerous honors and awards, including the Springorum Commemorative Coin; the Borchers Medal of the RWTH Aachen; the Scholarship Award of the Association of German Tool Manufacturers (Verein Deutscher Werkzeugmaschinenfabriken VDW); and the Otto Kienzle Memorial Coin of the Scientific Society for Production Technology (Wissenschaftliche Gesellschaft für Produktionstechnik WGP).

Dr. -Ing. Dipl. -Wirt. -Ing. Christoph Löpenhaus is since 2021 working with Flender GmbH as head of production for the part manufacturing plants in Bocholt and Voerde, Germany. Flender is a worldwide leading provider of drive systems especially for wind turbine and industry applications. From 2019-2021 he was Business Development Manager Geared Bearings at Cerobear GmbH, a leading manufacturer of hybrid bearings especially in the aerospace, space, and industry segment. From 2014–2019 he held the position as Chief Engineer of the Department of Gear Technology of WZL, RWTH Aachen with research focus on gear manufacturing, design, and testing. He previously worked with WZL as Team Leader and Research Assistant. His educational background is in the field of Industrial Engineering with a diploma in 2009 and a Ph.D. in mechanical engineering in the field of gear technology in 2015. For his scientific achievements he was awarded the Springorum Commemorative Coin in 2010 and the Borchers Badge in 2016.

Fabian Goergen studied mechanical engineering at RWTH Aachen University. He has bachelor of science and masters degrees in production engineering. He is a research assistant, Laboratory for Machine Tools and Production Engineering (WZL) at RWTH Aachen University (Gear Department), with a focus on Gear Power Density.

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AGMA Foundation

WELCOMES NEW EXECUTIVE DIRECTOR

The AGMA Foundation announced **Mary Ellen Doran** as the Foundation's new executive director. She assumed the role in June 2021.

The appointment comes after the retirement of **Cindy Bennett**, AGMA Foundation executive director, who had held the position since 2014.

Doran is currently the director, Emerging Technology for AGMA and she will hold dual roles for the AGMA and the AGMA Foundation.

"Mary Ellen has more than 20 years of non-profit experience with specific experience in fundraising," states Dean Burrows, chair of AGMA Foundation and president of Gear Motions. "In addition, her outstanding work at AGMA in communications and emerging technology roles, and the positive relationships she has developed over her ten years at AGMA, ensures she is the right fit to move the Foundation forward."

Doran will work with the Foundation Trustees to develop a strategic plan that leans toward the three pillars of the AGMA Foundation: Education & Training; Scholarships; and Emerging Technology specifically tailored for the needs of the gear industry.

"Mary Ellen has the right skill set to help us develop new avenues for fundraising including planned and corporate giving," commented Ruthie Johnston, AGMA Foundation Trustee and president of Croix Gear & Machining. "I look forward to working with her to help sustain and grow the great programs we offer."

www.agma.org

DVS Technology Group

MOVES FORWARD WITH NEW MANAGEMENT TEAM

On July 1, 2021, Dr. Christoph Müller-Mederer began his new role as CEO of DVS Technology AG. He was previously a member of the Executive Board as co-CEO since April 1, 2021, for a three-month transitional period. Müller-Mederer shares the management of the mechanical engineering group from Hessen with his fellow board members Stefan Menz (CFO) and Mario Preis (CTDO).

"The reorganization of the management has been planned for some time, and the handover of the reigns was thorough. Now, the time has come to move forward, initiate important and new developments, and to start writing a new chapter of our success story. I am looking forward to this new challenge," says Dr. Christoph Müller-Mederer on the occasion of becoming the new CEO of the technology group.

The highly experienced executive will focus on five areas in particular:

The further expansion of the DVS Group's internationalization and market penetration, especially in the important Asian and American markets and in the field of future mobility.

Increased focus on solution and customer orientation, in addition to technological expertise. The Group will further strengthen its position as an innovative solution provider.

Sales and service will be further emphasized in the service portfolio to ensure that customers will benefit from the products even more comprehensively and sustainably.

The Group's communication and market presence will be consistently geared towards customers and users, and the Group will present itself as a synergistic unit with a modern image.

Innovation and digitalization in terms of products and processes will be further emphasized. Even today, many customers see our Group as an innovation enabler.

This topic will primarily be the responsibility of Mario Preis, chief technology and digital officer (CTDO). This emphasis as a separate board of management department in conjunction with CEO Müller-Mederer's clear focus on customer orientation is indicative of the direction that the Group will be taking in the coming years: innovative products and processes as well as consistent focus on customers and solutions.

With the appointment of Müller-Mederer as CEO, the current CEO Josef Preis and CSO Bernd Rothenberger will be stepping down and take on an advisory role. "I'm aware of the fact that I have big shoes to fill as the new CEO. But thanks to the outstanding work of my predecessors, many important developments have already been initiated," says Müller-Mederer about the handover. The entire DVS Group thanks Preis and Rothenberger for their decades of forward-thinking management.

The new management will seamlessly continue what the two visionary and pragmatic personalities have successfully created over the last few years.

www.dvs-technology.com

Mitutoyo

PARTNERS WITH ATLANTIC TECHNICAL COLLEGE

Mitutoyo America Corporation is pleased to have partnered with Atlantic Technical College in Broward County, Florida, as a major supplier and supporter of its machining technology course.

Atlantic Technical College is a magnet school and one of three technical colleges, which are all part of the entire Broward County Public School System. The campus trains junior and senior high school students and adults during the day program. The college also runs a machining apprenticeship program in the evening.

The Machining Technology Class provides students with an industry overview, teaches how to set up and operate machines, including CNC machines, micrometers, and gauges, and provides the basics of CNC programming, use of CAD/CAM processes, and set up and performance of advanced level machining.

"We have seen an increased interest in the program over the last few years, as more students recognize that a trade can be a great long-term career," states Kevin Finan, the Machining Technology instructor. Finan has been an instructor for eight years after working in the industry for 25 years. "The program is a great opportunity to learn a skill set that is very much needed today." The program can accept 24 high school students (split between juniors and seniors) and twelve adult students every school year.

Finan was looking to improve the equipment in his classes and specifically wanted to add a CMM to the program. The Mitutoyo MiSTAR 555, which is the company's newest, fastest, and most compact shop floor CNC CMM is perfect for students to get some experience on.

"Metrology is a significant part of the success of every industry ranging from automotive, medical, aerospace and consumer goods," states Matt Dye, president of Mitutoyo America Corporation. "Precision measurement provides critical data for improving the manufacturing process, which is why Mitutoyo has a strong focus on helping educate the workforce and future generations at all experience levels. We are excited to support programs such as Atlantic Technical College. This course work will provide invaluable training and help lay the foundation for a successful career path."

Finan worked directly with Mitutoyo America distributor Chris Sudetic, from Measurement Supply Company to purchase and install the MiSTAR 555 and provide support throughout the process. Additionally, the class also works with other Mitutoyo tools and equipment on the shop floor, including a wide variety of micrometers, calipers, height gages and various other measuring instruments.

"I love working with schools because the future is right on this shop floor, and it's been especially gratifying to see so many adults learn new skills and find a whole new career for themselves," Sudetic says. "I totally appreciate a machine trades program that has a large portion of their curriculum dedicated to Metrology; everything from basic hand tool measurement to CMM's measuring 3D data. We need more of these types of facilities to help fill the multitude of open Quality Control jobs throughout the manufacturing sector."

Mitutoyo has a long-standing tradition of working with institutes of higher learning. The company has established relationships with trade schools, two- and four-year programs around the United States and continually look for ways to contribute to the advancement of manufacturing in the U.S.

www.mitutoyo.com

Neugart

RECEIVES SCHNEIDER ELECTRIC SUPPLIER AWARD

Neugart is currently the only company to have received this year's "Schneider Electric Supplier Award" in the "Quality" category. With this award, the French electrical engineering group, Schneider Electric, recognizes outstanding achievements from among its approximately 15,000 suppliers worldwide.

The jury based its decision in favor of Neugart particularly on the "ability of this supplier to deliver high-quality products day after day" and also highlighted the excellent service level.

The two Managing Directors, Bernd Neugart and Thomas Herr, accepted the award on June 3 at a virtual event - on behalf of all employees, as they emphasized: "This award shows once again how important the work and commitment of each individual is. The professionalism of Neugart and the flexibility provided to this internationally positioned company with our products and warehousing close to production makes a significant contribution to Schneider Electric achieving the highest customer satisfaction ratings continually, allowing it to remain competitive in the long term."

As a gearbox manufacturer, Neugart has been one of Schneider Electric's preferred suppliers for many years. The reasons for this longstanding relationship are: first, the expertise gained from over 90 years of experience and more than 400,000 planetary gearboxes delivered worldwide annually. And, secondly, a comprehensive overall package of gearbox hardware, tools, supply chain and services.

www.neugart.com

Compact Orbital Gears

WINS SMALL EMPLOYER OF THE YEAR

Compact Orbital Gears, which has a workforce of 43 based in Rhayader, mid-Wales, was named the Small Employer of the Year at the Apprenticeship Awards Cymru 2021 virtual ceremony.

The company designs, manufactures and develops bespoke gear solutions for aerospace, automotive and clean energy customers. This ability to offer bespoke solutions is key to the company's success.

Tricia Evans, Compact Orbital Gears' financial controller, said the company was delighted to be recognized for its commitment to providing quality apprenticeships.

"We are thrilled to have won the award because it recognizes the dedication of all those involved in the Apprenticeship Program at the company," she added.

"It's a huge achievement for a small, Mid Wales company to be recognized as a top employer of apprentices within the community and testament to everybody involved in the program, including Myrick Training and NPTC Group of Colleges.

"Apprentices are absolutely essential to our business. We have to grow our own skilled employees here in Mid Wales which supports the local community."

Celebrating outstanding achievement in training and apprenticeships, the awards saw 35 finalists compete in 12 categories on June 17.

The awards showcased businesses and individuals who have excelled on the Welsh Government's Apprenticeship and Traineeship Programs and gone the extra mile to achieve success during these unprecedented times.

Jointly organized by the Welsh Government and the National Training Federation for Wales (NTFW), the awards had Openreach, the UK's digital network business and passionate supporter of apprenticeships, as the headline sponsor.

The Apprenticeship Program in Wales is funded by the Welsh

Government with support from the European Social Fund. Welsh Government Apprenticeship Programs have benefitted 5,645 people across Mid Wales since May 2016.

Established in the 1960s, Compact Orbital Gears is proud of its highly skilled workforce, family ethos and long history of recruiting apprentices from within Mid Wales.

The company currently has three apprentices and five other young employees working towards Further Education qualifications. Myrick Training and NPTC Group of Colleges Newtown Campus deliver engineering and business and administration qualifications.

A focus on growing its own pool of skilled engineers is paying off for Compact Orbital Gears at a time when there is a UK shortage. Its Apprenticeship Program provides technical training, supported by in-house specialist instruction with experienced employees sharing their skills and knowledge with apprentices.

Providing opportunities for development ensures that staff turnover at Compact Orbital Gears is very low and the company's long-term aim is to introduce state-of-the-art, computer aided machinery which is ideally suited to apprentice development.

Believing that organic growth is key to the success of the business, the company also provides work placements for university graduates and budding engineers in local schools.

Congratulating Compact Orbital Gears, Minister for the Economy, Vaughan Gething, said: "Our award winners have excelled via the Welsh Government's Apprenticeship and Traineeship programs and gone the extra mile to achieve success during unprecedented and extremely challenging times.

"This Welsh Government has ambitious recovery plans to ensure there is no lost generation as we rebuild a new version of Wales that becomes an engine for sustainable, inclusive growth. I believe apprenticeships will be vital as we emerge from the pandemic.

"That's why the new Welsh Government has committed to creating a further 125,000 Apprenticeship places over the next five years. We are a small country, but we have big ambitions, and our aim is to create a culture in Wales where recruiting an apprentice becomes the norm for employers."

www.compactorbitalgears.com

API and QTE

ANNOUNCE METROLOGY PARTNERSHIP

API and QTE Manufacturing Solutions have announced a partnership to make API's laser-based dimensional metrology equipment available through QTE's support network in Missouri, Kansas, Tennessee, Arkansas, Oklahoma, and Southern Illinois.

As manufacturing projects continue to scale up in the Midwest and Southcentral US (both in terms of volume and tolerances), demand for comprehensive metrology solutions to support these projects is increasing as well. To match their shared company visions of helping manufacturers be successful and profitable, API and QTE are bringing their areas of expertise together.

API and QTE have been serving customers in every manufacturing industry (from automotive to aerospace to oil and gas and more) for more than 60 combined years, providing high quality dimensional metrology equipment, software, and services. This partnership brings all of those resources under one roof, including API's state-of-the-art Radian Laser Tracker series, and QTE's technical expertise across several major software platforms. For both companies, the partnership, was a natural fit.

"API is very customer focused and that fits with our company values," says Jason Quinn, president of QTE. "Being privately held is important to maintain that concept as a priority, especially compared to the competition. We saw the opportunity to simplify the process for customers by having a one stop shop for local technical expertise on hardware and software."

"QTE has been a valuable support partner for us for years on the software side, so we have seen firsthand their industry experience and technical expertise in manufacturing metrology," says Ron Hicks, API's vice president of North American sales and services. "That experience gave us great confidence that they could provide boots on the ground support for our products and the very important work taking place in Missouri, Kansas, Tennessee, Arkansas, Oklahoma and Southern Illinois."

API's equipment is available for demonstration and purchase throughout QTE's network effective immediately.

www.apimetrology.com

Emuge

UPDATES BRAND NAME TO EMUGE-FRANKEN

Emuge Corp. has announced that moving forward, the company brand name will be EMUGE-FRANKEN. With the exception of North America, the EMUGE-FRANKEN brand name has been in use internationally since 1958, when Emuge acquired Franken, a German manufacturer of milling tools. EMUGE-FRANKEN is the leading manufacturer of a wide range of high-performance end mills and has over 100 years of milling innovation, expertise, and experience. The EMUGE-FRANKEN brand in North America will now be associated with the company's full line of cutting tool solutions ranging from taps, thread mills and end mills, to carbide drills, tool holders, precision workholding/clamping devices, and other rotary cutting tools — over 40,000 manufactured items sold through distributors worldwide.

When Emuge's U.S.A. footprint was established in 1984, the strategy was to initially introduce the marketplace to core Emuge tapping and thread milling products, followed by broader product expansion. The Emuge brand experienced substantially increased awareness, growth and success since then, especially in core threading tools.

"North America became very familiar with the Emuge brand associated with threading tools for years, but the name Franken and associated end mills were known to a lesser extent. However, in recent years our EMUGE-FRANKEN end mill product sales have grown extensively. As we aggressively continue the expansion of our milling tool portfolio including the manufacture of end mills here in the U.S., as well as in Germany, we have decided to formally change the brand name to EMUGE-FRANKEN, as the company is known in Germany and throughout the world," said Bob Hellinger, president of Emuge Corp. "EMUGE-FRANKEN, the innovator of Circle Segment end mill technology, is dedicated to further developing the end mill program to meet evolving market requirements."

Today the EMUGE-FRANKEN North American headquarters is a newly expanded 50,000 square foot state-of-the-art facility in West Boylston, MA with a Technology and Training Center, tool reconditioning, and manufacturing, including end mills for advanced machining applications such as aerospace, medical, automotive, energy and more. The facility provides additional capacity to domestically manufacture special solid carbide tooling and other standard solutions within the EMUGE-FRANKEN milling tools portfolio.

www.emuge.com

Index

ADDS MACHINERY SOLUTIONS AS A DISTRIBUTOR

Index Corporation, as part of its continuing revitalized sales and service initiative, has partnered with Machinery Solutions, Inc. (Lexington, SC), to cover North Carolina, South Carolina and Virginia for the leading precision turning machine tool builder.

"Our distributor network plays a vital role in providing a high level of responsiveness at a local level," said Cris Taylor, president and CEO of Index in North America. "We are very selective in choosing distributors and Machinery Solutions meet the high standards we set for our partners. Their addition to our network will be a significant sales and service asset to Index customers in the southeastern US."

Well-established experts in its region, Machinery Solutions celebrates 40 years in the machine tool industry this year.

Us.index-traub.com


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Are you All-In on e-Mobility?

Matthew Jaster, Senior Editor

Collectively, 761,100 electric-drive vehicles were sold in the United States in 2020 according to the U.S. Bureau of Transportation. This includes electric, hybrid electric and plug-in hybrid electric vehicles. Global plug-in vehicle sales reached over 3.2 million in 2020. Despite a global pandemic, Europe — in particular — thrived as registered electric vehicles soared in the calendar year to the tune of 137 percent more than in 2019. (*EV-volumes.com*)

How does this happen? Green incentives, strict carbon mandates, intense promotion and the fact that many electric vehicles today are more attractive and perform much better than their gas-guzzling counterparts. So why are most automakers posting bold electric vehicle press releases and promises to makeover the entire industry by 2030? More importantly, can they actually pull it off?

The Technology Strategy

Volkswagen, for example, plans to maximize the potential of electric vehicles in terms of range, space and dynamics – and offer electric mobility at affordable prices. Three fields of technology play a key role in this major e-offensive: Firstly, a solid charging infrastructure, even over longer distances. Secondly, a unique production platform on which e-cars can be manufactured at competitive prices. And third, a newly developed battery system that enables scalable ranges for different customer and driving profiles. (*www.volkswagen.com*)

Increased Investments

Here in the States, General Motors recently announced that the company will increase its EV and AV investments from 2020 through 2025 to $35 billion, representing a 75 percent increase from its initial commitment announced prior to the pandemic. The company's enhanced commitment will accelerate its transformative strategy to become the market leader in EVs in North America; the global leader in battery and fuel cell technology through its Ultium battery platform and HYDROTEC fuel cells; and through Cruise, be the first to safely commercialize self-driving technology at scale. (*www.gm.com*)

A Charging Infrastructure

The European CEO Alliance has issued policy recommendations supporting a progressive and ambitious push to achieve climate neutrality. Tackling climate change requires strong collaboration between the public sector and industry. Decarbonizing mobility, transport and buildings will be the major challenges. For the transport and mobility sector, electric mobility for passenger cars, light vehicles and heavy-duty vehicles has proven to be the most efficient technology in terms of energy consumption and emission reduction. To foster the entire ecosystem around electric mobility, members of the CEO Alliance have initiated cross-sectoral projects to ramp up battery production and create a charging infrastructure across Europe with a goal of cutting carbon emissions by 55 percent by 2030. (*www.volkswagen.com*)

The Gear Industry Snapshot

AGMA recently published a white paper: A Gearing-Centric Snapshot of the EV Space written by members of its Electric Drive Technology Committee. The paper highlights drivetrain design, technology, machine tools, new manufacturing processes and the quest for the silent drivetrain and is a must read for the gear and power transmission market: (*members.agma.org/ItemDetail?iProductCode=ELEC_DRIV_PAPER&Category=EMER_TECH&WebsiteKey=1fa29655-e8c0-41f6-b6a8-418a374ae587*)

Looking Outside of Electric Vehicles

Biofuels are still making headlines with many pundits suggesting that the key to transportation in the future is going to take resources outside of EV. Plus, there's still a fair share of consumers bulking at EV costs, maintenance and range anxiety (imagine driving down a highway and worrying you may not make it to your destination without charging up). In addition, how will driving dynamics come into play? Does the weight of the batteries take some pleasure away from turning corners? Can the entire electric vehicle fleet of the future perform like the Porsche Taycan 4S — a vehicle that provides an extremely comfortable ride without much fuss with a sticker price of $191,000 MRSP?

Show Versus Tell

EV commitments have been made. The promises promised. The automobile industry as we know it is about to turn upside down, inside out and provide a whole new vehicle strategy moving forward.

Are we in or out?