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Grinding Burn Testing



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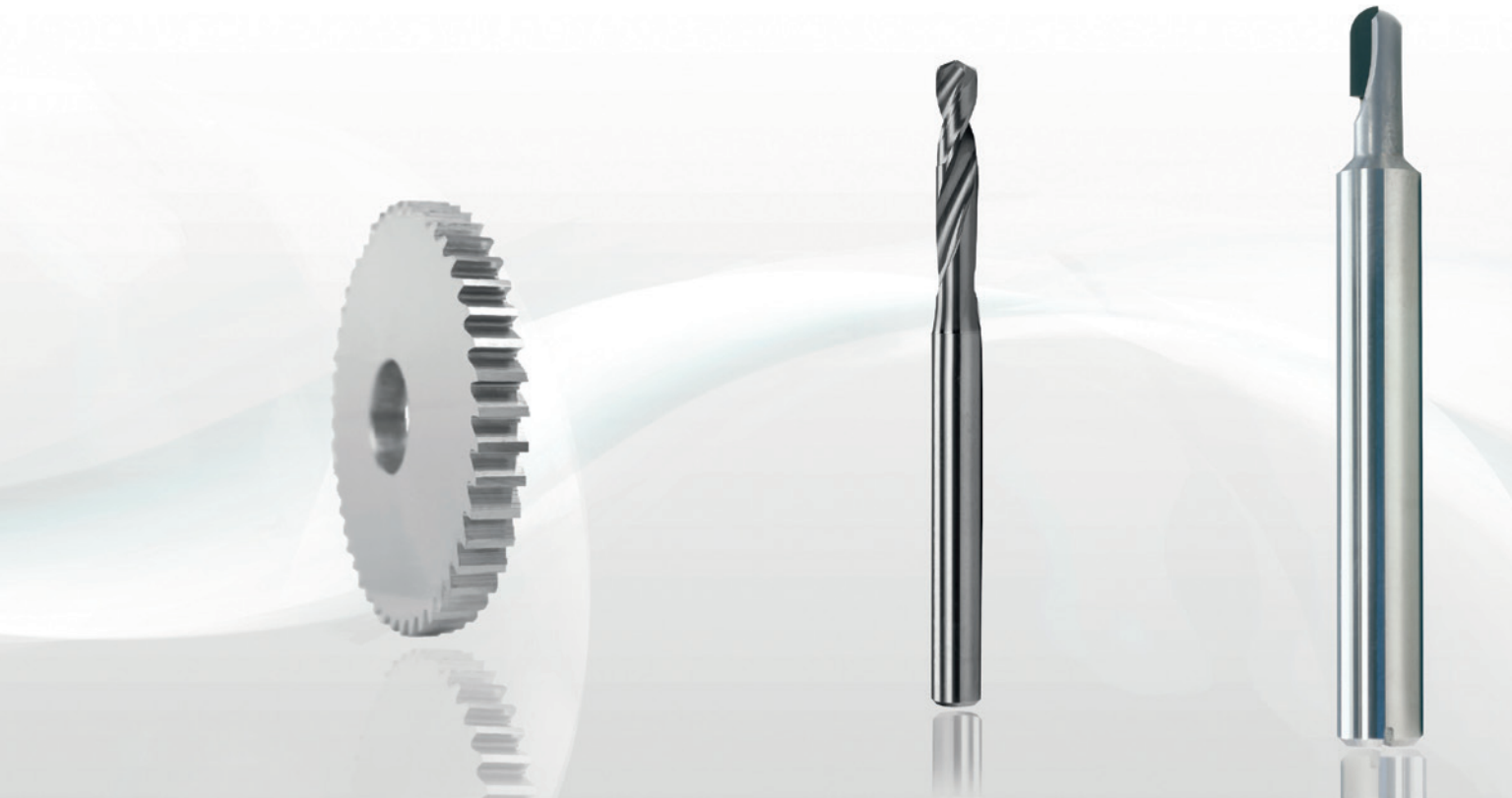
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The American Gear
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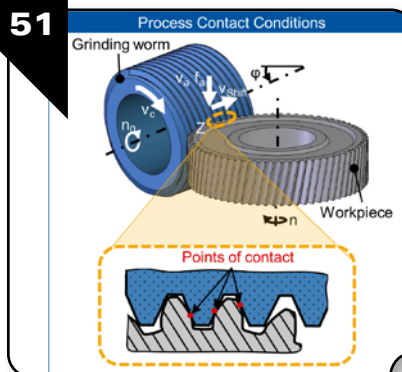
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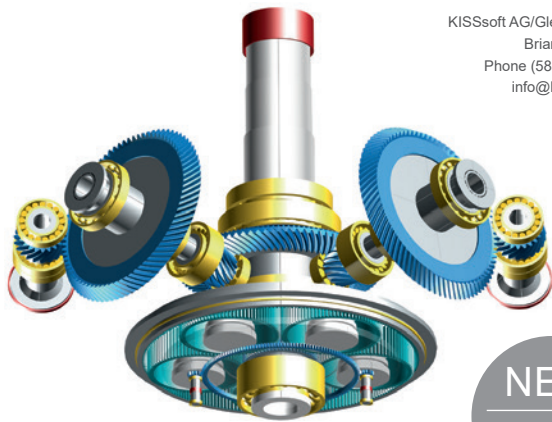
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- Bearing contact stress with modified raceways
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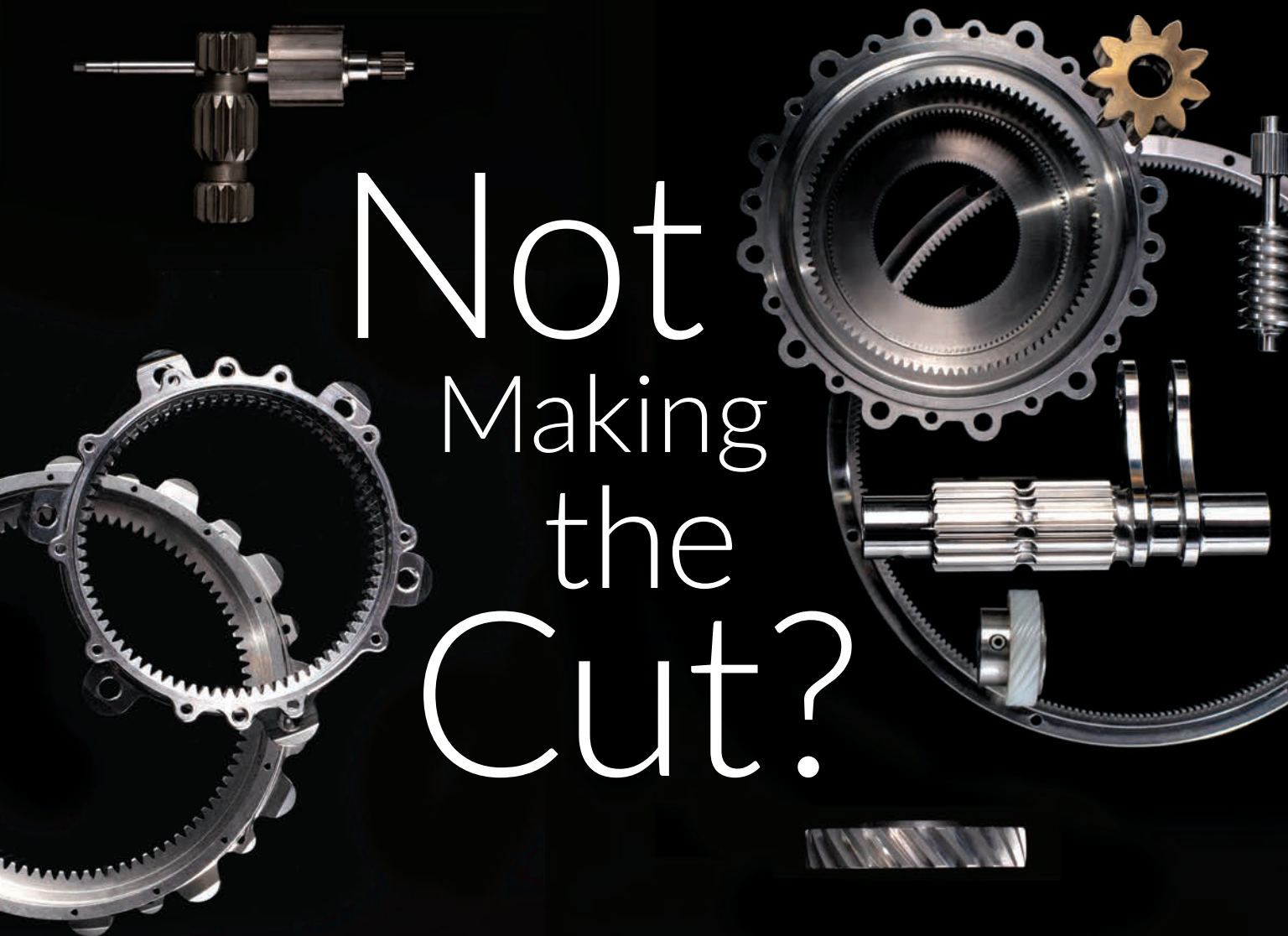
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GT Videos

DMG Mori Linear Pallet Pool for Multi-Machine Automation

This DMG Mori video looks at a linear pallet pool for multi-machine automation with up to 10 machines, 5 setup stations and up to 99 pallets. Ideal automation for multiple machines and short pallet changing time due to twin fork shuttle technology. Learn more here:

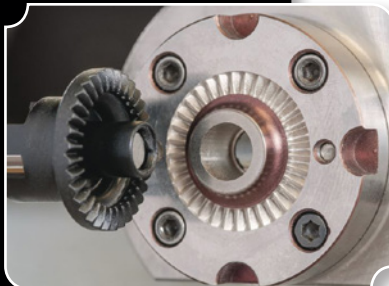


geartechnology.com/media/videos/play/257

GT Revolutions

Profile: Gleason Plastic Gears

In this interview, we learn about Gleason Plastic Gears (GPG), a division of Gleason Corporation that specializes in designing and manufacturing plastic gears using their proprietary no-weldline technology. GPG has diversified its customer base and serves various industries such as automotive, medical, electronics, home and leisure, marine, education, and hobby.



geartechnology.com/blogs/4-revolutions/post/30274-profile-gleason-plastic-gears-gpg

State of the Gear Industry Perspectives: Kapp Technologies

State of the Gear Industry Perspectives takes an in-depth look at the challenges and opportunities in gear manufacturing today and in the future. Our sixth installment online is an interview with Shane Hollingsworth, vice president of sales, Kapp Technologies.



geartechnology.com/blogs/4-revolutions/post/30207-state-of-the-gear-industry-perspectives-kapp-technologies



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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 38 years' worth of technical articles can be found online at geartechnology.com. Michael continues working with the magazine in a consulting role and can be reached via e-mail at michael@geartechnology.com.

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EVs are Driving Technology in the Gear Industry



Publisher & Editor-in-Chief
Randy Stott

A significant amount of work is being done to advance the technology of gears specifically for use in electric vehicles. No longer hidden by the noise of the internal combustion engine, the transmission has taken center stage as the noisiest component in most electric-driven cars.

And it's not just that these transmissions are too loud. It's that they often produce a high-pitched whine that's irritating to many drivers. Solving that noise problem has become one of the major tasks of those who develop technology for making gears. All the major machine tool manufacturers and research institutions are working on solutions specifically for EV gear trains.

So it's no wonder that this issue, with its focus on grinding and abrasives, also turned into an issue with a focus on electric drives. Gear grinding has long been one of solutions to gear noise. Make your gears more accurate, and they'll have less transmission error and run quieter. But today, grinding is also being used in creative ways to tailor the gear shape in an effort to eliminate the whine created by EV gearsets running at 20,000 rpm.

In the article "Technology Advances for Continuous Generating Gear Grinding in EV and More" (p. 18), the experts at Norton|Saint-Gobain Abrasives explain how electric vehicle transmissions require not just grinding, but also polishing to achieve the necessary surface finish. The article also explains how this can be accomplished in a single setup with a dual-purpose grinding and polishing tool.

In Gleason's article, "Noise Analysis for e-Drive Gears and In-Process Gear Inspection" (p.26), the authors take a deep dive into how inspection processes like roll-testing and laser

inspection can be incorporated directly into the production flow to fine-tune the manufacturing in a closed-loop system.

DVS Technology Group presents the article "Internal Gearing, Deburring, Honing and the Advancement of Robotic Cells," which describes the latest technology from Prävema to improve production efficiency and quality for stepped planetary gears and planetary ring gears, some of the most critical components in EV transmissions. This technology combines gear skiving with chamfering and deburring in a single machine and setup.

Of course, there is much more to the gear industry than just electric drives or even vehicle transmissions, so there's plenty of additional content as well, including articles on grinding burn detection (p. 36), crowned spline joints (p. 43) and force modeling in generating gear grinding (p. 51).

***Gear Technology* strives to bring you the latest, most relevant technical information for the gear industry, and we hope this issue demonstrates that commitment. As always, we thank you for reading and encourage your feedback.**

Feel free to contact me via e-mail at stott@agma.org.

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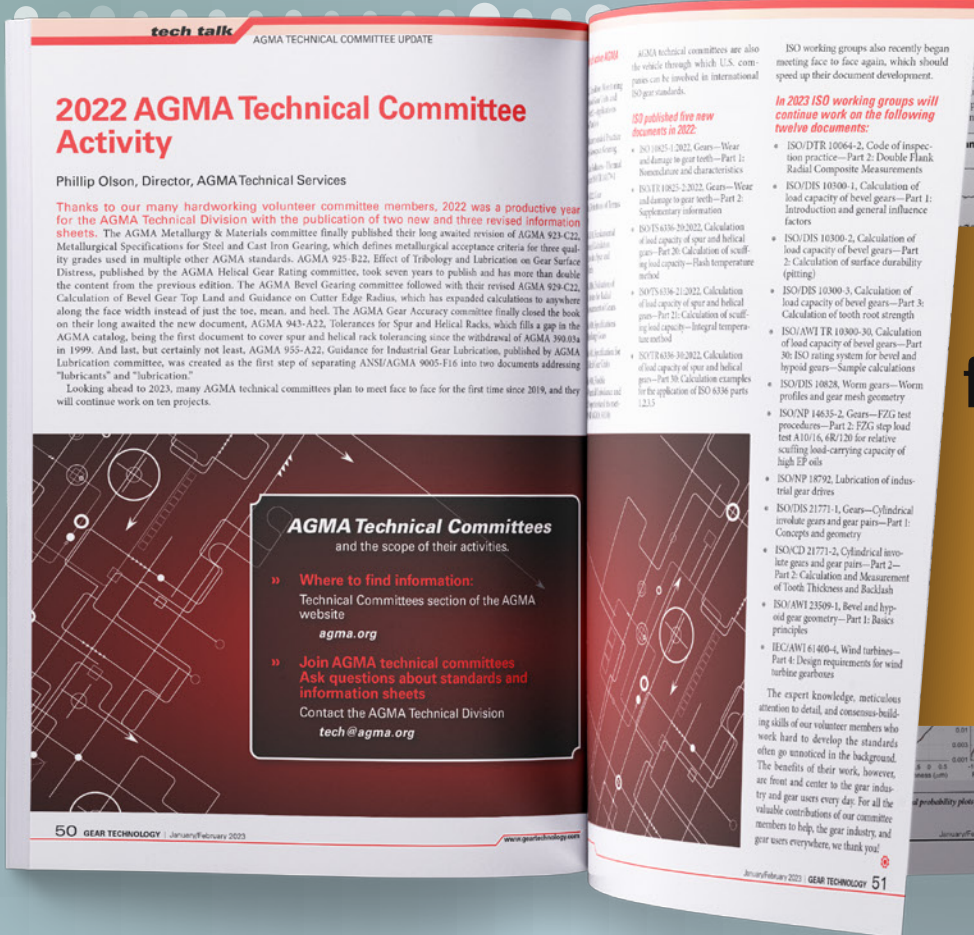
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Energy production, energy efficiency, energy crisis—the topic of energy concerns us today more than ever. The growth of clean energy technologies is relentless, companies want to manage their energy budgets efficiently and the carbon footprint of products will probably become a sales criterion soon.

Up to the end of the 19th century, energy was generated by means of human and animal power. The rapid progress brought about by the industrial revolution meant that faster, more efficient solutions were found. We're talking about all kinds of special small power plants.

WFL is also establishing itself in this sector with the complete machining of key components for small power plants: turbine, gear, and generator shafts as well as valves and pump wheels have the highest shape and position tolerances and place high demands on their machining process. For the efficient production of such workpieces, a Millturn machine masters the necessary special technologies such as the milling of special profiles or large gears as well as the grinding of shaft parts including concentricity and roundness measurement—all in compliance with the highest precision requirements.

The Machining Process

The untensioned blank in the generator shafts is often pre-turned and turned into a Millturn with welded-on bars. As an alternative to welded-on bars, some generator shafts are also made from solid material. One of the most important aspects of machining the welded-on bars is ensuring that the blank is aligned

in the circumferential direction in such a way that the longitudinal grooves are inserted in the center of the bars. Thanks to the WFL measuring cycles, the measurement of this blank is fully automated, with it even being possible to determine and correct welding errors. In the shaft area, beveled $\varnothing 60$ mm holes must be inserted, which meet the $\varnothing 100$ mm center hole at a depth of approx. 500 mm. All holes can be inserted in the Millturn without any tools, with very elegant rounding of the edges of the holes being carried out too. The precise outside diameter of the bars that is to be machined is finished in IT7 quality by means of turn-milling. Bearing seats on the pins are rotated with maximum precision and subsequently rolled. The WFL in-process measuring guarantees process reliability, even with IT6 quality.

Savings Guaranteed

The potential savings when machining generator shafts in a Millturn are considerable compared to sequential manufacturing on different machines: a full 60 percent can be saved by complete machining in the process chain. In the case of set-up time, the savings are as high as 80–90 percent.

wfl.at/en/

Sandvik Coromant

EXTENDS RANGE OF COROMILL DURA SOLID END MILLS

Cutting tool specialist Sandvik Coromant is expanding its line of CoroMill Dura versatile solid-end mills with aluminum-specific tools for flexible aluminum roughing with finishing capabilities.

“These new, truly versatile end mills for aluminum machining are developed to have excellent capabilities in all applications,” says Antti Wikström, global product manager, solid end mills, at Sandvik Coromant. “Stable cutting, small burr, good surfaces and minimal vibration is a combination that's hard to beat for a versatile end mill like this.”

“One of the main advantages of the new CoroMill Dura aluminum-specific end mills is their versatile performance

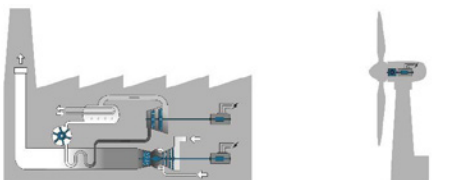
in all different types of roughing applications, while also offering finishing capabilities,” Wikström continues. “Up to $2 \times D$ full slot, pocketing, 5–20 degrees ramping, shoulder milling and more—all with the same end mill.”

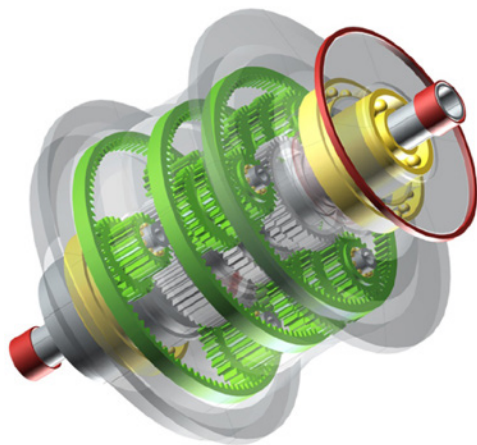
Another advantage is Sandvik Coromant's unique WhisperKut helix concept, in which each flute is carefully oriented, unequally spaced from the others and has its own individually adapted helix angle, effectively breaking up harmful harmonics. This design successfully eliminates vibrations, resulting in silent, safe, and efficient machining.

The standard assortment offers diameters from 2–25 mm, depths of cut between $1.5\text{--}3 \times D$, neck options, extended reach cutters, and sharp and corner radius styles. Tailor Made options include coated grades for more abrasive aluminums, specific diameters, corner designs and shank options.

To make tool selection easier, the online CoroPlus Tool Guide for CoroMill Dura assists with tool and cutting data recommendations. “Having the right cutting data is, of course, a prerequisite for both secure and efficient machining,” says Wikström. “With the CoroPlus Tool Guide for CoroMill Dura, we can give the most accurate starting values for a specific application. And, if you have CAM software with the CoroPlus Tool Guide plug-in, it makes it even easier—you get the most relevant cutting data recommendations directly into your CAM program.”

sandvik.coromant.com





KISSsoft

RELEASE 2023 NOW AVAILABLE

The new *KISSsoft release 2023* comes with numerous novelties. Among others, Gear Mesh Frequencies (GMF) can now be calculated for cylindrical and bevel gears. GMF results are visualized in two different diagrams, i.e., GMF versus rotational frequency of the reference gear, and GMF versus

amplitude. KISSsoft will also introduce more features in the new release such as:

- Bearing frequencies
- Crowned spline 3D geometry
- Fine sizing with additional variation possibilities
- Data exchange GAMA / GDE 3.2 / REXS 1.4
- FKM shaft rating with rainflow matrix
- and many more

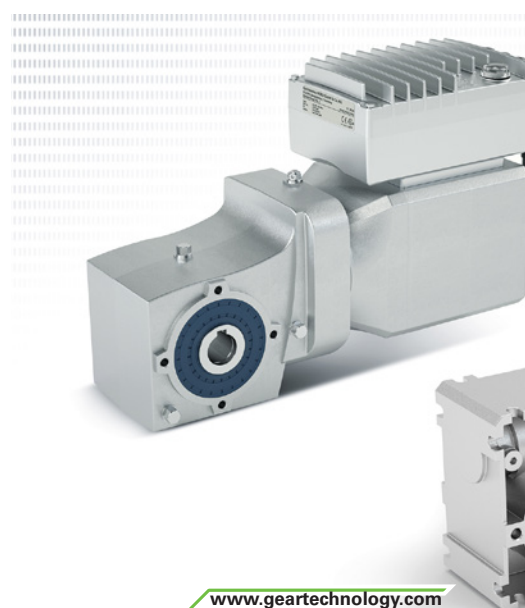
kisssoft.com

Nord

HIGHLIGHTS DRIVE SOLUTIONS AT INTERPACK 2023

At Interpack in Dusseldorf, the drive specialist Nord Drivesystems recently presented its wide product portfolio and great expertise in the packaging industry— from decentralized frequency inverters to energy-efficient drives to high-performance surface treatments for washdown or spray areas.

Whether primary, secondary or end-of-line packaging: For all stages in the packaging process, Nord implements economical, sustainable and tailor-made drive solutions that optimally meet the relevant application-specific requirements and, at the same time, can contribute to a considerable reduction of the Total Cost of Ownership (TCO). The exhibition highlights included the decentralized frequency inverter Nordac On/On+, the IE5+ synchronous motor, the patented DuoDrive geared motor and the nsd tupH surface treatment.



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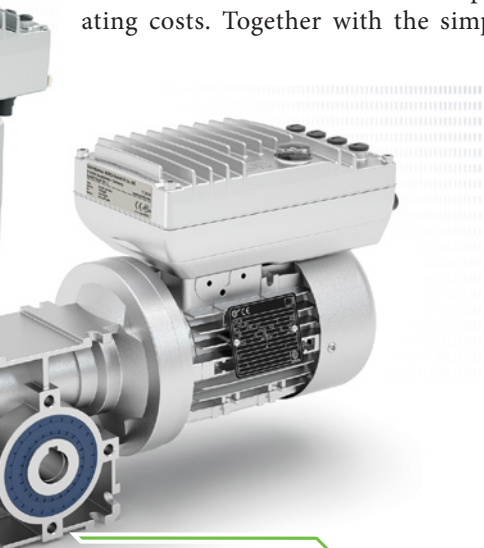
The decentralized frequency inverter Nordac On/On+ is characterized by an integrated Ethernet interface (Profinet, Ethernet/IP and Ethercat can be set via parameters), full plug-in capability and a very compact design. The smart inverters are ideally suited for integration into packaging machinery, saving space as well as the extensive motor cable wiring required for centralized frequency inverters. There are two versions available: Nordac On has been designed for use with asynchronous motors whereas Nordac On+ is intended for the combination with high-efficiency IE5+ synchronous motors.

IE5+ motor generation: Efficiency at a new level

With the IE5+ synchronous motor, Nord is setting new energy efficiency standards. Thanks to permanent magnet synchronous motor technology (PMSM), it achieves an efficiency of up to 95 percent—and this is relatively constant over a wide speed and torque range. The IE5+ motor thus provides an optimal energy consumption performance in partial load and partial speed ranges and even tops the highest defined energy efficiency class IE5.

DuoDrive: Seamless integration of gear unit and motor

The patented DuoDrive is an integrated gear unit/motor concept that covers power ranges of up to 3 kW. It combines the high-efficiency IE5+ motor and a single-stage helical gear unit in one housing. The constant motor torque over a wide speed range allows for consistent variant reduction and reduction of operating costs. Together with the simple



plug-and-play commissioning, this results in a significant reduction in the Total Cost of Ownership (TCO) in comparison with existing drive systems. The unventilated wash-down design with smooth surfaces meets the most stringent hygiene requirements and ensures optimum cleaning.

nsd tupH surface treatment: An alternative to stainless steel

The nsd tupH surface treatment is available for Nordac On/On+ as well as the IE5+ synchronous motor and the

DuoDrive geared motor. Thanks to a special method, the surface is made corrosion-resistant and harder and makes aluminum behave like stainless steel with regard to corrosion protection. This is not a coating, but a surface treatment that creates a protective layer which is permanently bonded to the substrate material. So, nothing can detach or flake off. The drives are easy to clean and largely resistant to acids and alkalis.

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Seco Tools

3D MANUFACTURING CREATES NEW OPPORTUNITIES

Additive manufacturing (AM), or 3D printing, allows Seco Tools to create products that would otherwise be difficult or impossible to manufacture. The advantages include shorter lead times, improved tool life and increased sustainability.

The development and manufacture of prototypes for metal-cutting machining by means of additive manufacturing is becoming increasingly commonplace in the operations of Seco Tools. One of the main strengths of this manufacturing method is the possibility of making specialized customer-specific tools and solutions that are difficult to achieve through conventional manufacturing. Above all, AM technology will come into its own when producing tools that must be designed in a special way. This may involve complex geometries or other customizations to customer-specific needs.

Examples of such customizations include making the tools lighter, which improves the vibration-dampening properties, or provide them with better cooling possibilities. "By directing the coolant to hit the cutting edge at just the right place, we can significantly extend the tool's useful life. With AM technology, coolant can be guided to locations that would otherwise have been impossible," explains Ingemar Bite, R&D specialist at Seco Tools, who also believes that AM technology is helping to shorten lead times. "AM allows for us to produce geometries that require less manufacturing steps, which often results in shorter lead times and thereby, faster deliveries."

Increased sustainability

AM technology will also open up the possibility of repairing broken tools in the future, by removing dysfunctional components and printing them anew. This could, for example, involve tool components or the reuse of different types of machine-side connections. This is particularly a good idea in terms of the environment and

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sustainability. Another advantage with AM technology, compared with traditional manufacturing in this context, is that there is less waste of materials. Overall, not as much material is used for AM manufacturing and any leftover powder can be reused.

Additive manufacturing could thus be a time-efficient and cost-efficient method for one-of-a-kind production and prototype development. However, it could also work excellent for large-scale manufacture of standard products. Seco Tools is already manufacturing cooling clamps for its Jetstream tools through 3D printing.

“The cooling clamps have a complex form with curved cooling channels and are thus well-suited to this type of manufacture,” says Bite.

Continuous improvements

The R&D department at Seco Tools works continuously to improve the use of AM technology for the development and manufacture of new and existing products. The company is constantly looking into ways to improve its products and how to best utilize AM technology. “We like to collaborate with our customers on these efforts and to conduct tests together with them,” says Bite, who is of the opinion that even the materials can be developed. “The materials that are currently used in AM are no different in nature than those being used in conventional manufacturing, and the technology works well with many different metals. In the future, we will add even more and superior materials, while regularly adapting our equipment and upgrading hardware and software as needed,” he concludes.

Different methods can be used for additive manufacturing; the one that Seco Tools uses is called SLM (Selective Laser Melting). Here, lasers and a bed of metal powder are used to construct the products. In an SLM machine, a roughly 20–60 µm layer of powder is spread, and then processed by a laser. This process is repeated, layer by layer. Once all the layers are in place, the excess powder is removed and the product goes into post-processing for its final form.

secotools.com

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manufacturing is all about—and why Suhner is expanding its suite of robotic grinding accessories and tools with the fully electric EFC-02 active compliance system.

Smart Automation for High Surface Quality Results

Exact contact force with the surface is the single most crucial factor in robotic grinding, sanding and deburring processes. It's also one of the biggest challenges, especially for hard-to-reach areas. Thoughtfully designed based on Suhner's decades of material removal process know-how—the EFC-02 helps overcome that challenge.

As with any end-of-arm tooling, the EFC-02 connects a grinding machine—angle grinders, orbital sanders, angle polishers, straight grinders and others—to the robot. What makes Suhner's system unique, however, is its compact design and fully electric operation.

The lightest and smallest in its category, the EFC-02 can be used for material removal or surface finishing even in tight or narrow spaces often found when processing stainless tanks and vessels for the food and pharma industries or fiberglass bathtubs and sinks. The all-electric technology also allows high-frequency measurements to monitor force and acceleration throughout the process. An advanced control algorithm then dynamically adjusts force and automates grinding processes based on pre-programmed parameters.

The result? Constant contact force with each movement from start to finish for a consistent surface quality—regardless of the surface type, shape, size or orientation.

In Line with Industry 4.0 Standards to Support Digital Transformation

Robotic processes are no longer just for mass production. As technology has evolved, robotics have become easier to use and more flexible—making them ideal for both small- and medium-sized manufacturers looking to add efficiency, lower production costs or both.



Suhner engineered the EFC-02 with this in mind, giving users:

Simple robot programming for setting up even complex processes using an intuitive web-based interface or Fieldbus communication. This includes defining target force, payload and stroke values.

Advanced functionality that is in line with the vision behind Industry 4.0. For instance, a visual LED indicator on the EFC-02 tells users whether the grinding wheel is in contact with the surface or not and when the stroke is at 50 percent to ensure maximum compensation, among other critical operational information. The EFC-02 even lets users know when maintenance is needed.

One stop for a custom, end-to-end solution

The end-of-arm EFC-02 active compliance system is fully compatible with Suhner's end effectors, including angle grinders, orbital sanders, angle polishers and straight grinders. Optional automatic changers for abrasives or belts, which integrate easily with the EFC-02, are also available. By storing and dispensing new abrasives for pickup by a sander – these automatic changers effectively help speed processes and increase productivity.

Suhner also gives its customers access to one of the most comprehensive ranges of abrasives in the market from all the industry's leading manufacturers. Plus, Suhner's ABRACare customized, volume-based pay-as-you-go inventory management program ensures you always have the abrasives you need.

Working with Suhner means more than having access to industry-leading tools and abrasives—manufacturers also have access to a global network of seasoned abrasives and material removal experts ready to help you solve virtually any challenge.

Put Suhner to Work for You Today

The EFC-02 combines over a century of Suhner's abrasives and material removal expertise with smart automation for the highest surface quality results. Its compact size, all-electric technology and simple programming make it possible to replicate and automate most grinding, polishing, sanding, and deburring on a variety of surfaces. This gives manufacturers a cost-effective, low-maintenance solution for replacing many time-consuming and tedious manual processes—saving time and money.

The company will showcase the EFC-02 at Booth #1850 at Automate 2023, May 22–25, in Detroit.

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Technology Advances for Continuous Generating Gear Grinding in EV and More

Meeting the challenges of gear grinding with innovative abrasive technology that improves gear efficiency and quality

Spencer Artz, Corporate Application Engineer, Norton | Saint-Gobain Abrasives

Continuous generating cylindrical gear grinding is one of the most demanding grinding applications for automotive and aerospace manufacturers. To improve gear efficiency, gear life, and noise levels, gear profile tolerances and surface finish requirements are becoming more stringent. This is especially true for EV gears, which typically require lower noise characteristics than traditional automotive gears. These new quality requirements must be maintained without sacrificing cycle time, and without inducing grinding burn. One of the biggest factors in achieving these goals is a grinding wheel capable of producing low grinding force and low grinding temperatures while minimizing the wear of the grinding wheel. The toughness and sharpness of the abrasive, porosity and strength of the bond, and interaction between the bond and workpiece are key. A new vitrified wheel matrix has been developed specifically for gear grinding which significantly reduces the friction generated between the bond and the workpiece while maintaining superior form holding at high removal rates. This new bond paired with the newest ceramic abrasive results in an extremely free cutting grinding wheel that exceeds all the requirements necessary to create quiet and long-lasting gears.

An understanding of what is needed for the latest gear designs and how abrasives composition and grinding wheel technology is satisfying the requirements will help define the overall landscape of today's gear grinding solutions.

Gear Requirements for EV

One of the biggest trends in the automotive industry today is the shift from internal combustion engines (ICE) to electric vehicles (EVs). Along with that trend, gear requirements are changing as well. The number of gears is expected to drop quite significantly. With ICE, there's an average of twenty-four gears in a vehicle, and eighteen of those are within the transmission. Whereas with EVs, there's only an average of about eight gears, which is about a third of internal combustion engines.

Furthermore, EV requires different types of gears. For example, electric vehicles operate at higher motor speeds than ICE vehicles, requiring a much finer gear flank finish to reduce friction and improve gear transmission efficiency. Shown in Figure 1 is a typical curve of vehicle speed versus

torque, and the shift points that would be normal in an internal combustion engine with a conventional transmission. In an EV, the electric motor would have to operate across this range of speeds, so it is a lot more demanding on the gears.

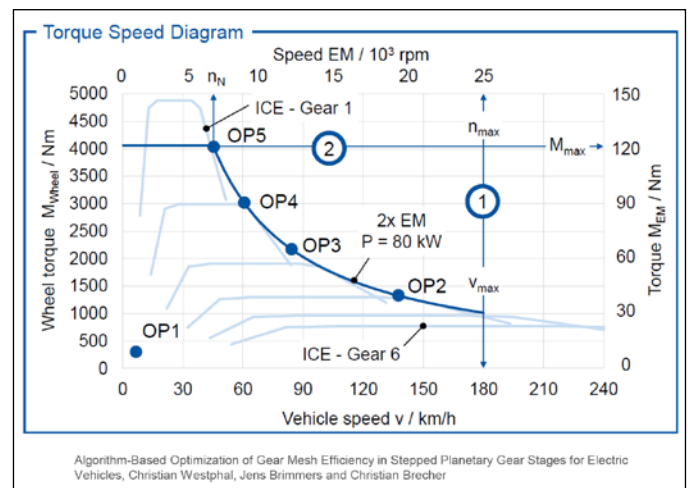


Figure 1

The noise level of gears is another consideration. Gears for EV have a unique challenge because there is no noise from the internal combustion engines. Any noise generated from the gears is not going to be masked, so they have to be considerably quieter. To address this, both sides of the gear flank must have similar performance with tight tolerances on both the acceleration and deceleration sides because of regenerative braking.

Gearbox Designs

There are two main gearbox designs that are currently used in EVs. One is a standard two-speed helical gearbox, and the other is a stepped planetary gearbox, which is much more compact.

Stepped planetary types are especially challenging for continuous generating grinding applications because of the close proximity and interference between the two gears. So, either a much smaller grinding wheel must be applied, or a completely different process has to be used, such as honing.

Aerospace applications also utilize planetary gear sets and other gear types. One example is a high-bypass turbofan engine that requires a speed reduction between the

turbines and fan blades, keeping the tips of the fan blades from going supersonic.

Aerospace materials can be difficult to grind, creating some unique challenges. Materials include superalloys such as Inconel's that have very poor grindability and very high heat resistance. Traditionally many aerospace gear grinding applications use profile grinding, but continuous generating grinding can provide a much better pitch accuracy and higher productivity where the gear design allows.

Hard Gear Finishing

There are several different gear finishing methods, each with its own advantages. For example, when performing *honing*, which produces a profile quality of DIN 4-5 and pitch quality 5-6, excellent noise characteristics are achieved, and tool life is good. When finishing by *hard skiving*, the profile quality falls between DIN 6-7, and the pitch quality is DIN 5-8 with good noise characteristics, but tool life is short. With skiving, the cutters are changed frequently, or some machines resharpen the cutter, which adds cycle time.

When *finish grinding*, the profile quality is like honing. However, when *continuous generating grinding* the pitch quality is much better than other methods, primarily due to the manufacturing process itself. Noise characteristics are also good. The tool life is typically much longer than skiving and slightly longer than honing.

Understanding Continuous Generating Grinding

Many types of gear-grinding processes exist with varying levels of part quality and productivity. Knowing the terminology related to continuous generating gear grinding is helpful, and described as follows:

- When *profile grinding*, the gear tooth profile is formed from a grinding wheel dressed with the same profile as the gear tooth.
- When *generating grinding*, the gear tooth profile is formed using machine motion with a grinding wheel dressed to a gear rack form.
- Within each profile and generating grinding finishing process there are continuous and discontinuous distinctions (see Figure 2).

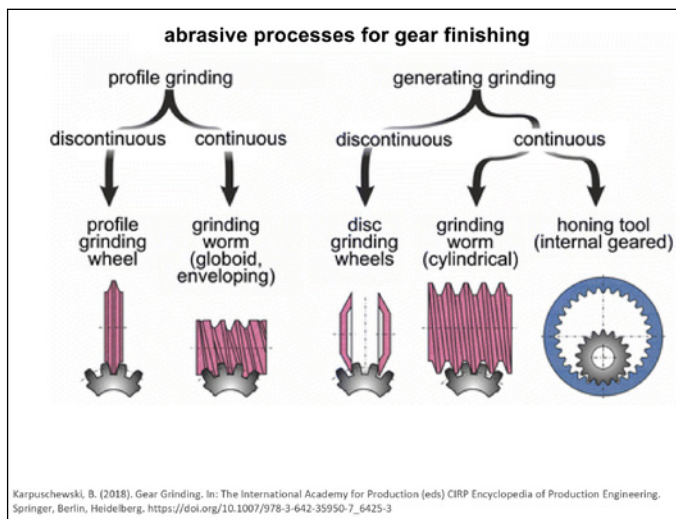


Figure 2

- *Continuous* processes refer to the gear and grinding wheel staying in rotation as the tooth profile is formed.
- Whereas, *discontinuous* means the grinding wheel retracts from the grinding wheel after each gear tooth is formed.

Continuous generating grinding is a unique and extremely demanding grinding process. Profile deviations and surface finish must be kept to an absolute minimum because of gear noise challenges. However, when considering the involute profile of the gear, the arc length and the chip thickness generated from the grinding cycle vary dramatically from the tip to the root. So, one edge will wear faster than the other, creating some difficulties when trying to increase the grinding wheel life. If these grinding wheels fail, it will typically be either due to profile deviation, from grinding burn, or as a result of waviness that is generated on the gear flank.

For grinding processes, it is also important to pay attention to chip length and chip thickness. For example, cylindrical OD grinding processes typically have a small contact area and will generate a chip with a large chip thickness, but short chip length. Creepfeed grinding, however, has a small chip thickness and a long chip length.

The chip thickness is generally a good index of how aggressive a grinding cycle is. The larger the chip thickness value, the more aggressive the grinding operation. Chip length, on the other hand, has a big effect on grinding temperatures, and chips with a long chip length are at risk of becoming embedded in the grinding wheel. With longer

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chip lengths, higher amounts of grinding wheel porosity are necessary to all the chips to be properly evacuated from the grinding wheel.

With surface grinding and profile gear grinding, the chip length is typically between three and four millimeters. However, continuous generating gear grinding has extremely long chips compared to these processes, making it closer to a creepfeed grinding process. A high porosity wheel is required to accommodate long chips. And a strong wheel is needed because the chip thickness is also fairly high (see Figure 3).

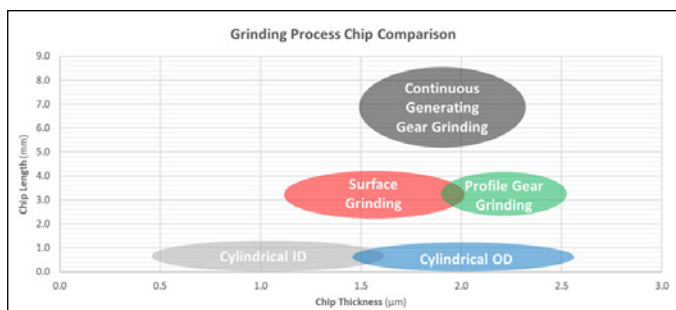


Figure 3

Grinding Wheel Wear Mechanisms

Both the abrasive and the bond are grinding wheel wear mechanisms. Figure 4 shows three abrasives with bond posts connecting them. The first type of abrasive wear is chemical or may have resulted from the flattening or flat spotting of the abrasive grain. When there are very flat abrasive grains, metal capping or loading will adhere to the tips of the grains, which can generate heat. Next is micro-fracturing, which is the preferred wear mode for abrasives. Micro-fracturing generates very small cracks that keep the grinding wheel sharp. The third type of abrasive wear is macro fracturing where the grain actually fractures in half. This accelerates wheel wear, increasing the overall surface finish.

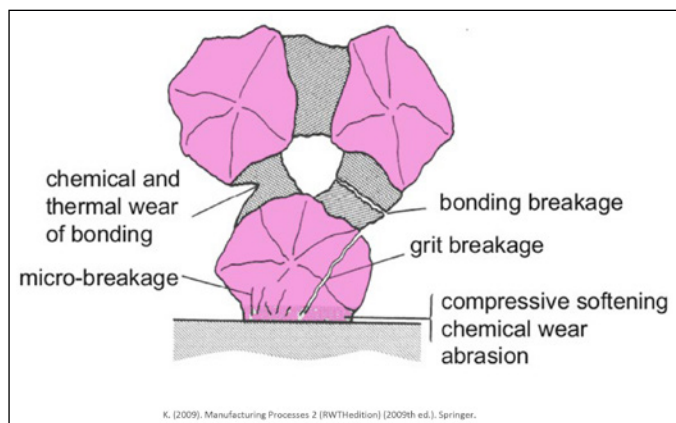


Figure 4

There are also three different primary types of bond wear. First, abrasive pullout is when the abrasive is totally pulled from the bond. In the instance of fracture bond wear, the bond will break. Or there is chemical or thermal wear that occurs from high grinding temperatures.

Essentially, you can enhance grinding wheel performance by either improving the wear resistance or toughness of the grain, or by increasing the strength and wear resistance of the bond. Wheel wear is also impacted by the homogeneity or uniformity of the grain dispersed throughout the grinding wheel. Even distribution of the grinding forces will create even wear, which is important for reducing transmission error and tooth variation.

When quantifying grinding wheel wear, G-ratio is an important index. G-ratio is defined as the ratio between the volume ground from the workpiece and the volume lost from the grinding wheel. So, a higher G-ratio indicates that a grinding wheel can remove more material before it requires dressing to restore the profile. G-ratio becomes even more critical as the grinding wheel gets smaller and reaches the end of its life because wheel wear increases as wheel diameter decreases. Also, the wheel speed is reduced as the wheel gets smaller, but because wear increases from the smaller wheel diameter, wheel volume is decreased.

Figure 5 shows the typical wear that you would see in continuous generating gear grinding. The profile and flank would start to become wavy, resulting in slope errors and form errors.

Monitoring the G-ratio is important for continuous generating gear grinding because these wheels should be running at a constant RPM for the best results. Performance must be maintained from the new grinding wheel diameter to stub.

The G-ratio is also directly affected by how aggressive the grinding cycle is. Chip thickness is a good indicator of aggressiveness. Different factors will affect the aggressiveness of the grinding cycle to varying degrees, some more than others. Factors include wheel speed, the number of wheel starts, feedrate, wheel diameter, and depth-of-cut.

Aggressive grinding cycles typically require tougher abrasives and stronger bonds to maintain wheel form, creating a challenge when trying to keep grinding temperatures low. It is critical to avoid excessive heat generation in gear grinding, as high temperatures can lead to thermal damage of the gear flank. Subsequently, thermal damage can cause tensile residual stress, which will significantly reduce the load-carrying capacity and fatigue life of the gear tooth. To help reduce grinding temperatures, grinding parameters can be adjusted, but these adjustments are usually at the expense of cycle time and overall productivity. Thankfully, new grain and bond technology advancements can reduce grinding temperatures while maintaining productivity.

Abrasive Types, Evolution

There are two commonly used abrasive types in gear grinding—fused and sintered. Fused abrasives tend to break apart into large particles, while sintered abrasives are designed to break down slowly into smaller particles while maintaining sharpness. Superabrasives are also an excellent option, although their usage is still emerging in gear-grinding applications (see Figure 6).

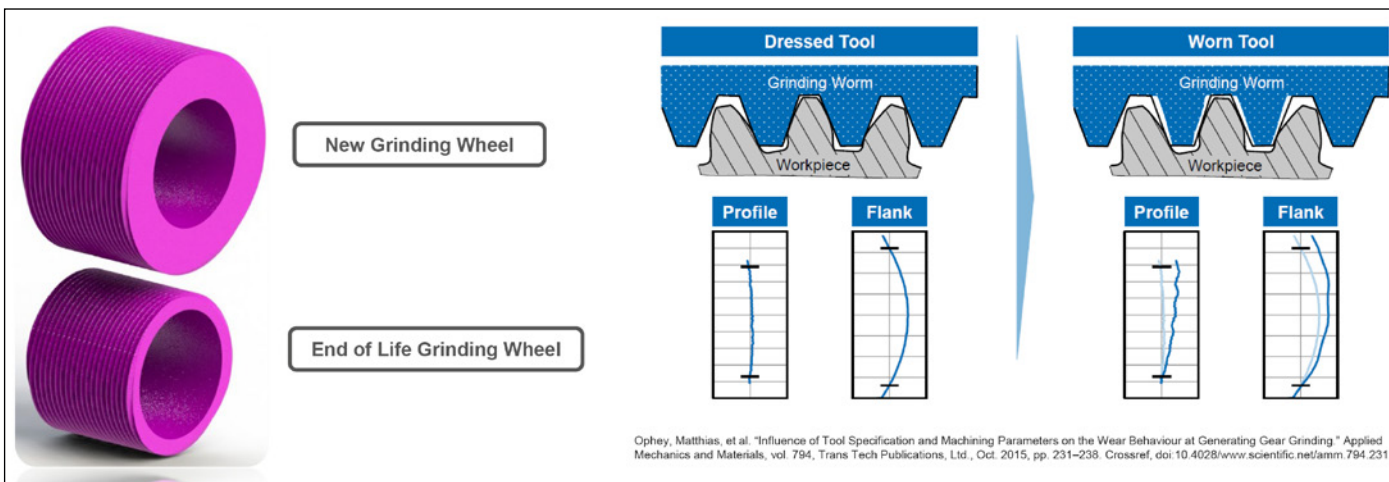


Figure 5

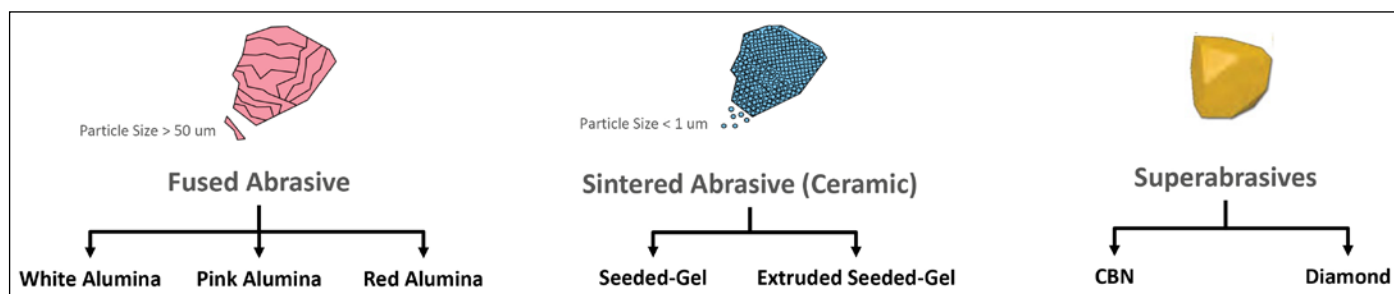


Figure 6

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Abrasive grain comes in several forms. Aluminum oxide is one example that will change in appearance, toughness, and hardness based on the manufacturing process. Brown or natural aluminum oxide is typically brown and has a high toughness but lower hardness due to its impurities. White or pure aluminum oxide is typically white and is very sharp and reliable. By adding chromium oxide or titanium oxide, the properties of the abrasive can be modified. Adding ~0.2 percent chromium oxide results in pink aluminum oxide, and adding ~2 percent chromium oxide creates red/ ruby aluminum oxide. In gear grinding applications, pink and red aluminum oxides are the most used (see Figure 7).



Figure 7

Seeded-gel ceramic abrasives are another form. Norton revolutionized the grinding industry in 1986 when it introduced “SG”, the first of its kind, and Norton has been continually enhancing this seeded-gel ceramic technology ever since. SG is a small microstructure that creates a very tough abrasive, enabling controlled grain breakdown at high material removal rates. Seeded-gel abrasives typically have ~1:1 aspect ratio and provide a good balance of performance and quality. Norton Quantum, also known as NQ, was released in 2007 adding fracture point inducers to increase grain friability, resulting in reduced grinding forces when compared to its SG predecessor.

In 2021, Norton introduced its newest seeded-gel ceramic abrasive, Quantum Prime also known as NQN. Norton Quantum Prime has a smaller grain size, reducing wheel wear and producing finer surface finishes. This newest seeded-gel abrasive technology is well suited for gear grinding due to its ability to maintain sharpness while consistently breaking down (see Figure 8).

Norton released the first extruded seeded-gel abrasives in 1999 called “TG”. Due to its geometry, extruded ceramics facilitate higher material removal rates and higher G-ratios than traditional seeded-gel ceramics. Typically, extruded ceramic abrasives are used in larger, cylindrical gears that require high material removal rates, or for grinding gears from solid. Norton “TQ” is the second-generation TG grain that uses NQ chemistry to produce smaller fracture plans. The smaller microstructure results in longer wheel life and lower grinding power.

It is important to note that in gear grinding, ceramic wheels are not typically 100 percent ceramic, instead they

are blended with various aluminum oxides to make the grinding wheels more economical. In continuous generating gear grinding, ceramic concentration is typically in the range of 10–50 percent with 10–30 percent being the most common. The concentration of ceramic and the selection of the secondary abrasive play a big role in the grinding wheel performance. Higher ceramic grain content improves profile retention and extends grinding wheel life at the expense of increased dresser wear.

Bonds

The purpose of a grinding wheel’s bond is multifaceted. Bonds enable the abrasive to retain sharpness and enough porosity for coolant and grinding chips. They also release worn abrasive, and reduce bond and workpiece interaction as much as possible. Typically gear grinding wheels tend to use a porous structure and relatively soft bonds to keep grinding temperatures low. The disadvantage is this also increases wheel wear.

A new bond technology from Norton for gear grinding reduces grinding temperatures and forces. The novel bond technology allows the bond itself to grind and remove workpiece material rather than rub against the workpiece, generating heat. An abrasive phase is grown into the bond during the manufacturing process which enhances grinding wheel performance (see Figure 9).

New Grinding Wheel Technologies

As gear designs are influenced by EV and other industries that demand lower, finer finishes, grinding wheels alone are unable to achieve the surface requirements. By using a dual polishing grinding wheel, the roughing and finishing process is performed with the grinding portion of the wheel, while an additional polishing step is performed with the wheel’s polishing portion. The resulting polishing creates a much lower surface finish than previously attainable with just a grinding capability. And significantly lower flank roughness values result in reduced micro-pitting of the gear flank as well as improved transmission efficiency (see Figure 10).



Figure 10

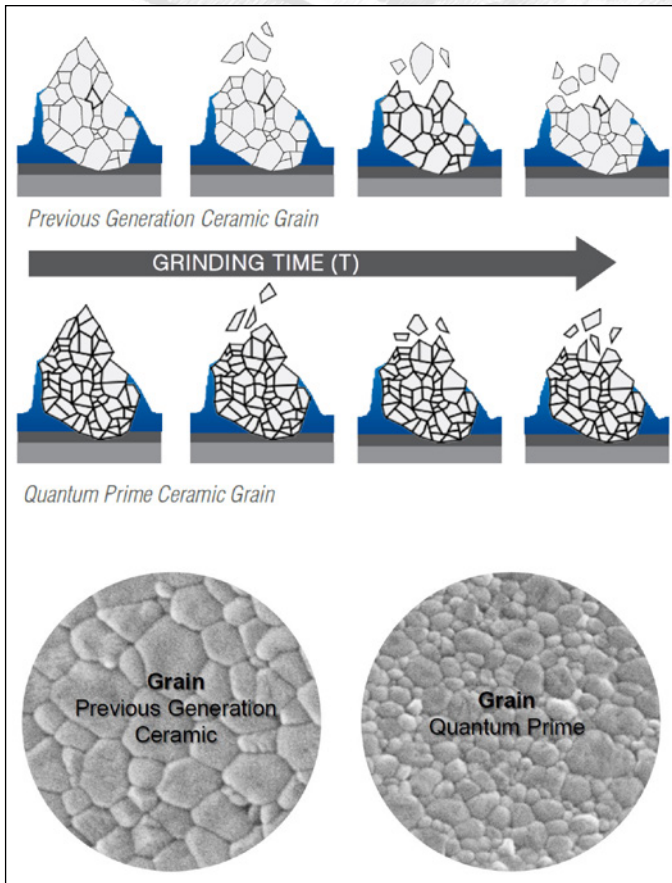


Figure 8

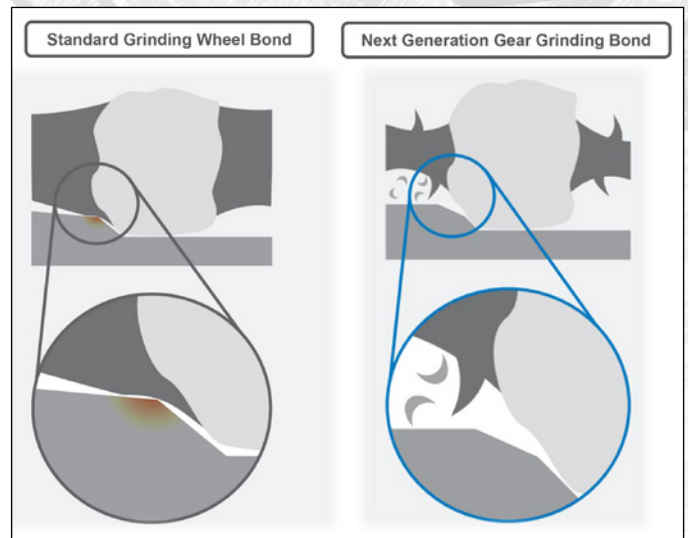
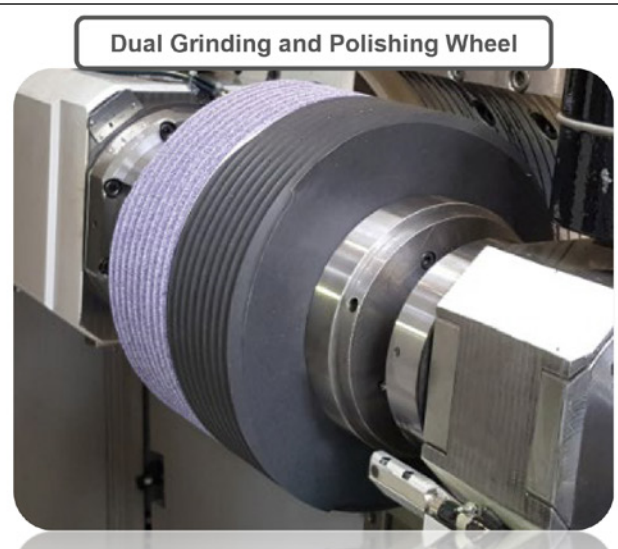
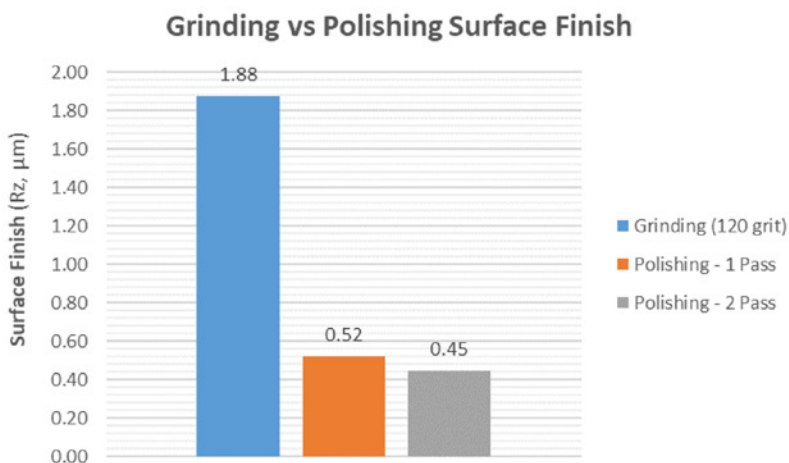


Figure 9



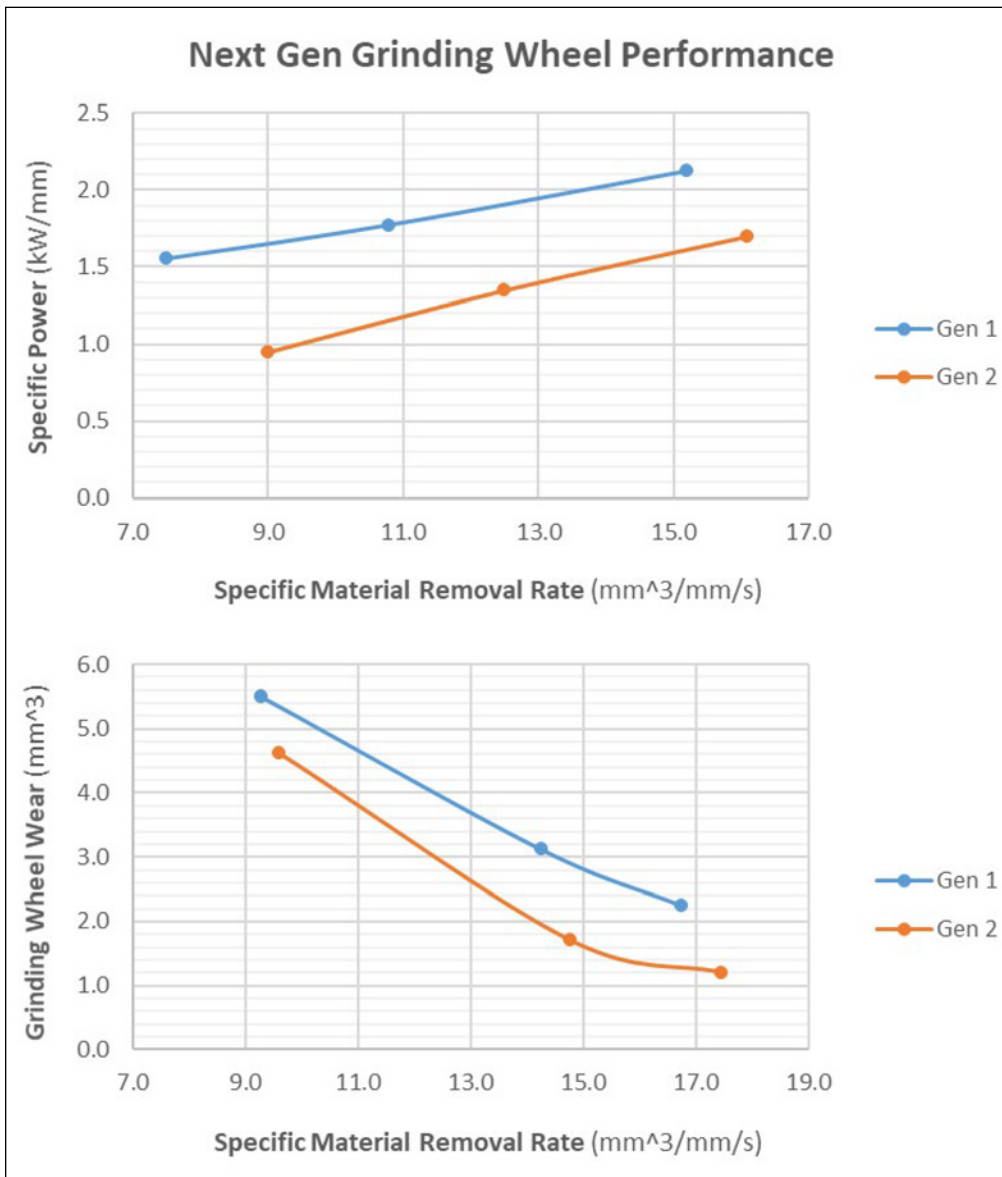


Figure 11

Also, the use of a hard resin instead of a typical rubber bond reduces the amount of polishing wheel deformation during the polishing cycle and improves the form accuracy of the gear tooth.

Benefits Proven in Tests

Field testing has shown that the newest generation gear grinding wheel bond system provides a lower specific power at all material removal rates, indicating that the abrasive phase grown into the bond is reducing friction between the bond and workpiece. Grinding wheel wear is also lower, likely due to the reduction in grinding forces and temperature (see Figure 11).

The profile retention was also improved with the new bond technology. When comparing the generation 1 wheels with the generation 2 gear grinding wheels, Ffa was reduced ~25 percent on average. This improvement results in lower process Cpk, and makes it possible to extend the dressing interval of the wheel.

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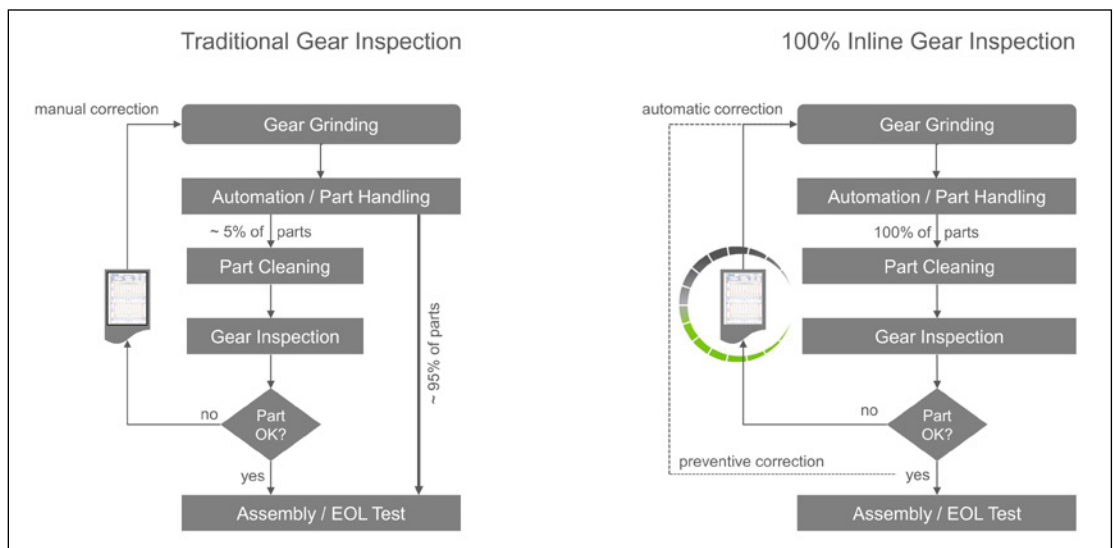
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Traditional gear inspection versus 100 percent in-process gear inspection.

In conventional gear manufacturing, quality control is carried out for a number of pieces per batch. Most parts enter final gearbox assembly without any inspection. Among other things, this approach is based on two facts: measuring time is significantly longer than the machining time, and the limited measuring capacity available. In hard fine finishing, for example, continuous generating grinding, it is not unusual to measure only one or two workpieces per dressing cycle or directly after the machine setup. Depending on the dressing cycle,

the number of inspected parts corresponds to only about 5 percent of workpieces produced in total. However, to guarantee almost 100 percent reliability, statistical evaluation is instead used to validate the gears being produced. Typical measuring characteristics can be represented and statistically evaluated with a Gaussian bell curve. By deliberately narrowing down tolerances on the measured components, it is possible to guarantee compliance with the actually required drawing tolerances with a sufficiently high probability (typically greater than 99.99994 percent). This method is commonly used for machine and process capability studies and is

globally recognized. The machine or process capability values c_{mk} and c_{pk} frequently taken as a basis are usually set on or above 1.67. Statistically, the reject rate is only 0.57 workpieces per 1 million manufactured workpieces, which means that only about 50 percent of the intended drawing tolerances are available as manufacturing tolerances. This situation is aggravated by the fact of increasing quality demands, especially with e-drive gears due to NVH and other topics leading to increasingly tight tolerances. Clearly, this high dependency on statistics poses a significant challenge to a growing number of gear manufacturers.

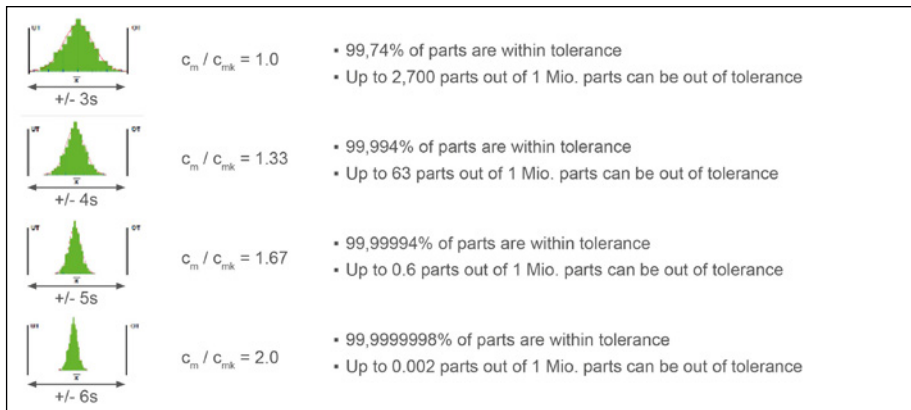
Another problem of traditional gear inspection is the long (waiting) time between part removal for inspection and the actual availability of measured results. Waiting and inspection time can easily amount to between 30 to 45 minutes depending on the inspection room capacity. After inspection, a decision must be made whether a correction of machine settings is necessary and the implementation of such corrections must be carried out by the machine operator taking additional time, all while the production is continuously running, good or bad. So far, today, the focus has been given to establishing a “closed loop” connection between the metrology system and the production machine, installing the measuring machine near the production machine, e.g., by employing so-called “shop-hardened” metrology systems.

Now, what would an ideal solution to overcome the described challenges look like? Ideally, all parts could be inspected immediately after they have been produced, bearing various advantages. The quality achieved on each workpiece could be documented. Workpieces out of tolerance could be corrected immediately by a closed-loop auto-correction system. And even better, by inspecting up to 100 percent of parts, one could also monitor trends and apply preventive corrections before parts are getting out of tolerance. The goal would result in predicting whether a workpiece could cause noise issues within the gearbox after its assembly.

So, the key to creating an ideal situation is a metrology system that is capable of inspecting gears as fast as they are produced, and which can easily be installed close to the production machine.

In-Process Gear Inspection—Roll Testing and Laser Inspection

In 2018, Gleason introduced a very special metrology system. The GRSL combines the latest non-contact analytical gear inspection with well-proven double flank roll testing of gears applied in most of today’s high-volume gear production environments in order to achieve 100 percent inspection of specific attributes. But the GRSL is much different than these traditional systems. It tests both the composite functional



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GRSL—Multiple inspection methods combined in one platform.

error by double flank roll testing with a master gear as well as an individual gear’s characteristics of involute, lead, and index error by applying laser scanning technology.

During the roll testing cycle, two laser heads move automatically into position to scan both gear flanks (left and right) simultaneously. In addition, different sections along the face width of the gear can be scanned to inspect even the lead. Laser technology significantly reduces the overall inspection time compared to a standard tactile measuring system. Example: The inspection time required for a typical, automotive planetary pinion can be reduced with laser technology by a factor of four, from roughly 2.7 minutes down to 39 seconds. With the inspection time being greatly reduced, this process can even add additional value by measuring profile and lead on all gear teeth—not just the usual inspection of only four teeth around the circumference of the gear.

With such comprehensive data available through laser scanning, it is also possible to further evaluate gears beyond standard gear inspection habits such as profile, lead, pitch, runout, and size. In addition, the 3D laser used on the GRSL gathers much higher-density data at higher speeds than a traditional tactile probe. The gear flank area seen and scanned by the laser probe at any given instance during the measurement is much higher than using a contact probe. The contact probe simply makes a point contact while the GRSL laser emits light in the form of a line, which provides typically up to 4 mm scanning measurement area at high frequency with a sample

spacing of microns. This allows capturing a large surface area of gear with higher density at much faster inspection times. Such a high-density measurement of the entire surface is simply not practical to achieve with a tactile probe. For a typical 2D trace such as a profile or lead trace used for gear measurement, a 3D laser probe captures 10+ times more data points at much higher speeds than with a conventional tactile contact probe.

Understanding the profile and lead of all teeth makes it possible to calculate a so-called “Advanced Waviness Analysis” resulting in an order analysis of the gear topography waviness. In contrast to the traditional gear measurement technique, where periodic components

or waviness are only captured as form errors f_{ra} or f_{rp} in the profile and/or flank line, Advanced Waviness Analysis goes far beyond this. Advanced Waviness Analysis evaluates periodic errors in the profile, the flank line, or the pitch according to their frequencies/orders and their amplitudes and essentially corresponds to the waviness analysis according to VDI/VDE2612. Measured profile and/or flank lines of all teeth are first connected to each other along the correct path of contact. The obtained “signal” represents a theoretical transmission error and is then decomposed into its corresponding components (frequencies/orders and amplitudes) either by an FFT or with the aid of a Gaussian least square method.

Order analyses are shown for the profiles (involute) and flank lines (lead) on the right and left tooth flanks. The lower section of the chart summarizes the most conspicuous orders and amplitudes in table form. This allows for quickly distinguishing between mesh harmonics, mainly influenced by the gear design, and other orders, so-called “ghost orders” which typically have their root cause in manufacturing errors.

Whereas in single flank roll testing the actual transmission error between gear and master gear is detected and displayed as an order analysis, in Advanced

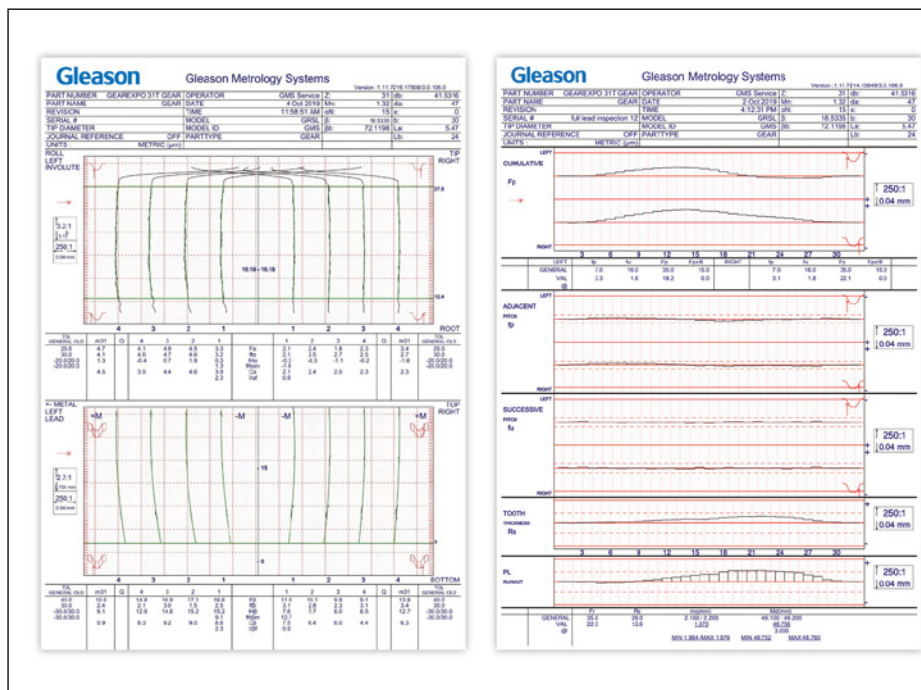


Chart possibilities of a GRSL including advanced waviness analysis.

Grinding Machine

Automation Cell

Inline GRSL Inspection



The stacking cell accommodates baskets of various manufacturers and styles and is ideally suited for the autonomous processing of large lot sizes of gears.

The 200/260GX uses a double spindle concept to bring down nonproductive idle times to an absolute minimum with less than four seconds per workpiece change time. Machine setup is extremely easy and fast using Gleason's Quik-Flex Plus Workholding, just one tool for the exchange of all mechanical components and a menu-guided workflow for all necessary setup steps.

In addition to four different dressing systems for highly productive or flexible production, today's quality demands require modern grinding processes. This includes the possibility to grind gears with extremely good surface quality and twist control. A novelty in the industry is that neither grinding nor dressing times is negatively affected by Gleason's twist-controlled grinding process.

Gleason's Closed Loop system connects the grinding machine with the integrated GRSL metrology center. Inspection results are directly returned to the grinding machine without any involvement of the operator. The machine compares the measured values with the target nominal values and automatically performs the necessary corrections. With the GRSL being directly integrated in the Hard Finishing Cell, results are available right after the workpiece has been ground, typically in less than five minutes. Compared to the traditional approach of gear inspection in a

separate inspection room, reaction time is dramatically reduced. And most probably the biggest advantage is that with this new system, for the first time ever it is now possible to evaluate every produced gear for potential gear noise issues by using Advanced Waviness Analysis.

Summary

e-Drive gears differentiate from other automotive gears by two essential points: Higher Quality and the need for excellent noise behavior.

Gear noise can have many causes. When gear noise issues occur, many people start to look for the causes in the manufacturing process only. However, this is not always the root cause. In order for a gearing system to function quietly, it must first be designed properly according to the load characteristics which will appear later in the real gearbox. Even perfectly designed gears are subject to manufacturing errors that can also lead to gear noise often called "Ghost Noise". Hence, it is important to have analysis tools capable of detecting potential noise issues and to distinguish between manufacturing and design reasons. The gear inspection thus has another important task, namely the reliable detection of potential noise issues.

Gleason's Hard Finishing Cell provides the capability to inspect up to 100 percent of workpieces with a fully

integrated GRSL Double Flank Roll Tester and Laser Scanner. The ground gear is transferred to the GRSL for inspection of all relevant gear characteristics including profile, pitch, runout, and, if desired, lead—in real-time. In addition, Advanced Waviness Analysis can detect gears with potential noise issues such as ghost orders. Deviations determined in the hard-finishing process are fed back directly into the production machine by means of a closed correction loop. If deviations are within tolerance, fully automatic correction and real-time adjustment of the corresponding parameters can be automatically achieved. During traditional gear inspection 45 to 60 minutes may pass between removing the workpiece from the machine, its transfer to the inspection room, waiting in line, the actual inspection process and the analysis of the measurement result. Compared to the conventional measuring process, HFC's in-process inspection and Closed Loop correction ensure optimum quality in a fraction of the time. With up to 100 percent quality control, statistical evaluation can be eliminated from the manufacturing process, resulting in stringent compliance with tolerances according to original drawings.

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Internal Gearing, Deburring, Honing and the Advancement of Robotic Cells

DVS Examines the changing face of machine operation today

DVS Technology Group

The electrification movement is in full swing despite many obstacles still in play. Regardless of these challenges, machine tool providers are expanding their machine operations and tooling capabilities to meet the e-mobility demands of the future.

VarioChamfer, the new, patented process from Prävema enables skiving and deburring in a single clamping when manufacturing gears, thus significantly increasing production efficiency.

At the heart of the VarioChamfer is a rotating tool including a tool spindle. Deburring takes place continuously on the rotating workpiece, whereby the transmission ratio is determined by the specific design and corresponds to the ratio of the number of teeth between the tool and the workpiece.

“At first glance, this may appear like the conventional production process. Previous solutions used the so-called ‘Entgratomat’ or similar methods, which are primarily intended for the external toothing of gears. For internal gears, which are usually difficult to access due to space restrictions, these methods are limited. Components for high-quality electric drives are especially challenging,” said Ralf Painczyk, head of mechanical design, Prävema Antriebstechnik.

Prävema has been a well-known manufacturer of machine tools for the automotive industry and a market leader in gear honing for many decades. The boom in electromobility and the demand for related components gave the company the impetus to expand the efficient gearing process to include a rational deburring process. The result is VarioChamfer. It was also important that the integration of deburring into the gear cutting machine should have as little impact as possible on the overall machining time of the components.

VarioChamfer is a solution for the critical components in planetary gears: the so-called stepped planets (see Fig. 1) and the ring gears (see Fig. 2).

In stepped planets, two gears of different sizes with a small distance from each other comprise the workpiece. Nowadays, the parts are usually machined using skiving, e.g., on the Prävema SynchroFormV. As with any machine operation, this process produces a burr on the exit side of the peeling tool.



Figure 1—Illustration of a stepped planet.

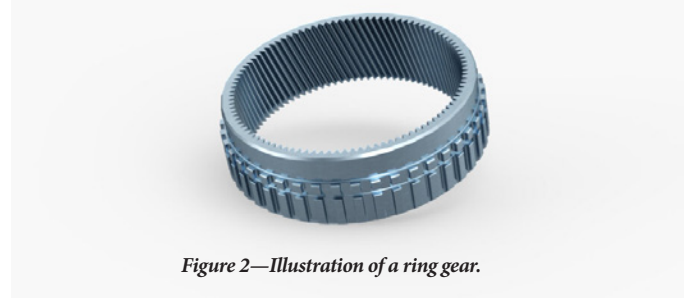


Figure 2—Illustration of a ring gear.

This burr is inevitably located exactly between the two gears, which are usually arranged at a small distance from each other (see Fig. 3).

“This is where the VarioChamfer process plays to its full strength due to its space-saving tool.

Ring gears are internally geared components. As in the previous example, the burr occurs on the exit side of the gearing due to the cutting process. Here we have geometric limitations because this area is inside the clamping. Using a similar type of tool as for the stepped planet, collision-free immersion into the workpiece and chamfering is possible,” Painczyk said.

A particular advantage of the VarioChamfer process is that the workpiece can be deburred in the same clamping in which it was geared (see Fig. 3). It is not necessary to set it down and turn it over, which means no additional solutions are needed. The workpiece is deburred right after gearing.

VarioChamfer makes it possible to combine processes in the production lines on a small space, which saves investment costs for an additional machine. All processing steps take place inline in one machine. This is particularly important in the series production of transmission components. Thanks to VarioChamfer, for example, a stepped planet can be deburred in less than ten seconds.

The concept underlying the VarioChamfer is based on the tried-and-tested backing milling process. This method

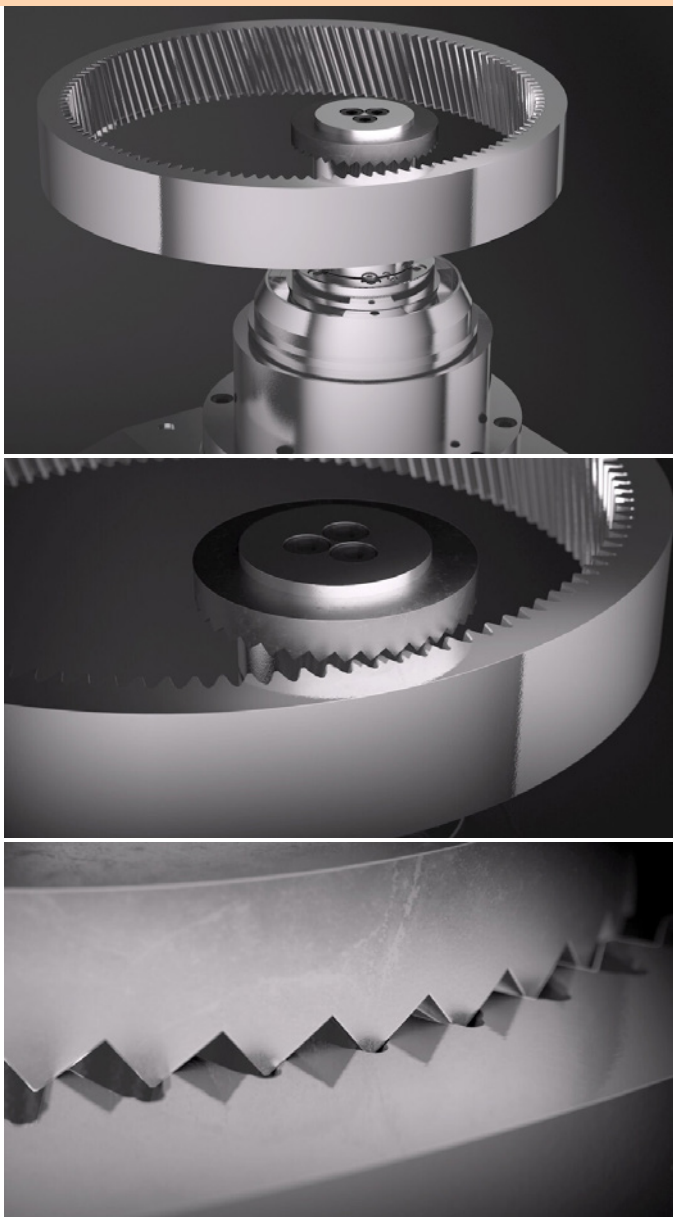


Figure 3a-3c—With VarioChamfer, a ring gear can be splined and deburred in a single clamping operation.

enables the use of (usually conical) pockets in the tooth flanks. “VarioChamfer and backing milling use principles of kinematics, in which the movements of bodies are described purely geometrically with the variable’s location, time, speed, and acceleration: The circumference of the tool has a cutting edge which gradually plunges into every gap in the workpiece. This is generated by the axes of rotation, which are coupled at a fixed ratio. Breaking it down to a single axis, it can be imagined as follows: When you roll the wheel of a bicycle over the ground, the wheel’s valve points precisely downwards once every revolution. The path of the valve is always the same,” Painsczyk said.

Now, if the ground is bent into a circle, after the wheel has rolled through the circle once the valve “immerses” at a different position than when it was rotated the last time. But the ratio between the wheel and diameter can be selected so that the valve always immerses at the same distance, i.e., where the imaginary gap is, added Painsczyk.

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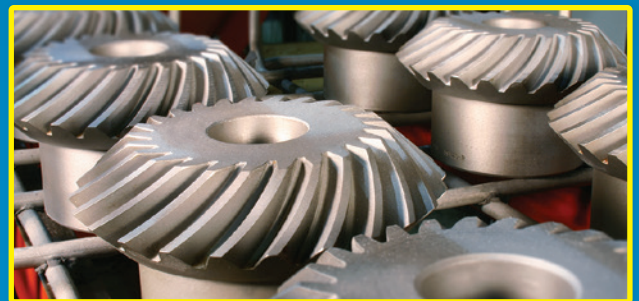
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Figure 4—Industrial robots combined with the latest 2D/3D sensor technology for capturing the position of components will be key to flexible automation in the future.

Future-Proof with Smart and Modular Robot Cells

Today, the ability of a company to compete in the future is largely dependent upon its efficiency and flexibility to adapt to shifting challenges – both are key strengths of the smart and modular robot cells from rbc robotics.

At the DVS Group, modularity is somewhat of a DNA building block. In the production process for electric motor drives, for example, Pittler's skiving, Buderus's hard turning, and Präwema's gear honing technologies are combined to form an efficient turnkey process to produce high-end workpieces as needed in today's modern drives. The modular robot cells from rbc robotics play a special role in this ensemble.

"Our customers' requirements are constantly prompting us to push the boundaries of what is possible. Moving this "boundary of possibility" continuously over the course of two decades is what has made rbc robotics a leading solution provider of camera-guided robot systems. Today, the experience gained in well over 500 completed projects is reflected in the modular robot cells of the FX series," said Dirk Hablick, division manager sales and project development, rbc robotics.

Key to future-proof and flexible automation are industrial robots combined with the latest 2D/3D sensors for capturing the position of the components. The modular system enables the seamless combination of individual robotic modules and thus facilitates compact production concepts. A very important aspect of future viability!

"The modularity of the robot cells from rbc robotics enables more than just the optimal connection of individual robotic modules: as an automation module, the systems are also an excellent match for the CNC machines from the DVS Group and thus ensure a perfectly coordinated overall production and machining process," Hablick added.

In real production environments, the robot parameters change constantly due to the different sizes, geometries, manufacturing tolerances, and surface characteristics. Thanks to tried-and-tested image recognition solutions, the automation cells from rbc robotics can conquer the next frontier: they are able to see and grip workpieces more precisely and efficiently than ever before.

"Today, almost all industries are affected at all levels by labor shortages, from highly specialized professionals to helpers for simple tasks. And for demographic reasons alone, that will not change any time soon. One of the solutions to this problem is smart, flexible, and camera-controlled robot systems that require minimal space and are very powerful. They are also easy and intuitive to operate and adapt to different components with a high degree of flexibility," Hablick said. "So modular, smart automation solutions create continuity, efficiency, and flexibility in production, which means security in the future. And finally, modularity ensures that any solution can be very individually adapted to specific circumstances and challenges."

dvs-technology.com/en/rbc-robotics

Tool Technology



» Sandro Schafer, head of the DVS Tooling Systems division, recently shared his thoughts on the changing tooling requirements taking place for modern drive technologies.

Sandro Schafer, head of the DVS Tooling Systems division.

Regarding tool technology

In addition to the traditional and rather quantitative characteristics of tool performance, such as the service life and throughput, today there are additional, high qualitative requirements: modern drive technologies require gears with extremely fine surfaces and complex micro-geometries. This new generation of workpieces can only be achieved with high-end tools, such as the Vario Speed Dressing technology from Präwema SynchroFine in combination with high-performance honing rings from Naxos. So, it could be said that modern tool technology is the enabler of future-oriented technology.

Integrated solutions

Working together synergistically has long been a guiding principle of our Group. We optimally coordinate technologies, materials, and services and deliver virtually seamlessly integrated processes to our customers. On a day-to-day basis, our customers also notice this in terms of their single point of contact, who has an overview of the entire DVS realm, from machine issues and tool supply to process optimization. These integrated solutions are certainly also the reason why the Präwema honing machine and the specially matched DVS honing tools are market leaders.

Digitalization

Digitalization is par for the course from the manufacture of tools to their controlled and documented use. Recording the service life and process data is pivotal to maximizing process optimization and thus enabling our customers to save costs. I'm certain that AI will continue to accelerate this process in the future or enable it in the first place. The future of the tool industry is inconceivable without digitalization, digital services, and digital innovation like DVS Connect.

New materials

New materials play a decisive role both in terms of the workpiece and the tool. For example, look at the brake discs that

are mandatory in all new cars from 2025: extremely hard and never-before-used materials are used here. This means the tools used for processing these brake discs must also perform at an entirely different level. Some of these requirements can only be achieved with new types of tool materials. And so, the circle of constantly increasing quality closes.

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Industrial Methods for Grinding Burnout Testing

Current state-of-the-art and developing trends

Martin W. Seidel, Antje Zösch, Konstantin Härtel
imq Ingenieurbetrieb GmbH



Figure 1—Mobile etching table for the Nital etching process. (Source: imq GmbH)

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grinding burn

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When grinding steel parts, the surface of the part can "burn" if too much heat is applied in a short time. Grinding burn refers to all those structural changes in edge zones of steel parts that are caused by grinding processes in steels due to the thermal energy introduced. Grinding burn can mainly occur in the form of tempering zones or new hardening zones.

In the meantime, it has become generally accepted that under economical production conditions, the risk of grinding burns may be reduced, but not completely eliminated. Furthermore, not only "severe grinding burn," in which large surface areas are affected, can cause the premature failure of components, but even small local grinding burn phenomena can have the same consequence.

The manifestations and conditions for the occurrence of grinding burn as well as the procedures that can be used for grinding burn testing are detailed and discussed in *Grinding Burn and Its Testing* (Ref. 1).

Industrial Methods for Grinding Burn Testing

Various test methods can be considered for grinding burn testing. Industrial procedures are test methods which, due to short test times, allow larger numbers of manufactured parts to be tested in a short time without destroying them. These include the Nital etching method (also known as Surface Temper Etching STE), eddy current testing (ET), the Barkhausen noise method (BHN). The micromagnetic

3MA method combines several electromagnetic procedures as eddy current testing and BHN.

Nital etching (NE) exploits resistance to acids, especially dilute nitric acid. According to ISO 14 104 and AMS 2649D, the testing process is divided into a number of individual sub-steps: cleaning of the parts, the actual etching in aqueous or alcoholic nitric acid, and the evaluation of the part surface on grinding burn indicators. To enable the grinding burn test to be carried out directly on the grinding machine, a mobile etching table (Fig. 1) was developed.

Up to now, the STE is the only standardized process for grinding burn testing (see an overview of the currently applicable standards in Ref. 1). STE can be used for a wide range of parts made of unalloyed or low-alloyed steel. However, strict environmental and health-and-safety regulations must be observed because of the use of acids. It is also problematic that the evaluation of the etch indications on the part surface is currently still carried out exclusively by an inspector. To ensure the reliability and reproducibility of the process, reference bodies were developed in which artificial grinding burn was generated by means of a laser (Fig. 2) (Ref. 2).

These reference blocks are used very successfully by many companies, including a number of global acting corporations, to monitor the NE process.

The electromagnetic test methods include the Eddy Current (ET) and Barkhausen Noise (BNR). They rely on the different electrical and magnetic properties of tempering and re-hardening

zones and belong to the nondestructive testing methods. However, they require calibration on parts with defined tempering or re-hardening zones. For this purpose, reference bodies with an artificially generated grinding burn can also be used (Ref. 1).

For grinding burn testing by means of the ET method, surface probes are usually used. Their magnetic field detects only smaller surface areas of the parts and thus enables the scanning of surfaces and thus also the localization of grinding burn. At present, therefore, the differential probes known for crack detection are mainly used for grinding burn testing.

Figures 3 and 4 show examples of the inspection of bearing rings applying ET.

Here, by means of a robot, the test probe is contactless guided over all functional surfaces of the ring.

The testing machine is CNC-controlled so the testing process is automated. The test can be performed without contact, although the distance between the probe and the surface must be kept as constant as possible.

The BNR method is based on the generation of the so-called Barkhausen noise during the alternating field magnetization of a ferromagnetic material. It is generated and registered by means of special BHN probes.

Decisive for the reproducibility of BHN measurements is the contact between the test probe and the part surface. The BHN method is also suitable for testing gears (Figure 5). However, the test speed is significantly lower than the test speeds achievable with eddy current testing.



Figure 2—Comparison body NE Test Set. (Source: imq GmbH)



Figure 3—ET testing of a rolling bearing ring. (Source: imq GmbH)

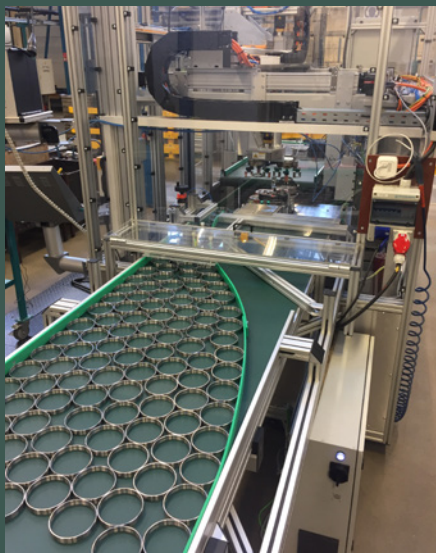


Figure 4—QuaSor E automatic testing machine for grinding burn testing of rolling bearing rings: General view with feed belt. (Source: imq GmbH)



Figure 5—BHN-Testing of gears. (Source: Stresstech GmbH)

Summary and Outlook

At present, STE is still frequently used as a laboratory test for random sample inspection and in (partially) automated systems for 100 percent inspection of entire production batches. Particularly because of occupational safety and environmental issues, there is a trend toward using electromagnetic methods in its place. However, STE will continue to be needed as a reference method for electromagnetic methods in the future. Mobile test systems are particularly suitable for this purpose, with which STE can be carried out directly on a grinding machine, for example, after a new batch has been started up.

The ET method is currently being used very successfully for the grinding burn test of rotationally symmetrical or similar parts. A particular advantage is that high test speeds may be achieved, and noncontact testing is possible. The BHN method is available for parts with gear teeth.

There are currently three trends in electromagnetic methods: First, there

is increasing demand for mobile testing equipment that allows testing directly on grinding or honing machines. Secondly, testing systems will be integrated into grinding and honing machines. The aim is to carry out the grinding burn test immediately after grinding in a further work cycle. This will allow a faster response to any deviations from the normal process. Finally, another development is to apply artificial intelligence (AI) to evaluate test results (Ref. 3).



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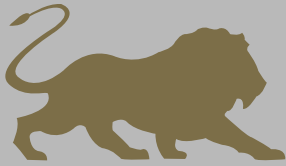
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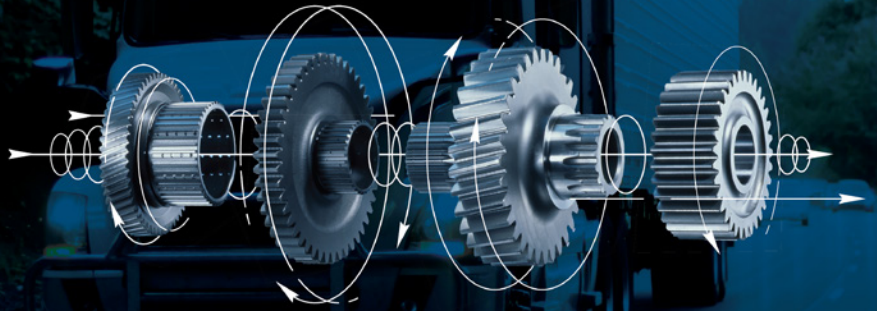
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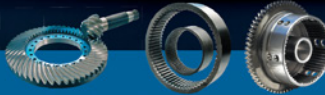
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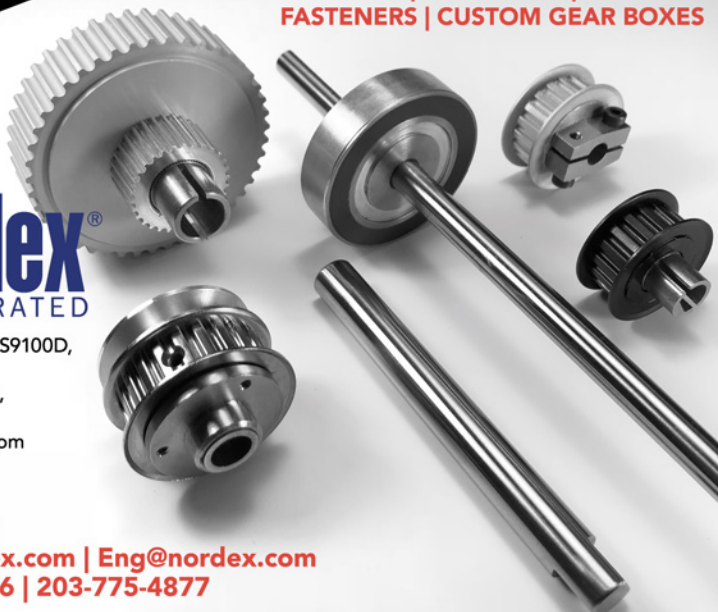
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AI and Industry Standards: Evolution or Revolution?

Phillip Olson, Director, AGMA Technical Services

I've been seeing a lot of hype surrounding OpenAI's artificial intelligence chatbot ChatGPT-4 recently. Including acing standardized tests and writing college term papers in seconds. Each time I read about it, I wonder how it, or a future generation of artificial intelligence (AI), will be used in companies and particularly in my job. To answer my question there's no better place to go than to ask ChatGPT-4 itself.

The process to ask it questions is pretty simple. I went to openai.com, created a free account, and clicked through the terms, which importantly say OpenAI collects and stores all your input data—so it's a bad idea to have it analyze confidential or proprietary information. The home screen lists three limitations; one that it may occasionally generate incorrect information, two that it may occasionally produce harmful instructions or biased content, and three that it has limited knowledge of the world and events after 2021. And at the bottom of the home screen is a text box ready for input questions.

When I asked it:

How can artificial intelligence be used to write industry standards?

I got the response of:

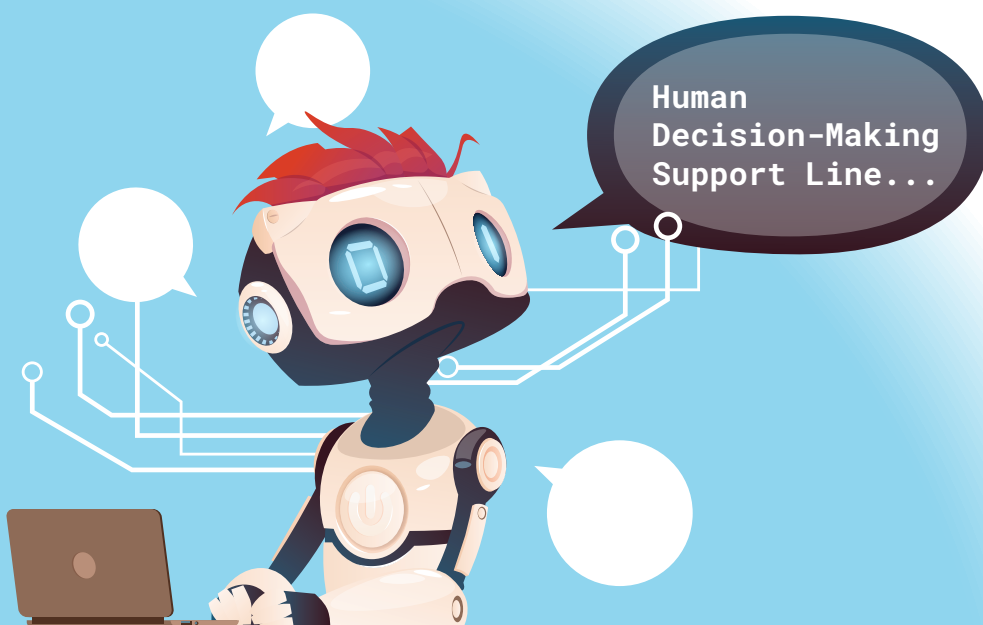
AI as the potential to revolutionize the way industry standards are written and updated. AI systems can be used to analyze vast amounts of data, identify trends and patterns, and make recommendations for improving existing standards or creating new ones. Here are some ways in which AI can be used to write industry standards:

1. *Data analysis: AI can analyze large datasets to identify trends and patterns that may be relevant to the development of industry standards. For example, AI can be used to analyze accident reports, safety incidents, and other types of data to identify common causes of accidents or failures. This information can be used to develop new standards or update existing ones.*
2. *Natural language processing: AI can be used to analyze and interpret large volumes of text, such as technical reports, regulations, and industry standards. Natural language processing (NLP) algorithms can extract key concepts and ideas from the text, identify relationships between them, and summarize the information in a more digestible format. This can help industry experts review and update existing standards more efficiently.*

3. *Machine learning: Machine learning algorithms can be used to learn from existing standards and identify patterns that may be used to improve or create new standards. For example, a machine learning algorithm could analyze a large number of standards and identify common themes, such as specific design requirements or testing procedures. This information could then be used to develop new standards that are more comprehensive and effective.*
4. *Expert systems: Expert systems are AI programs that mimic the decision-making processes of human experts. They can be used to provide guidance and recommendations for developing industry standards based on best practices and existing regulations. Expert systems can also be used to identify potential conflicts or inconsistencies in standards, which can be addressed before they become problematic.*
5. *Automated documentation: AI can be used to automate the documentation of industry standards, which can save time and reduce errors. For example, AI algorithms could be used to automatically generate standard operating procedures or test protocols based on specific requirements. This would allow industry experts to focus on more complex tasks, such as reviewing and updating existing standards.*

In summary, AI has the potential to transform the way industry standards are written and updated. By using AI algorithms to analyze data, interpret text, learn from existing standards, and automate documentation, industry experts can develop more comprehensive and effective standards that are better suited to the needs of the industry. However, it is important to note that AI should be used as a tool to support human decision-making rather than replace it entirely.

It is definitely an interesting technology to watch, and I'm happy to see its last sentence says it doesn't plan to replace humans yet!



Test Rig for Crowned Spline Joints with Optimized Surface Treatments Under Misaligned Conditions

Gerrit Hellenbrand, Dieter Mevissen, Jens Brimmers and Christian Brecher

In powertrain technology, spline couplings are used to connect gears and shafts in order to transmit high torque (Ref. 1). Furthermore, spline couplings are used in modern gas turbine aero engines to connect shaft systems and compensate shaft misalignments (Ref. 2). The compensation for shaft misalignments leads to a reduction of the constraining forces affecting surrounding machine parts (Ref. 3). While considering a load reduction based on the reduced constraining forces, the design engineer is able to reduce the required packaging volume and components weight of the whole system. Overall, this can be used to cut manufacturing costs because of a material reduction and to improve the system efficiency and simultaneously decrease the system emissions due to reduced inertia (Ref. 4).

As shown, the specific compensation for shaft misalignments with spline couplings can lead to different benefits in powertrain applications. On the downside, a growing misalignment inside of the spline coupling leads to growing sliding velocities that raise the risk of upcoming wear and fatigue phenomena on the tooth flanks (Ref. 5). Whether damages related to wear and fatigue occur is determined by the ratio between the prevailing stress and the load-carrying capacity. While increasing the stress throughout growing sliding velocities, it must be ensured that the load-carrying capacity is not exceeded. Factors influencing the load-carrying capacity of crowned spline joints include the material and heat treatment, the manufacturing history and single manufacturing steps, the final surface properties as well as the prevailing boundary conditions during operation, such as lubrication and temperature. Going further, recent research is carried out to minimize the wear effects in crowned spline joints throughout the development of surface treatments, such as PVD-coating and laser-structuring (Ref. 6).

Overall, the demands on the load-carrying capacity increase when spline joints are used for the compensation for shaft misalignments. To enable safe operation while excluding over-dimensioning, a detailed knowledge and understanding of the influencing factors on the load-carrying capacity of crowned spline joints under misaligned conditions is necessary. To investigate and evaluate the influencing factors and the performance of new surface treatments for crowned spline joints, component tests under high rotational speed and torque within misaligned shafts must be carried out. Looking at an exemplary application of spline joints in gas turbine aero engines, component testing in the application is not suitable for research investigations. To obtain time-efficient and

economic test results, a sufficient test rig is essential. This paper aims to identify and summarize existing possibilities of spline-joint test rigs in literature and present a new test rig, designed for the investigation of crowned spline-joints under misaligned conditions, high rotational speed, and torque within misaligned conditions.

State-of-the-Art Analysis

Spline couplings loaded with cyclic strains are susceptible to plain fatigue, fretting fatigue, and fretting wear (Ref. 2). Investigations according to these spline-joint phenomena are mostly carried out on test rig concepts that can be divided into three categories:

- I. Analogy Tests with Simple Specimens
- II. Analogy Tests with Spline Joints
- III. Spline-Joint Tests Under Real Working Conditions

Following, different test rig setups are introduced to outline the state-of-the-art knowledge for the investigation of wear phenomena, which appear in loaded spline-joint connections, see Figure 1.

I. Analogy Tests with Simple Specimens

Limmer et al. state that the use of inline hydraulic test machines, such as linear actuators, is an efficient way to cut specimen-manufacturing costs compared to the testing of full-scale splines. Describing an assembly of a static specimen that is clamped between two fretting pads, which are moved up and down, the appearing contact conditions in running spline joints were reproduced, see Figure 1. While using a pulsating actuator for the fretting pad movement, the test time was reduced due to the possible high load frequencies (Ref. 7).

Ferre et al. additionally applied a normal load between simple-plane and cylindrical fretting pads. Combined with the load of a pulsator, that created a cyclic displacement amplitude, fretting fatigue was investigated (Ref. 8).

Also applying a normal load and a displacement amplitude, Hyde et al. and Leen et al. used representative spline specimens, with simplified tooth flanks to reproduce the frictional contact in spline joints for their fretting investigations (Refs. 9, 10).

Wavish et al. went further and combined a low-frequency in-plane cyclic normal clamping load and a higher-frequency out-of-plane cyclic fatigue stress. This enabled fretting investigations by superimposing multiaxial fretting conditions (Ref. 11).

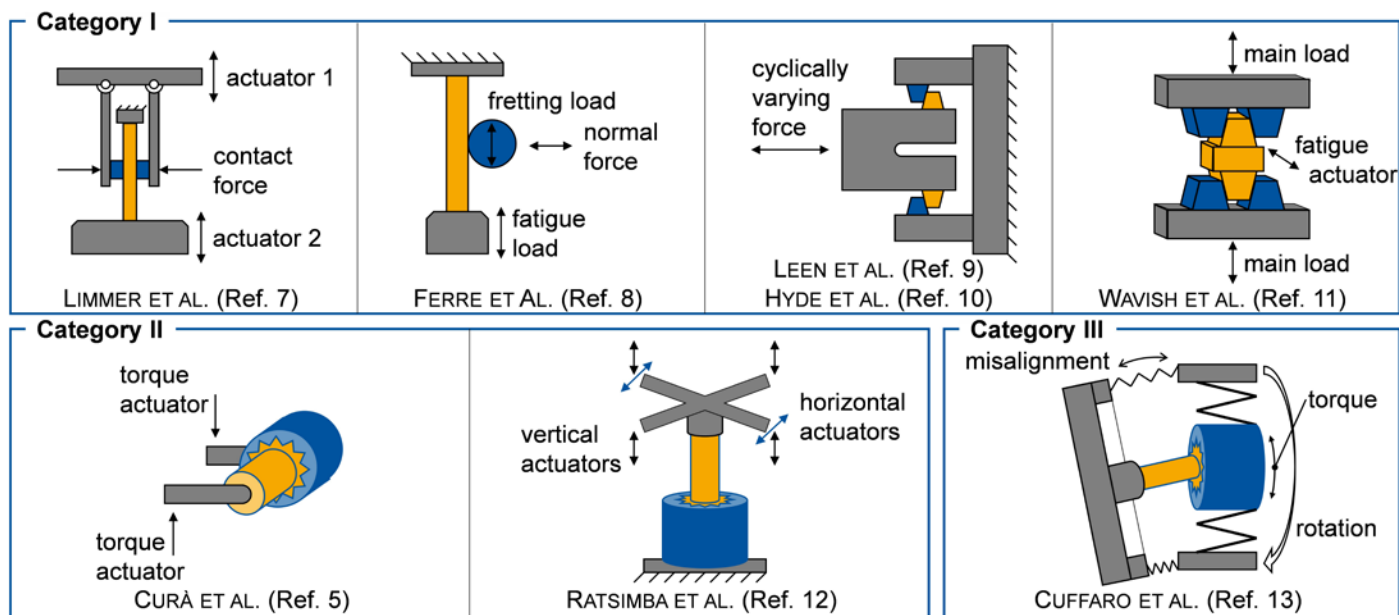


Figure 1—State of the art: test-rig setups for the investigation of wear phenomena in spline joints (Refs. 5, 7, 8, 9, 10, 11, 12, 13).

II. Analogy Tests with Spline Joints

Curà et al. used a pulsator with a torque-generating lever device for spline-joint testing. By means of this device, component tests with variable torque amplitudes could be proceeded. Throughout the use of the Pulsator, time-efficient testing was realized (Ref. 5).

Ratsimba et al. investigated fatigue failure and fretting wear on a spline-joint test setup with multiple actuators to reproduce multiaxial loads. While testing a vertically clamped spline coupling, the torque was generated by two horizontal actuators, which were mounted on two opposing levers. Additionally, four vertical actuators in combination with a crossed lever system were mounted to the spline shaft. By means of this setup, axial loads and rotating bending forces appearing in spline joints under misaligned shaft conditions were reproduced and could be tested economically (Ref. 12).

On the one hand, analogy tests with spline joints enable resource and time-efficient testing, by using pulsating actuators and torque-generating lever devices. On the other hand, the use of these actuators instead of rotating spline joints, results in the neglect of the axial pressure peak movement associated with misaligned spline joints. Therefore, different contact patterns according to each single flank are generated. Additionally, the prevailing flow of the lubricant in the tooth mesh is not properly reproduced. Due to the missing centrifugal forces and radial conveyance effects because of the movement of the contact zone, the lubrication conditions in the analogy tests differ from real applications.

III. Spline-Joint Tests Under Real Working Conditions

Testing spline joints under real working conditions requires a more extensive test rig setup to properly account for the load case, including the rotational speed, torsional load, and dedicated shaft misalignment. Cuffaro et al. presented a spline coupling test rig fulfilling these requirements by installing a split coaxial shaft system with mechanical power recirculation. For

this purpose, the two parts consisting of each one inner and one outer shaft were connected. The inner shafts were connected with the tested spline joint and the outer shafts by a flexible joint. While rotating this shaft system, pretensioned with the test torque, the spline joint ran under more realistic working conditions. For tests under misaligned conditions, the two parts of the shaft system could be tilted against each other along the axis of the spline parts. With this test setup a maximum torque of $T_{max} = 5000 \text{ Nm}$ and a maximum rotational speed of $n_{max} = 2000 \text{ rpm}$ could be provided for spline testing with a maximum temperature of $\vartheta_{max} = 60^\circ\text{C}$. Related to these operating specifications, the performance characteristic of the test rig presented by Cuffaro et al. aims at high torque applications under lower rotational speed (Ref. 13).

Conclusion on the State of the Art

As shown, the majority of spline coupling test rigs entrenched in literature were built up as analogy test rigs. Analogy test rigs with simple specimens reproduce a sliding condition between test specimens under contact pressure to reproduce the contact properties prevailing in loaded spline joints. On the one hand, the benefits of testing on analogy test rigs with simple specimens is that the specimen manufacturing is cost-efficient, and the testing time is short since pulsating actuators with high test frequencies are used. This enables statistical testing in a reasonable time and cost frame. On the other hand, the major disadvantage of analogy test rigs is that the prevailing working conditions of the application are not completely reproduced. Especially when spline joints are operated under angular misalignments of the shaft systems, the specific kinematics of the tooth contact is not sufficiently replicated by analogy test rigs even if they use spline joints as test specimens. Finally, the axial movement of the contact zone over the tooth flank cannot be reproduced on the existing analogy test rigs. To fully examine occurring damage mechanisms and wear phenomena of misaligned spline joints, it is necessary to test spline joints under real working conditions. A test rig that can be used for

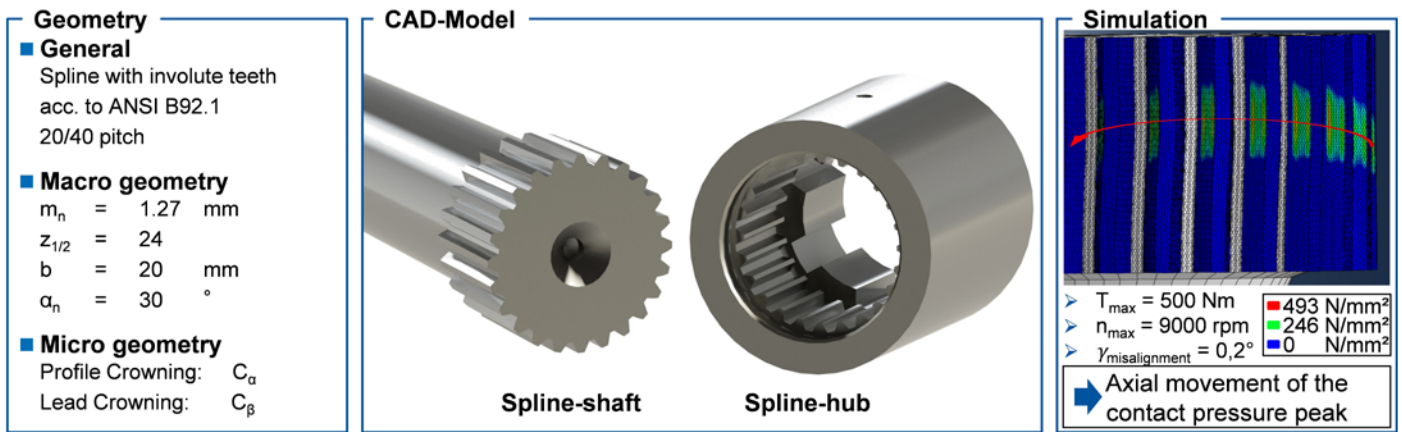


Figure 2—Test spline joint design.

this purpose is described by Cuffaro et al., which focuses on high torque, lower rotational speed, and moderate temperature testing. However, high rotational speeds and high test temperatures are prevalent in modern gas turbine aero engines, so there is a deficit in the capability to test spline joints under application near test conditions. Therefore, the objective of this paper is to present a newly developed test rig and a test spline geometry for high rotational speed and high-temperature testing of crowned spline joints under misaligned conditions. For this purpose, a back-to-back test rig is enlarged by multiple features to test misaligned spline joints inside the power recirculation circuit of the test rig. Besides high rotational speed, high test temperatures up to a maximum of $\vartheta_{\max} = 120^\circ\text{C}$ are realized by a controlled oil injection into the tooth mesh.

Design of a Test Spline Joint

For the investigation of wear phenomena of misaligned spline joints under real working conditions with a performance characteristic of high rotational speed, medium torque, and high operating temperatures, a full-scale spline joint and a test rig were designed. The design of the test spline geometry is presented for a working, crowned, side fit spline-joint, see Figure 2. In the design process, the focus was to generate the same contact conditions, which prevail in the tooth flank contact of spline joints in aircraft-engine gas turbines. To enable testing on existing test rigs, the size of the test spline was reduced in comparison

to the application. To ensure that the prevailing contact conditions resemble the contact conditions of the application, the contact pressure and the ratio of the sliding velocities were used as design parameters.

Considering the target value for the contact pressure, the spline macrogeometry was designed according to ANSI B92.1 to fit a test torque that matches the common load levels of a back-to-back test rig (Ref. 14). Additionally, the spline microgeometry and the dedicated shaft misalignment $\gamma_{\text{misalignment}}$ were designed to further fit the kinematics of the application. Therefore, a FEM simulation of the spline connection was carried out. In the operation of loaded, misaligned spline joints, the maximum pressure peaks move cyclically on each rotation axially along the tooth flanks. While analyzing the static contact zone distribution over all teeth, the displacement of the contact zone over the angular positions of the single teeth was recorded, see Figure 2. With this data and the rotational speed, the kinematics of the contact movement was calculated. The contact zone movement can be described by a cyclic sliding velocity function. For the calculation of the movement of the contact zone, not only does the rotational speed and the distance between the contact zones need to be considered, but also the sine relation of the sliding velocity function must be considered. To calculate the maximum local sliding velocity as well as the maximum global sliding velocity, the sine-dependent nonlinearity of the sliding velocity function

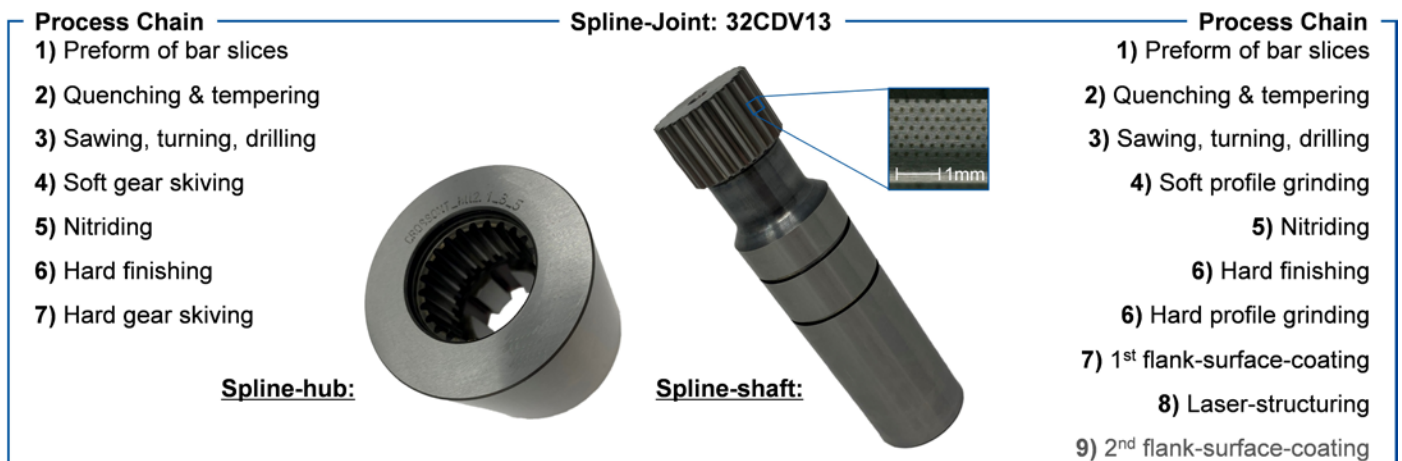


Figure 3—Test-spline joint: process chain.

was evaluated. Based on this calculation, the spline design was finalized to generate a tooth mesh characteristic with the dedicated contact pressure and maximum axial sliding velocity.

In the next step, to assess the capabilities of newly developed surface treatments, spline joints for the tests were manufactured. The designed spline geometry was processed out of the nitriding steel 32CDV13, which is widely used in aerospace applications. This material was chosen to meet the application of an aircraft-engine gas turbine. For the manufacturing, the process chain followed a conventional gear manufacturing process route for nitriding steels, see Figure 3.

After quenching and tempering the preforms, the blanks were machined, followed by soft machining of the gear. Next, the specimens were plasma-nitrided and then the functional surfaces and the gears were hard-finished. For the gear manufacturing steps, a gear-skiving process was carried out for the soft- and hard-machining of the spline hubs and a discontinuous profile grinding process for the spline shafts. Then, the different surface optimizations were applied. For this purpose, the coating and structuring systems described by Stephen et al. were used (Ref. 15). Two different variants were manufactured in terms of physical vapor deposition (PVD) to generate TiN + MoS₂:Ti and TiN + DLC + MoS₂:Ti:C multilayered coatings. Additionally, a laser structuring process took place, where dimples with diameters between $d_{struct} = 40$ to $80 \mu\text{m}$ were applied on the tooth flanks, as shown in Figure 3. Finally, a second coating step took place for selected test variants to apply a solid lubrication layer.

In the next step, the presented spline joints will be tested according to their wear behavior under misaligned conditions. To realize reproducible test conditions within a time-and-cost-based economic framework, a suitable test rig for the planned investigations is presented.

3 Test Rig Design

A common method in gear load capacity testing is to use power recirculation for the test power generation. The idea

behind this approach is to apply and entrap a static torque in a power circuit through pretensioned spring elements. A motor then drives this power circuit (Ref. 16). Due to the entrapped static test torque, the motor only needs to overcome the power dissipation of the system but not the actual test power. This leads to an economical test rig design since only the power dissipation of the system must be applied during endurance testing, rather than the high power, which is transmitted by the test gears. A test rig that features a power circuit and is widely used for this testing is the back-to-back test rig, standardized by DIN ISO 14635 (Ref. 17). This test rig is built to investigate cylindrical gears. Following, the extension of a back-to-back test rig is presented, which enables the testing of spline joints, see Figure 4. Based on the test spline geometry and the targeted contact pressure and contact kinematics for spline-joint testing, the following test rig requirements were implemented:

- Test torque: $T_{max} = 500 \text{ Nm}$
- Rotational speed: $n_{max} = 9000 \text{ rpm}$
- Dedicated shaft misalignment: $\gamma_{misalignment} = 0.2^\circ$

To match the performance range of the presented test spline-joint, a back-to-back test rig with a center distance of $a = 112.5 \text{ mm}$ was used. For the testing, the spline joint was integrated into the power circuit of the test rig. Therefore, the shaft system of the standard setup was reconfigured. On the motor averted side, the clutch was removed to gain space for the test spline. An axial slim clutch and the torsional shaft were applied in the shaft system on the motor side. On the motor averted side, a new bearing system was applied since the rotational speed for the testing of the spline-joints $n_{max} = 9000 \text{ rpm}$ exceeds the speed spectrum of the standard setup. Going further, two new shafts were designed for this side to integrate the spline joint into the power circuit. The test spline hub was directly mounted and clamped onto the right-hand side test shaft. Due

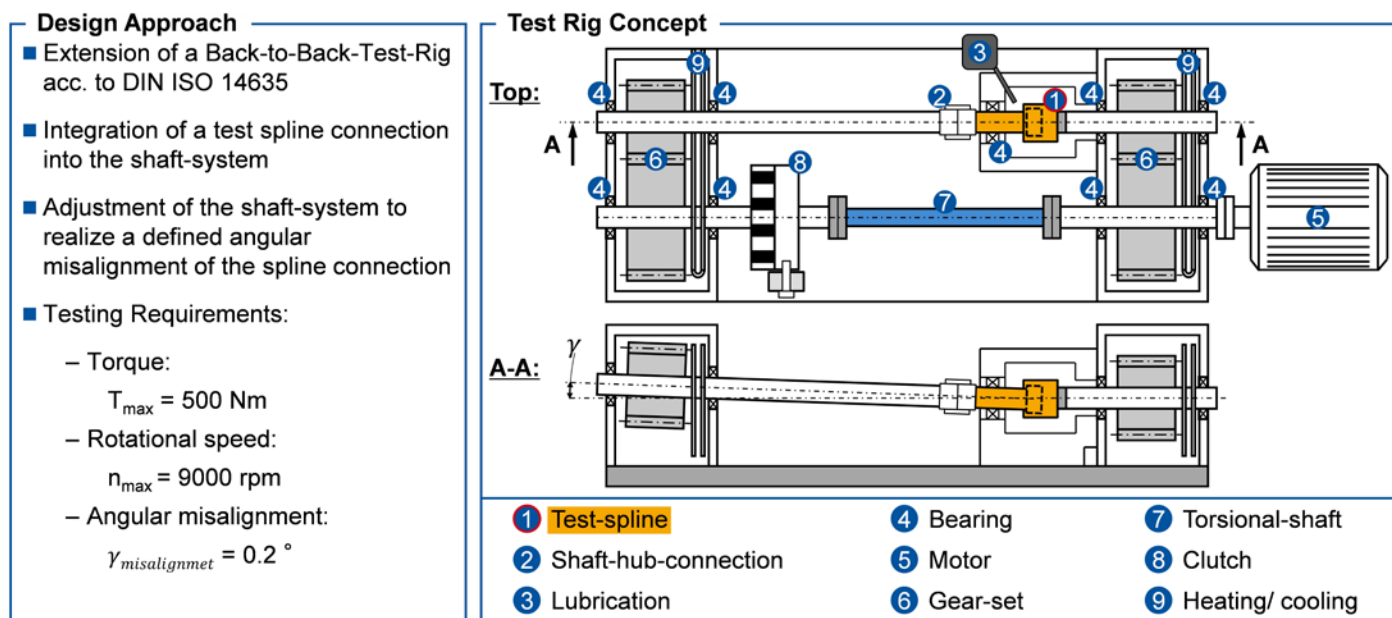


Figure 4—Test rig concept.

to the mountability, the spline shaft was attached to the left-hand side shaft with hydraulic-shaft hub connections, which can be removed during assembly. To additionally stabilize the spline joint, a support bearing was attached to the spline shaft and the housing. The housing shields the spline joint during the test run, seals the test space against oil leakage, and enables a consistent test temperature.

To generate the dedicated spline-joint misalignment of $\gamma_{\text{misalignment}} = 0.2$ degrees the left-hand side of the motor averted shaft system, including the spline shaft, was tilted upwards around the center of the spline joint, see Figure 4. Therefore, special bearing bushes were designed. The bearing seats of the left-hand side shaft system were aligned with the necessary deviation from the axis of the right-hand side shaft to generate the dedicated spline misalignment. To gain high precision for the manufacturing of the bearing seats, the final processing was done in a single clamping. With this procedure, the angular spline misalignment is fixed for the assembly. To change the dedicated misalignment, it is necessary to change the bearing bushes. The benefit of this design is, that the misalignment is fixed for the assembly and therefore remains the same for all tests of a test series. Going further, two cylindrical gear sets were installed, to connect the motor- and spline-shaft systems and to raise the rotational speed from the motor to the testing speed. Due to the dedicated angular misalignment of the spline shaft, the microgeometry of one gear set was specially designed for this application. Within the design, the angular misalignment is compensated for, gaining a centered contact pattern in the tooth mesh, and excluding contact pressure elevation due to edge wear.

Finally, an additional oil supply was built up to provide a dedicated oil flow rate on a controlled injection temperature for the spline joint. With this extension, the spline joint can be tested under lubricated contact conditions. During operation, the oil is constantly injected into the tooth mesh. An additional sealing, which inner diameter is smaller than the pitch diameter of the spline joint creates an oil bath in the

tooth contact and reduces the radial oil flow out of the tooth mesh, see Figure 5. Since the injection temperature of the oil supply is controlled, injection temperatures up to $\vartheta_{\text{max}} = 120^\circ\text{C}$ are realized, which enables application-related testing according to the prevailing lubrication and temperature in the spline-joint contact.

To validate the manufactured shaft misalignment an additional measurement of the bearing seats on a coordinate measuring machine was performed. Despite the distance between the machined bearing seats of $l \approx 600$ mm, the precise positioning is shown by the straight line through the measuring points, which reflects the real axis position of the test rig. Additionally considering the alignment of this axis to the axis, which is generated by the already existing bearing seats, the resulting intersection is shown in the diagram. Based on the data, the actual manufactured angular misalignment of the test rig is measured to $\gamma_{\text{measure}} = 0.2006$ degrees with an intersection point of the shaft axis that meets in the center of the spline joint, see Figure 6.

In addition, the test spline-joint design regarding the axial movement of the contact pressure peak was validated during commissioning. A static contact pattern was used for this purpose. Therefore, the clutch of the test rig was locked, and a cyclic torque was applied to the stationary shaft system over a few minutes. Due to this load, the wobble of the flank contacts resulting from the angular misalignment becomes visible in the static contact pattern. The contact distribution, following a sine curve over the circumference, is shown in Figure 6. Compared to the results of the static contact simulation from the design process, it can be seen that the calculation of the contact length with a value of $\Delta_{\text{CL,simulation}} = 2.45$ mm agrees with the measured value of $\Delta_{\text{CL,measure}} \approx 2.5$ mm. Continuing, the dynamic contact pattern was recorded to verify the previous measurements of the dedicated shaft misalignment and to validate the generation of the targeted contact conditions. To record the dynamic contact pattern, the spline shaft was painted with contact pattern lacquer before mounting it and rotating the spline joint

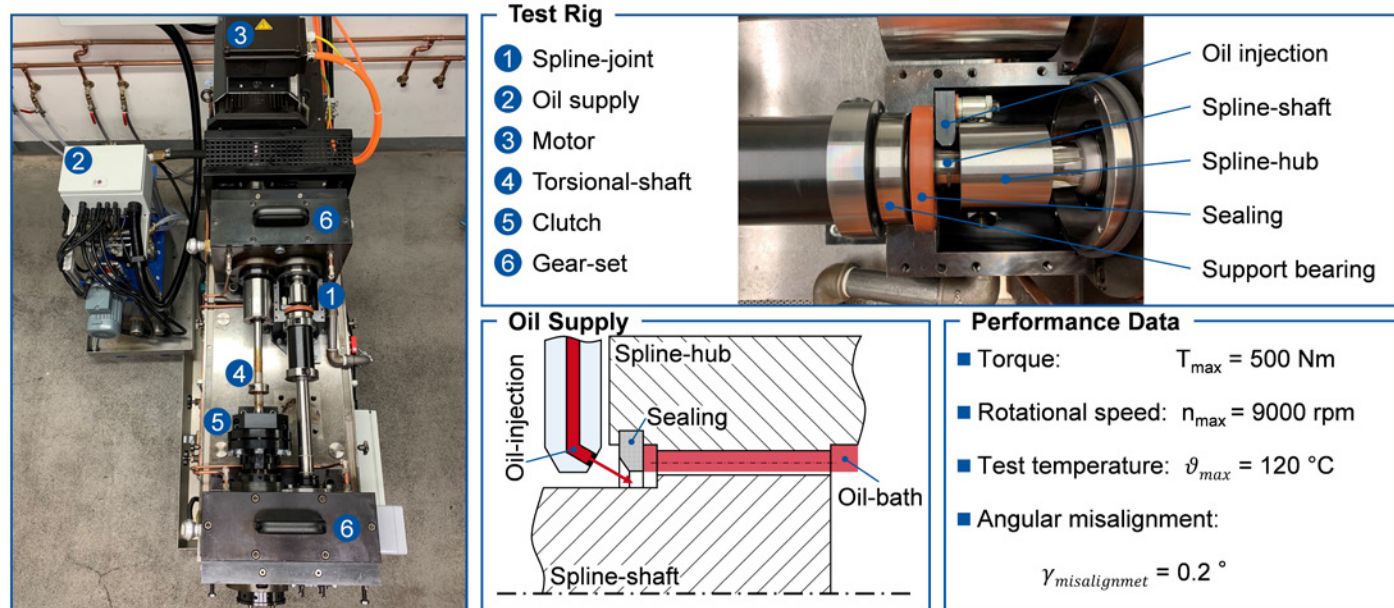


Figure 5—Test-rig setup.

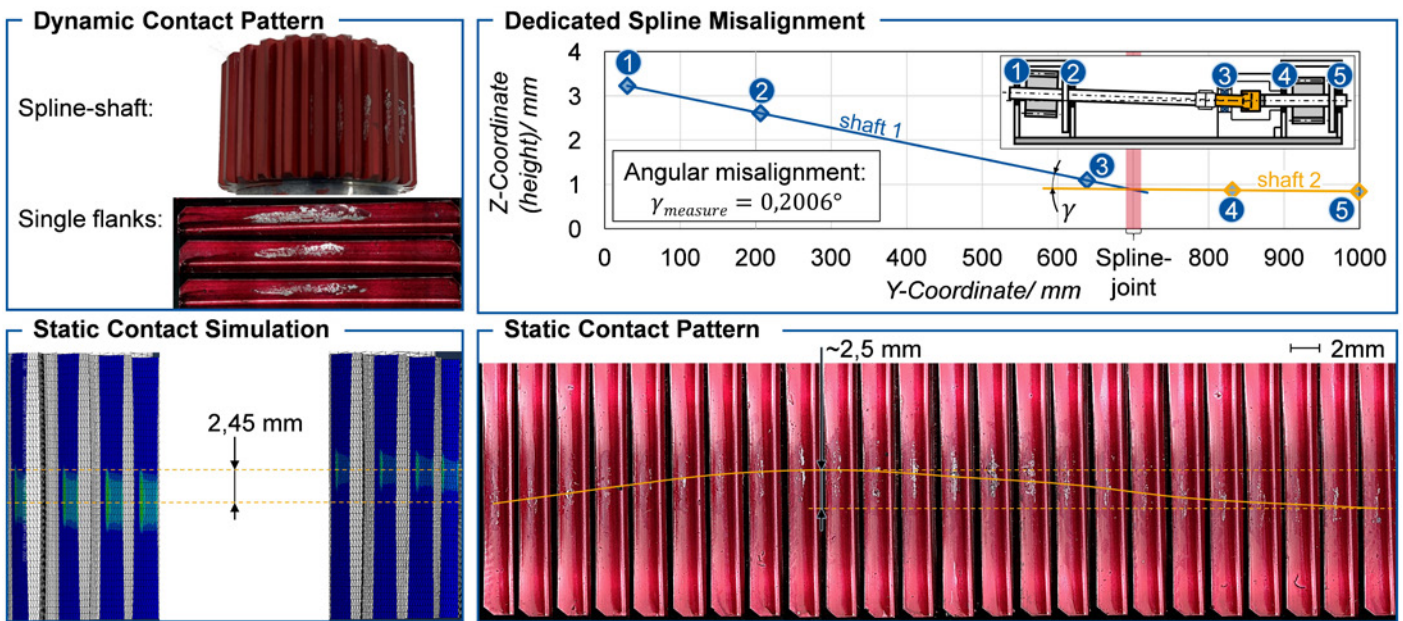


Figure 6—Test-rig validation.

within moderate torque on the test rig. The dynamic contact pattern shows that the manufactured spline joints and the implemented test rig extension generate a centered contact zone over the spline flanks in operation.

Finally, the test rig commissioning was completed with test runs. The capability of the test rig to provoke wear and fatigue phenomena on misaligned spline joints was shown by the occurrence of tooth flank damage, see Figure 7. Therefore, a first specimen with an as-ground surface finishing has been used. While analyzing the microscopic images of the run tooth flank, the contact zone showed slight changes in the appearance of its surface color. Going further, damage with material removal in the center-right of the contact zone appeared. In the second step, a coated specimen was tested to validate the capability of the test rig setup for the generation of coating wear. Since the different coating layers have different colors, the coating wear was analyzed by its appearance in microscopic images, see Figure 7. For this coating, the MoS₂:Ti top layer is visible in silver. For the middle layer, a C:H:Ti layer was used, which can be seen in a black area, where the top layer was removed. Finally, the TiN bottom layer became visible in the golden areas. In the event of a total coating failure, the substrate material became visible underneath the golden layer in a gray hue.

The occurrence of tooth flank damage validated that the presented test rig in combination with the test spline-joint

geometry is sufficient for the testing of wear and fatigue phenomena in misaligned spline joints. Following spline-joint testing and detailed investigations on different surface treatments and optimizations, such as coatings and laser structuring will be performed to raise the load-carrying capacity of crowned spline joints.

Conclusion and Future Work

The state-of-the-art shows that various concepts for the investigation of wear and fatigue phenomena of spline joints exist. For the majority of the existing test rig setups, analogy tests with simple specimens or spline joints are used to generate the contact conditions of loaded spline joints. Especially concerning the contact conditions of rotating misaligned spline joints, the use of analogy test rigs neglects various boundary conditions of the tooth contact. Thus, it becomes apparent that for a comprehensive investigation, component tests with spline joints under realistic operating conditions must be carried out. Cuffaro et al. present such a test rig, which is used for the testing of spline joints under misaligned conditions, whereby the concept is designed for investigations at high torque, lower rotational speed, and low test temperatures (Ref. 13). To investigate misaligned spline joints under high rotational speed, medium torque, and high test temperatures, there is a need for new test concepts.

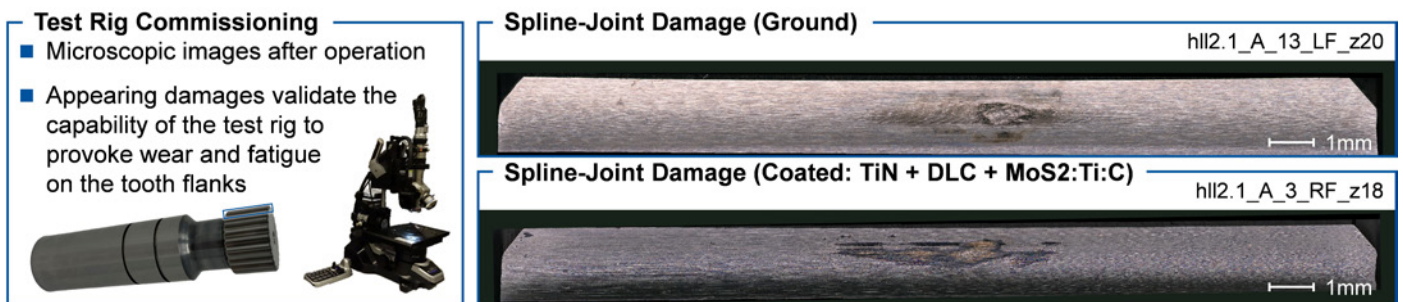


Figure 7—Spline-joint damage.

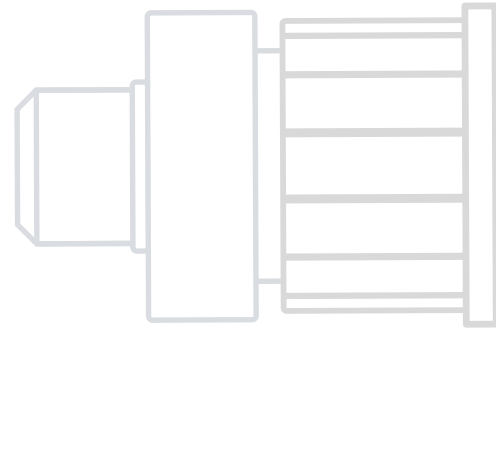
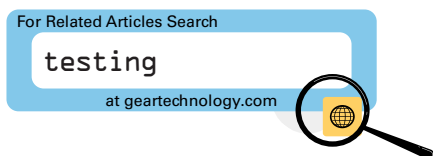
In the present paper, a spline-joint design and the extension of a back-to-back test rig were presented, which enable the testing of crowned spline-joints under high rotational speed, medium torque, high test temperature, and angular misalignments. For this purpose, the design approach for a spline-joint geometry based on a simulation of the contact conditions with respect to the contact pressure and contact kinematics was presented. Furthermore, the extension of a back-to-back test rig was presented which allows the integration of the designed spline joint into the power circuit of the test rig, while simultaneously enabling test conditions under angular misalignments. Finally, it was shown by the static contact pattern in comparison to the static contact simulation and an additional axis measurement, that the combination of the developed test rig and spline joint is sufficient for the generation of the loads that appear in misaligned spline joints. Therefore, the test rig can be used for spline-joint testing under application-related conditions. Going further, damages that occurred during the test rig commissioning were presented. These damages validate the capability of the test rig to generate wear and fatigue phenomena in misaligned spline joints under high rotational speed, medium torque and high test temperatures.

In the future, spline joints will be tested on the developed test rig to assess wear and fatigue phenomena that arise in misaligned spline joints. The benefits of special surface treatments such as coatings and laser structuring will be evaluated on the presented spline-joint design to demonstrate and validate their potential for industrial applications. Additionally, more spline-joint geometries can be designed to generate different contact conditions on the existing test rig. Therefore, further investigations on the influencing variables on the spline-joint load capacity such as different materials, heat treatments, surface conditions and optimizations, lubrications, test temperatures, or microgeometries can be performed. Throughout these tests, an increase in the power density of spline joints is likely to be enabled and safety margins can be cut due to the availability of extended test data. By achieving this objective, an improvement of the systems can be realized, which ultimately enables the reduction of manufacturing costs and energy consumption of modern aircraft-engine gas turbines.

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Force Modeling in Generating Gear Grinding Considering the Grinding Worm Topography

Patricia de Oliveira Löhner, Mareike Solf, Jens Brimmers, Thomas Bergs

Introduction

Continuous generating gear grinding is a hard finishing process mainly used to meet the high requirements for gears in terms of geometry and surface quality (Ref. 1). During grinding, a major percentage of the generated energy is converted into heat. Depending on the process conditions, a fraction of 60–90 percent of the generated heat can flow into the workpiece (Ref. 2). This fraction of generated heat leads to high temperatures in the contact zone, which can cause thermal damage in the workpiece (Refs. 3,4,5).

To better understand and control the part of the generated heat that flows into the workpiece, it is first necessary to specify the according energy partition. In the work of Hahn, it was established that the removal of material by each grain of the grinding tool during the process is performed based on three different mechanisms: friction, plowing, and shearing (Ref. 6). Each of these mechanisms contributes to the partition of energy that goes into the workpiece in a singular way (Ref. 4).

The grain energy generated in each of the three phases of material removal depends on grain-workpiece microinteraction characteristics such as grain contact length, grain penetration depth, and grain cross-section area (Ref. 2). These microinteraction characteristics are significantly influenced by the grinding tool topography and the grains interacting with the material (Ref. 7). In turn, the interaction of the grains of the grinding wheel topography with the gear is characterized based on both process kinematics and process parameters. To develop a suitable grinding energy calculation for generating gear grinding, it is necessary to consider how each grain interacts in the contact zone, based on the process parameters to which they are submitted.

For the research developed in this work, an existing simulation model of the generating gear grinding process based on a penetration calculation approach is used. Further, an extension of the model considering a realistic modeling of the grinding worm topography and the macro movements of the grinding worm during the process is presented. The result of the simulation is the microinteraction characteristics throughout the grinding of the gear flank. In the end, the information about microinteraction characteristics obtained will be used for the calculation of force and energy in generating gear grinding.

State of the Art

Generating gear grinding is one of the most efficient processes for hard finishing of gears. In the process, the cylindrical grinding worm whose profile equates to a rack profile in a transverse section meshes with an external gear (Ref. 1). The involute of the gear is generated by the continuous generating motion of the grinding worm and workpiece by the profile cuts method. One special characteristic of the process is the multiple points of contact between the grinding worm and the gear, Fig. 1. The number of contact points changes continuously during the tool rotation (Ref. 1).

Based on the grinding worm topography, process parameters, and process kinematics, the microinteraction characteristics are different for each grain. Ultimately, these differences influence the force and the energy in the contact zone. To predict the force and energy of the process, simulation models have been developed in the last years, considering the complex kinematics of generating gear grinding as well as the microinteraction characteristics (Refs. 8, 9, 10). One of these simulation models will be reviewed in the next section. Furthermore, a review of the microinteraction characteristics currently considered in the software for the calculation of the forces is performed. In addition, the calculation of the energy for generating gear grinding considering the microinteraction characteristics is described and reviewed.

Modeling for Generating Gear Grinding

Modeling of manufacturing processes can be done by means of a penetration calculation approach. In a penetration calculation, characteristic process values can be calculated considering the kinematics and geometry of the workpiece and tool. A three-dimensional model is simplified to a two-dimensional model by means of sectional planes. In the work of Brecher et al., a simulation model is described (Ref. 9), Figure 2.

The simulation is performed in several steps. In the first step, input data such as gear and tool geometry and process parameters are read. Next, models of the grinding worm and the pre-cut gear based on sectional planes are generated. The sectional planes in the grinding worm represent the tool profile. To keep the computational effort as low as possible, only a segment of the actual grinding worm is considered for the simulation, defined by an opening angle of φ_{0y} , middle of Figure 2. In the next step, an abstraction of the actual process kinematics was introduced in the simulation model, to decrease the complexity of the modeling. In the abstracted kinematics, the grinding worm segment is positioned relatively to the gear, following a trochoid curve. The trochoid-generating motion of the grinding worm of the simulation model represents a combination between the movements of the gear and tool, occurring in the real process. Despite the kinematics abstraction, the same contact conditions and material removal to the real process are achieved in the end of the simulation. The trochoid-generating motion is discretized along the process by a defined generating increment $\Delta\xi$. Between the first and the last generating increment $\Delta\xi$, a complete machining of the tooth gap's sectional planes is performed. The contact geometry between the grinding worm segment and the gear is calculated for all discrete generating positions, in the lower middle of Figure 2.

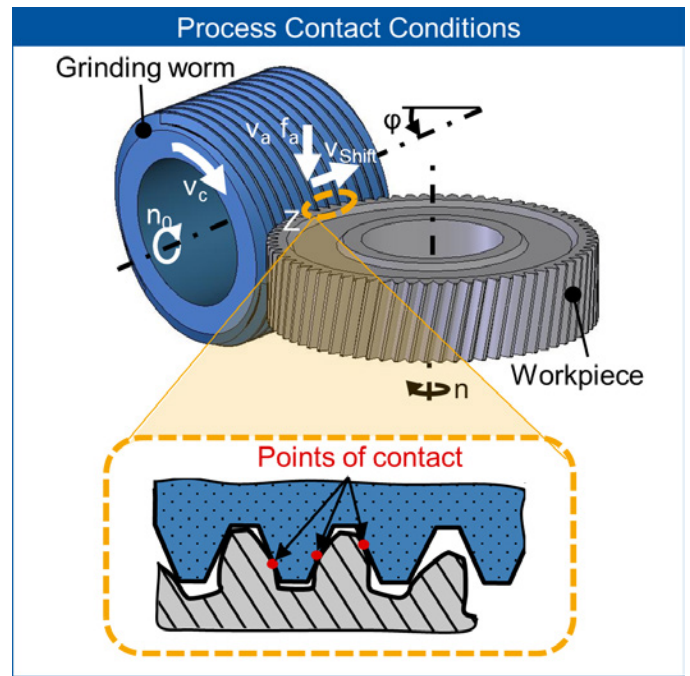


Figure 1—Generating gear grinding process.

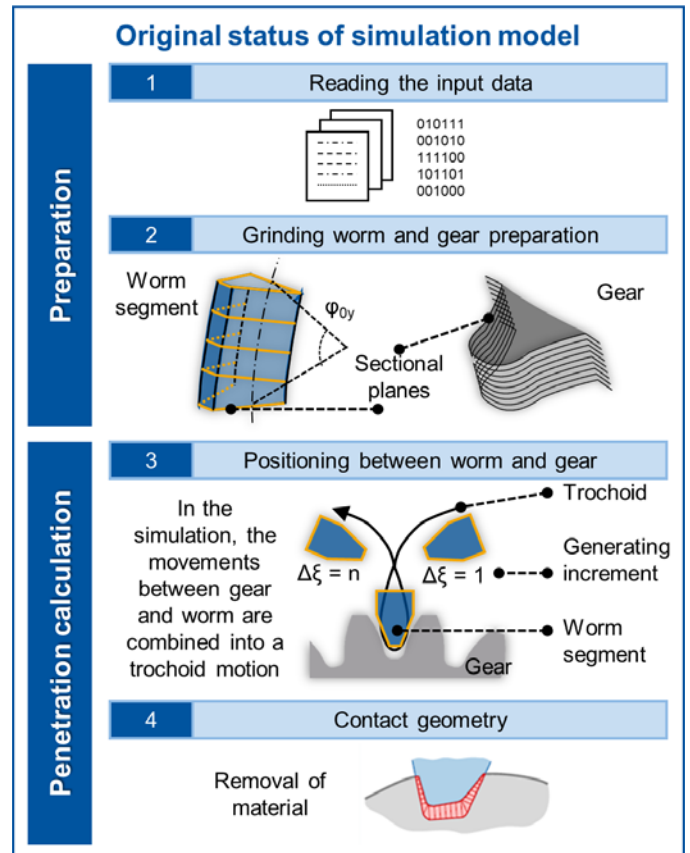


Figure 2—Steps for the simulation model.

Now, the simulation model only considers the macro interaction of the tool and the gear. However, for an accurate energy and force calculation, the microinteractions between the grinding worm and the gear are also of high relevance. The abstraction of the process kinematics used in the simulation model, without an accurate representation of the tool rotation and the cutting speed, makes modeling of microinteractions not possible. The rotational movement of the tool surface has a significant influence on the grinding worm topography interaction with the material. The rotational movement is essential for the generation of the path of contact between grains and gear during the process, and it cannot be neglected in the simulation if the microinteractions should be analyzed.

Microinteraction Characteristics in Generating Gear Grinding

In the work of Hübner, an investigation of the normal force calculation considering the engagement of the grains with the help of the simulation model (see “Modeling for Generating Gear Grinding”) was performed (Ref. 12). In his work, the normal force model developed by Werner was transferred to generating gear grinding (Ref. 13), see equation shown in the upper of Figure 3. Except for the specific force k , all the variables were calculated in the simulation model. In the work of Hübner, the grinding worm topography was modeled by means of measured 2D contours of individual grains. Those individual grains were subsequently mapped onto the grinding tool profile manually. While this approach can be suitable for monolayer galvanic grinding tools, the irregularities of the grain distribution of vitrified grinding worms are not reproduced accurately. Therefore, the approach used by Hübner, did not consider two important factors of the grinding worm topography. The first factor is the different protuberance of the grains from the grinding worm topography, which leads to the situation where not all the grains from the grinding worm topography are in contact with the workpiece. The second factor is the shadowing effect during the contact between the workpiece and the grinding worm. The shadowing effect characterizes the influence of the first grains in contact with the material on the engagement of the grains which are in contact with the material immediately afterward.

The process energy E_w corresponds to the energy required to remove material and is commonly assumed to be equal to the spindle energy (Ref. 2). In the previous work of Teixeira, an energy model considering the chip formation mechanisms of the engagement of one single grain for generating grinding was proposed (Refs. 14, 15). This model was based on the work of Linke, where the energy of each chip formation mechanism was calculated differently, considering its specific aspects for the process of surface grinding (Ref. 2). In the model of Teixeira, the work of Linke was expanded for the process of generating gear grinding, upper right of Figure 3, and single-grain trials were performed for validation. A more detailed description of the calculation method for the energy of each chip formation mechanism can be found in (Ref. 14).

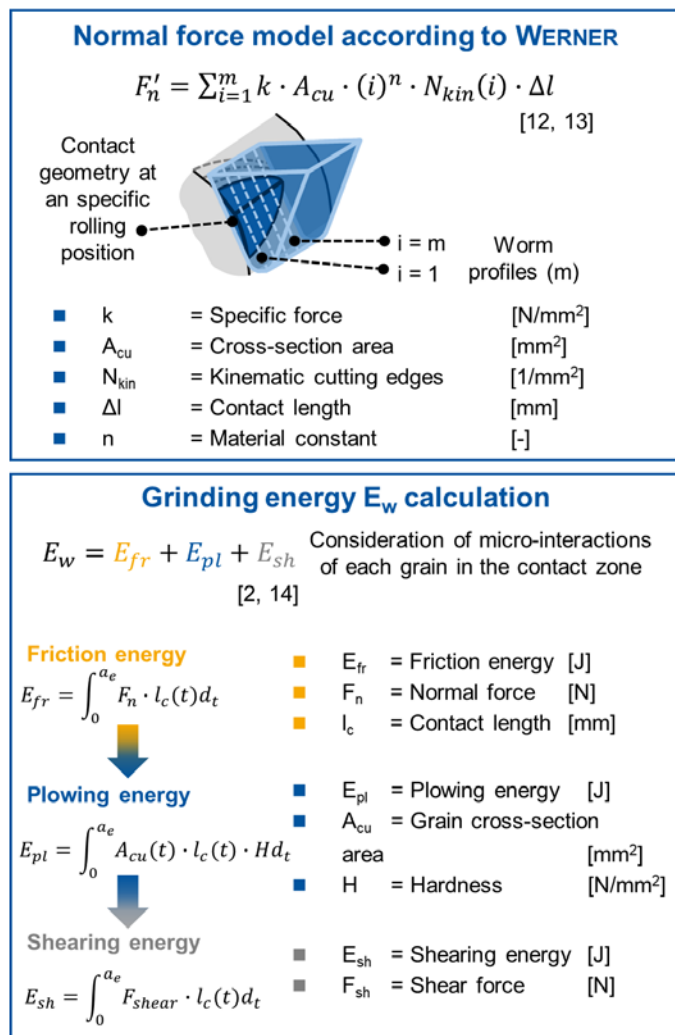


Figure 3—Calculation of force and energy for generating gear grinding process from previous research.

For the calculation of the energy of each chip formation mechanism, information regarding the microinteraction characteristics of the grains, such as contact length l_c , grain cross-section area A_c and chip thickness h_c are required. In the end, the process energy E_w was calculated as the sum of all the energies from each chip formation mechanism, of all the grains engaging in the material, upper right of Figure 3. Even though different research has been performed on the topic of simulation models for force and energy for generating gear grinding, an investigation of the microinteraction characteristics using more realistic modeling of the grinding worm topography while considering the complex kinematics and tool rotation movement of the process is required. The consideration of tool topography and grinding worm rotation will enable a more detailed calculation of the energy for generating gear grinding process.

Objective and Approach

Based on the scientific gap in the simulation model explained in “State of the Art” regarding the consideration of grinding worm topography and tool rotational movement, the objective of this work is defined. The main

objective of the work is the development of a force and energy model for generating gear grinding considering the process kinematics and the microinteraction of grinding worm topography and gear.

Extension of Simulation Model Considering the Tool Topography

In this section, the extensions implemented in the simulation model are described. There are two different types of extensions to be performed: (1) grinding worm topography and (2) grinding worm rotational movement. The implementation of the grinding worm topography in the simulation model is first described, Figure 4.

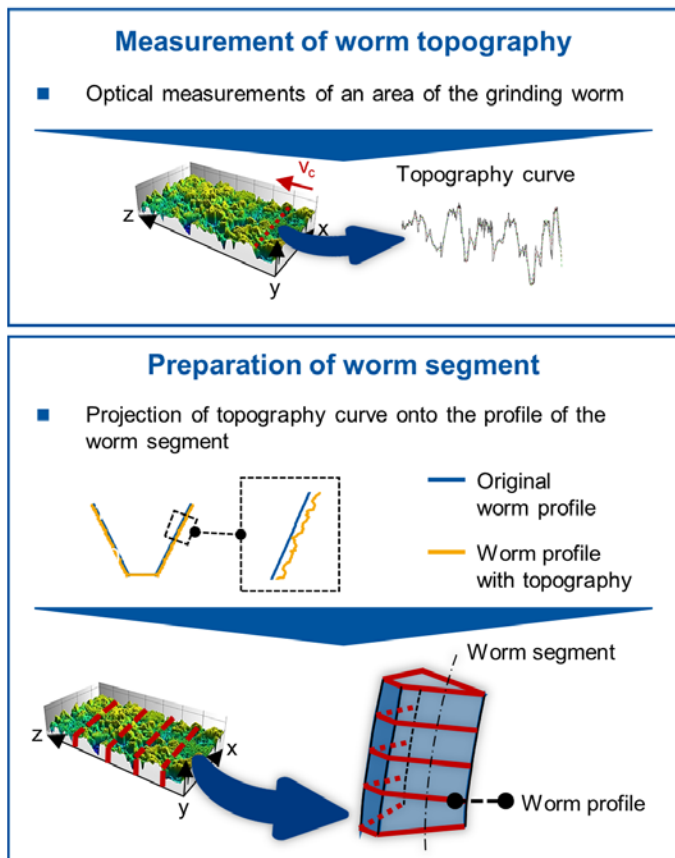


Figure 4—Extension of simulation model regarding grinding worm topography.

The first step is an optical measurement of the grinding worm topography with a laser scanning microscope. The measurement is performed with a resolution of 20x, in an area of the grinding worm large enough for a representative sample of the entire grinding worm specification. The optical measurement is analyzed with the support of the software *MountainsMap*. In the software *MountainsMap*, topography curves are extracted in several positions along the z-axis, Figure 4. Next, the topography curve is brought onto the worm segment. The worm segment, shown at the bottom of Figure 4, is formed by sectional planes called tool profiles. Each topography curve of the real grinding worm is projected onto one different tool profile. In the end, the topography of the real grinding

worm will be represented in the worm segment used in the simulation model.

The second extension required in the simulation model is regarding the grinding worm rotational movement. The worm segment is positioned relative to the gear following a trochoid motion. In the original version of the simulation model, the position of the worm segment changes along the simulation, but the worm segment itself does not change or rotate. In addition, all the tool profiles of the worm segment are the same. In the extended simulation model, each tool profile from the worm segment has a different topography curve. The rotational movement of the worm segment is implemented by a change in the position of each tool profile during the simulation, see Figure 5.

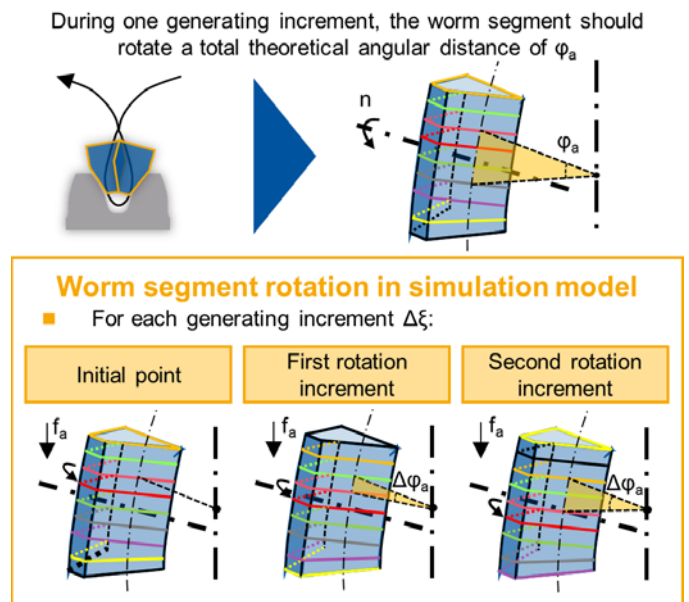


Figure 5—Extension of simulation model regarding grinding worm rotational movement.

The changes in the position of the tool profiles are correlated to the process parameters and the generating increment $\Delta\xi$. During one generating increment $\Delta\xi$, the worm segment should rotate a total theoretical angular distance of ϕ_a . Based on the theoretical angular distance ϕ_a , the number of times the position of tool profiles has to be changed is defined. The change of position of the tool profiles is conducted by single rotation increments until the theoretical angular distance ϕ_a is reached. After the angular ϕ_a distance is reached, the simulation continues to the next generating increment $\Delta\xi$, and the procedure for the change of position of the tool profiles is repeated within the new generating increment. With this procedure, the simulation model was extended in terms of a realistic consideration of the grinding worm topography as well as the rotational movement.

Analysis of Results

In this section, the calculation of force and energy for the process of generating gear grinding based on the microinteraction characteristics of the grains engaging with the gear material is performed and discussed.

Verification of Extension of Simulation Model

After the extension of the simulation model, the microinteraction characteristics of all the grains engaging with the gear during the process are obtained. With the microinteraction characteristics from the simulation model, the normal force F_n for generating gear grinding is calculated, based on the model of Werner (see Figure 3) (Ref. 13). To verify if the microinteraction characteristics used for the force calculation are suitable, the normal force F_n calculated in this work is compared to the results from the model developed by Hübner, which was already validated by means of experimental trials (Ref. 12). A simulation with the extended simulation model is performed, with the same parameters used in the work of Hübner (Ref. 12). The diagrams in the lower part of Figure 6 show the normal force F_n calculated in the work of Hübner, upper diagram, and the normal force F_n calculated using the model in the current work, lower diagram.

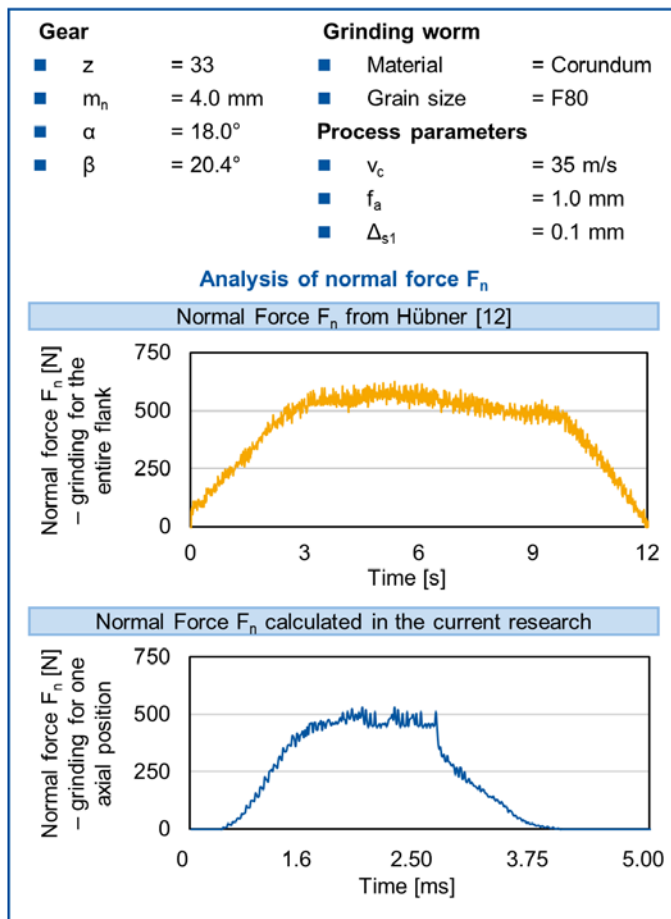


Figure 6—Analysis of the generating gear grinding normal force calculation.

In the simulation model, a type of simulation called fast simulation is possible. In this type of simulation, only one area in the middle of the gear flank is considered, where full contact between tool and gear occurs. The simulation represents only one axial position of the gear gap and only the maximum values of the process characteristic values are calculated. In his work, Hübner was able to validate the

normal force F_n calculated by means of experimental trials. The diagram shows the normal force F_n calculated by Hübner, during the grinding of a gap in the entire flank. The next diagram shows the normal force F_n calculated in the current work, during the grinding of a gap in only one axial position.

A comparison between the normal force obtained by the extended simulation model and the model developed by Hübner shows good accordance. It is possible to assume that the microinteraction characteristics calculated by the extended simulation model are in accordance with the real process.

Energy Calculation Method for Generating Gear Grinding Process

The process energy E_w is calculated based on the sum of the energies induced by each of the three chip formation mechanisms along the grain engagement (see Figure 3). For the analysis of the calculated process energy E_w , a simulation is performed. The gear, grinding worm, and process parameters used in the simulation are the same ones used in the simulation described in “Verification of Extension of Simulation Model.” In the upper side of Figure 7, the process energy E_w resulting from the simulation is shown.

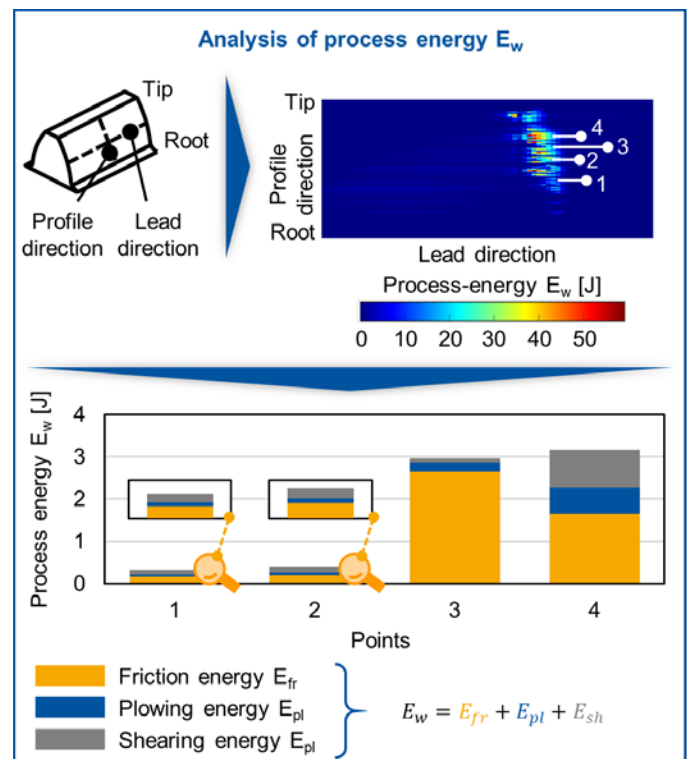


Figure 7—Analysis of the process energy calculation for generating gear grinding.

In the image of the process energy E_w plotted on the gear flank, the upper side of Figure 7, four points are randomly chosen at the area of contact between gear and tool are highlighted. In these four points, a further analysis of the energy was performed. In the diagram, it is possible to see

the contribution of each individual energy of each chip formation mechanism to the process energy E_w . For points one and two, similar process energies and contributions are obtained. Regarding points three and four, the process energies E_w are also like each other, but the contributions of each individual energy of each chip formation mechanism are different. The friction energy E_{fr} is responsible for the highest contribution to the process energy E_w , in all four points analyzed. The contribution of the plowing energy E_{pl} is slightly smaller than both friction E_{fr} and shearing E_{sh} energy for all points except for point three. For point three, the plowing energy E_{pl} is greater than the shearing energy E_{sh} .

Each of these chip formation mechanisms has a different contribution to the heat transferred into the gear. Almost all the friction energy E_{fr} is conducted as heat to the workpiece, while for plowing E_{pl} and shearing E_{sh} energies, this fraction is smaller (Ref. 4). The fraction of energy conducted as heat to the workpiece for the shearing mechanism is the lowest of the three mechanisms. Therefore, most of this energy is used for chip removal and not to heat the workpiece. If most of the process energy is not converted to heat, the possibility of grinding burn during the process decreases.

Due to this, even though points three and four presented similar process energies E_w , the contribution of each individual energy of each chip formation mechanism is different for each of these points, leading to different amounts of heat transferred into the workpiece.

Conclusions

To achieve the objective defined, an extension of a simulation model focused on the implementation of the grinding worm topography and its rotational movement was performed. Based on the microinteraction characteristics calculated in the extended simulation, the normal force of the process was calculated, and it showed good agreement with the literature. Hence, the extended model was verified against an experimentally validated model. The process energy E_w was calculated as the sum of all the energies of each chip formation mechanism, for all the grains engaging in the material. The energy of each chip formation mechanism contributes differently to the total energy partition and conduction of heat to the workpiece. Therefore, the extended simulation model allows us to understand how much of the energy generated during the process can be conducted as heat to the workpiece. Ultimately, this can be used to avoid grinding burn in the process of generating gear grinding. As an outlook, validation by means of grinding trials is planned. Critical values of process energy E_w and the influence of each chip formation mechanism energy on the grinding burn presence need to be defined. In addition, to avoid the time-consuming task of measuring the grinding worm topography optically, a routine for generating a generic random grinding worm topography as input for the simulation will be implemented soon.

Acknowledgments

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Pittler T&S

NAMES CHRISTIAN RHIEL
MANAGING DIRECTOR



Christian Rhiel, managing director, Pittler T&S

Christian Rhiel started in 2007 as area sales manager for turning machines for Europe and Russia and became sales manager in 2013. Due to these decades of experience in sales management, he has a feel for the needs of his customers. He has a clear understanding of the markets and knows how to expand the company and achieve its goals. With his colleagues, he will drive the company's further development and future direction.

"With Mr. Rhiel, we have gained an experienced executive and suitable successor for the position of managing director, who has proven himself as a competent and reliable manager in recent years. He has a strong vision for the future of Pittler T&S and wants to bring the company back on track for success," says Dr. Christoph Müller-Mederer, CEO of DVS Technology Group. "On behalf of my colleagues, I wish him every success."

dvs-technology.com

Forest City Gear

ATTENDS TRAINING
RETREAT HOSTED BY DMG
MORI

Two Forest City Gear employees, CNC Supervisor Mike Miller and CNC Lead/Programmer Josh Gates, recently attended a 4-day training retreat in Pfronten, Germany hosted by DMG Mori. The

event featured various seminars and opportunities for guests to experience firsthand DMG's newest equipment and technologies, as well as networking and a taste of German culture.

Forest City Gear has a DMG Mori NLX 1500 SY on order and scheduled to be delivered later this year. At the open house, Gates and Miller were invited to tour the factory floor and try out new machine software. "I was extremely impressed by the sophistication and integration of the gear inspection that is being performed right on the machines," said Miller.

DMG Mori's trainings included a seminar on accuracy, in which Gates and Miller gained insight on how to increase Forest City Gear's machines' accuracy even further.

At networking events, conversations focused on the importance of automation and apprenticeships in manufacturing, to ensure the industry appeals to future generations of workers. These discussions were held over meals of authentic Bavarian cuisine, which was enjoyed by all.



forestcitygear.com

Fisher Barton

EXPANDS AND BUILDS
THE TURNING CENTER OF
EXCELLENCE

Fisher Barton has selected MSI General Corporation for the design and construction of its new industrial building and site development for Accurate Specialties' Turning Center of Excellence on Bluemound Road. To kick off

construction, a groundbreaking ceremony took place in March.

Accurate Specialties, Inc. (ASI), a division of Fisher Barton, is a manufacturer of bronze gear blanks for power transmission and agricultural applications. With innovative and integrated manufacturing techniques, they specialize in precision machining, chill casting, centrifugal casting, and spun-cast gear blanks. As a full-service bronze foundry with automated machining capabilities, ASI delivers complete, fully machined, ready-to-hob bronze gear blanks and shafts made to exact customer specifications.



Scott Hoffman, CEO of Fisher Barton states, "We are expanding our capacity with this high-speed, fully automated 56,000 sq.ft. facility adjacent to our Accurate Specialties division to offer our customers additional manufacturing capabilities for close tolerance components, shafts, and bearings that compliment Fisher Barton's already robust offering."

fisherbarton.com

Index

LAUNCHES TRAINING
PROGRAM FOR JUNIOR
TECHNICIANS

Index has announced the launch of the Index Technician Development Program (ITDP), a new, eight-month formal training program for junior technicians. Developed in response to the ongoing skilled labor shortage, the ITDP incorporates both classroom and hands-on instruction, including two months spent at the company's global headquarters in Germany.

"The manufacturing industry as a whole is facing a skilled labor shortage," says Jose Zamora, training, and development manager for Index. "That issue is even more pronounced when you look for people with the breadth

of knowledge required to service and install advanced machine tools. We have very consciously developed the ITDP curriculum to grow the pool of labor in our industry.”

Ideally, individuals selected to join the program possess some level of experience in a field related to mechanical or electrical engineering, but the only prerequisite is a demonstrated aptitude for technical subject matter. The ITDP launched in January with an inaugural class of six students coming from varied backgrounds that include IT, warehouse logistics and law enforcement.

Over the course of six months, students complete fifteen courses that incorporate a mix of classroom, online and shop floor instruction. Each course ends with an exam that must be completed to progress. At the end of six months, the ITDP culminates in a week-long exam that includes written components, as well as a practical demonstration of knowledge through troubleshooting and solving issues on actual machines in Index’s showroom. Upon completion of this exam, students travel to Germany for two months to participate in building an Index machine from the ground up.

While the current class is made up of individuals pursuing a career change, Index plans to expand the ITDP to include internships and apprenticeships for current high school students and recent graduates later this year.



“I started my career in a German apprenticeship program,” says Cris Taylor, president and CEO of Index. “We have incorporated elements of that type of program to provide people with access to the incredible career opportunities offered by manufacturing. The program is currently focused on expanding our own team, but we

are purposefully building something that can eventually be expanded to train operators and programmers for our customers as well.”

Those interested in applying for a future spot in the ITDP can contact Jose Zamora at jzamora@indexusa.com

us.indextraub.com

AGMA ANNOUNCES NEW BOARD OF DIRECTORS AND OFFICERS AT ANNUAL MEETING

The American Gear Manufacturers Association (AGMA) has changed its board of directors. These changes took place at the 2023 AGMA Annual Meeting in Lake Buena Vista, FL.

New officers

The 2023 Annual Meeting marked the changing of the AGMA board chair and other key positions. The following people will serve as board officers through 2025:

Chair
Michael Cinquemani, CEO
and president, Master Power
Transmission, Inc.

Treasurer
Sara Zimmerman, vice president,
business development, Sumitomo
Machinery Corporation of America

Chair, TDEC
Todd Praneis, director, product
development, Cotta LLC

Chair, BMEC
Michael McKernin, COO, Milan’s
Machining & Gear Manufacturing
Company, Inc.

Chair Emeritus
Greg Schulte, president, Bonfiglioli
USA

Incoming board members

Additionally, AGMA’s membership elected four new members to its board of directors during the 2023 Annual Meeting. These directors will serve a three-year term, from 2023 to 2026.

The newly elected board members are:

William Galdo, CEO, Flender
Corporation

Wayne Hanna, president, Brad Foote
Gear Works, Inc.

John Perrotti, president and CEO,
Gleason Corporation

Eric Van Rens, CEO, Schafer
Industries

Outgoing board members

Three outgoing board members were honored with the AGMA Board Award for their years of service to the industry. The following individuals served on the board from 2020 to 2023:

Gregory Estell, founder and managing
Partner, The Estell Group LLC

Robert Rye, president, Cincinnati
Gearing Systems, Inc.

Scott Miller, strategy manager,
Caterpillar, Inc.

agma.org



Weiler Abrasives

ANNOUNCES NEW CEO

Weiler Abrasives, a provider of abrasives, power brushes, and maintenance products for surface conditioning, is pleased to announce that after a comprehensive global search, its board of directors has chosen Arjang “AJ” Roshan-Rouz as the next CEO. He succeeds Chris Weiler in the role; Weiler will remain with the company and serve as executive chairman.



Arjang Roshan-Rouz, CEO, Weiler Abrasives

Roshan-Rouz, who began as CEO on March 27, will lead the executive team and join the company’s board of directors. As CEO, his job responsibilities include developing and executing strategy, implementing operating plans congruent with the company’s long-range plan, and fostering company culture in line with Weiler Abrasives values.

“AJ’s leadership style and experience align with Weiler Abrasives values and our desire to have a CEO who can execute our business strategy, while also having the vision and ability to define and develop the next phase of the company’s growth,” Chris Weiler said. “AJ brings significant experience in leading a global organization. What really made AJ stand out was his clear recognition and excitement about the growth potential of Weiler Abrasives and his desire to build a long-term, sustainable business.”

Roshan-Rouz started his career in 1992 as a development engineer with Ford Motor Company and later was a project manager at Bosch-USA. He then transitioned into international roles in the field of engineered materials, working for Umicore, where he became a senior executive and led its Asia Pacific business while living in Shanghai. After six years in Asia, Roshan-Rouz and his family moved to Brussels, where he was responsible for the company’s global business in energy and surface technologies. From 2016 to 2021, Roshan-Rouz served as the CEO of 5N Plus, a publicly held engineered materials company, where he led the transformation of that business, moving the strategic focus from commodity materials to high-value semiconductor and performance materials. He was also responsible for reinvigorating the company’s product development pipeline and significantly improving financial performance. Roshan-Rouz studied electrical engineering at Michigan Technological University and business management at Michigan State University and the University of Michigan.

With Roshan-Rouz taking responsibility for leading the business, Chris Weiler steps into the role of executive chairman after nearly 15 years as CEO. As executive chairman, Weiler will serve as the direct link between management and the board of directors, leading the board in overseeing the strategic direction of the business and ensuring the business operates in a way that is aligned with the Weiler family values.

weilerabrasives.com

Croix Gear & Machining

INSTALLS GLEASON PHOENIX II 600HC BEVEL GEAR CUTTING MACHINE

Croix Gear & Machining, recognized as a leader in the custom manufacturing of loose gears, is excited to announce the installation of a Gleason Phoenix II 600HC Bevel Gear Cutting Machine. This new equipment, combined with software upgrades on existing Gleason Phoenix 280c bevel gear cutting machines, will expand capacity and precision capabilities for spiral, straight, hypoid, and Zerol bevel gears.

These combined investments will:

- Increase capacity and reduce lead times.
- Improve part quality and repeatability.
- Expand capabilities up to 24" OD for all bevel gears.

“As a job shop, we are in a unique position to offer this breadth of bevel gear manufacturing capabilities. We are excited about the positive impact this addition will have for our customers who rely on us for bevel gears,” stated Ruthie Johnston, CEO/Owner.

croixgear.com



May 24–25—CTI Symposium USA 2023

The CTI Symposium USA (Novi, MI) will update attendees on the latest technical developments and applications on automotive transmissions for conventional and alternative drives. Exchange experiences, discuss technologies and strategies with automotive experts from the United States, Asia and Europe. The conference and exhibition provide expert-led plenary and technology sessions as well as expert discussions and product showcases representing the full range from complete drivetrain systems to components and engineering services. CTI drives progress in passenger cars and commercial automotive transportation. Manufacturers and suppliers are actively demonstrating how to keep pace and staying ahead of customer needs, environmental, institutional and economic demands.

geartechnology.com/events/5064-cti-symposium-usa-2023

June 18–21—Powdermet 2023



The leading technical conference on powder metallurgy and particulate materials in the Americas, Powdermet 2023 (Las Vegas) is a hub for technology transfer for professionals from every part of the industry, including buyers and specifiers of metal powders, tooling and compacting presses, sintering furnaces, furnace belts, powder handling and blending equipment, quality-control and automation equipment, particle-size and powder-characterization equipment, consulting and research services, and much, much more. The show is co-located with AMPM 2023 focusing on metal additive manufacturing. AMPM 2023 will feature worldwide industry experts presenting the latest technology developments in this fast-growing field.

geartechnology.com/events/5069-powdermet-2023

June 27–30—Automatica 2023

Automatica (Munich) is a trade fair for intelligent automation and robotics covers the entire value-added chain: from components to systems; from services to applications—for all manufacturing sectors. It offers an overview of current developments and innovations and thus provides the necessary orientation and investment security. Whether autonomous production, climate protection, supply chain resilience or a shortage of skilled

workers: Automatica addresses the major global challenges of our time. To this end, it explores the potential of the key technologies of robotics and automation and offers the greatest possible practical relevance as well as concrete solutions.

geartechnology.com/events/5072-automatica-2023

July 5–6—Dritev 2023



The International VDI Congress “Dritev” is one of the world’s largest automobile congresses (Baden Baden, Germany). Hundreds of experts with an R&D background meet every year to exchange thoughts on current developments in the field of drivetrain and transmission. It’s the ideal place to reach out to long-known fellow experts, find new project partners and pave the way to establish new business ties. This is the one place where you can listen to more than 60 expert presentations and learn about current matters prevailing in series development of powertrains and transmissions.

geartechnology.com/events/5070-dritev-2023

July 31–August 3—Reliable Plant 2023



This three-day event (Orlando) offers attendees learning sessions and case studies on the latest industrial lubrication and oil analysis technologies. The comprehensive conference schedule covers every facet of the machinery lubrication industry and includes workshops on topics such as employee performance, lubrication fundamentals, condition-based maintenance, and maintenance planning. Reliable Plant is focused on both entry level and management positions within the lubrication industry including engineers, plant managers, maintenance professionals, safety personnel, planners, quality managers and more.

geartechnology.com/events/5068-reliable-plant-2023

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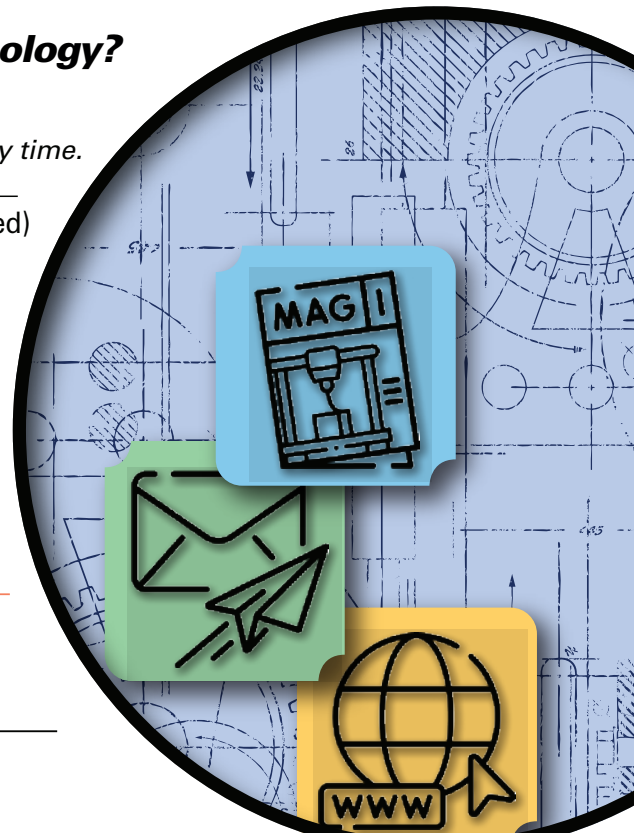
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The Right to Repair

Aaron Fagan, Senior Editor

Next year, farmers in Colorado will be able to fix their own tractors, and manufacturers will have to provide them with resources to help them do it. In late April, Colorado became the first state to ensure farmers can work on their own equipment with Governor Jared Polis signing “The Consumer Right to Repair Agriculture Equipment Act,” which forces manufacturers to make available the necessary manuals, tools, parts, and software to farmers who rely on complex and expensive machinery, such as tractors, combines, and other farm equipment.

Ranches and farmland are the lifeblood of many states, and Colorado took the lead on the issue in the light of a nationwide right-to-repair movement for the ability of consumers to fix and maintain their own equipment, rather than being required to rely solely on authorized dealers and manufacturers for repairs. This has the potential to indirectly affect the gear industry to the extent that it directly disrupts the farm equipment manufacturers, but it could directly affect the gear industry if broader right-to-repair laws gain ubiquity in the future.

Lawmakers in at least ten other states have introduced similar right-to-repair legislation, including Florida, Maryland, Missouri, New Jersey, Texas, and Vermont. For Colorado, the process of bringing the proposal to law left lawmakers stuck between their farming constituents making a case for the ability to repair their equipment and the manufacturers and dealerships who raised deep concerns that providing tools and information to farmers would expose trade secrets and allow equipment owners to illegally tamper with the horsepower and bypass emissions controls—putting operator safety and the environment at risk, but those are things that would remain illegal.

However, the spirit of this law aims to provide farmers with more control over their equipment and reduce downtime caused by equipment breakdowns. Time is money, and Nature doesn't wait—so when farmers claim the current conditions compromise valuable days waiting for an authorized service professional to arrive, that delay could spell a weather event eradicating a crop or the closing of a proper planting window, creating the potential for bankruptcy. Prior to the law's



passage, farmers were often restricted to using the manufacturer's repair services, which could be more expensive and time-consuming than local repair shops.

The law also prohibits manufacturers from voiding warranties or denying service if farmers use independent repair shops or perform repairs themselves. Manufacturers are required to provide the same diagnostic and repair information to independent repair shops as they do to authorized dealers.

Farmers across the country have long been fighting for the right to repair their own equipment. Modern tractors are full of electronics that have given manufacturers the ability to lock farmers out of the repair process and lead some to go so far as to hack their own tractors. The used tractor market exploded, with farm equipment manufactured before the advent of computers selling for hundreds of thousands of dollars.

Currently, many manufacturers limit access to repair information and may even void warranties if the device is repaired by an unauthorized third party or the owner themselves. In practice, this means manufacturers may have to change their policies and invest in creating repair manuals and diagnostic tools as well as supplying replacement parts to independent repair shops and consumers.

Furthermore, manufacturers may have to redesign products to make them more easily repairable or to reduce the need for repair services in the first place. This could lead to changes in the manufacturing process, which may result in increased costs for the manufacturer but may also create new revenue opportunities for training programs, easily replaceable parts, and specialized tools.

The law is intended to give farmers more choice and control over the maintenance and repair of their equipment, which can be critical to their livelihoods. The law may also create opportunities for independent repair shops and parts suppliers to compete with manufacturers for repair business.

Overall, “The Consumer Right to Repair Agriculture Equipment Act” can be seen as a challenge for manufacturers to balance the needs of consumers with their own business interests. Given the scope of technological complexity in most modern wares, there may be something altruistic and romantic to the notion we should all be able to repair our belongings, however, it may also create opportunities for manufacturers to build customer loyalty by demonstrating a commitment to sustainability and consumer choice.





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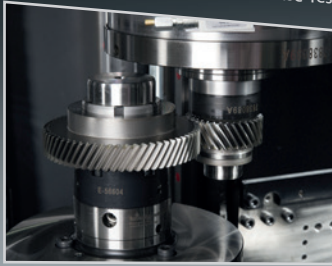
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Due to the increasing quality requirements in large-scale transmission manufacturing, some transmission and vehicle manufacturers now require a certificate of quality for all gears installed in the powertrain. A further driver of ever-higher inspection levels is e-mobility, which places much higher demands on the noise behavior of a transmission due to the elimination of the combustion engine. To meet this challenge, Klingelberg has developed the Höfler Cylindrical Gear Roll Testing Machine R 300. Designed for all five roll testing methods, this compact machine is the ideal solution for anyone who wants to combine inspection cycles and reduce disassembly costs while benefiting from a user-friendly design.

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