gear TECHNOLOGY®

SEPTEMBER/ OCTOBER 2024

Small Bevel Gears
Shop Air Quality
Digitization of Hard Fine Machining
Honing: A Path to Precision

TECHNICAL

Investigation of the Interaction Between Process Signals and Modeled Thermomechanical Energy in Generating Gear Grinding

geartechnology.com

Gear Technology is POWERED by **The American Gear Manufacturers Association**

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SEPTEMBER/OCTOBER 2024

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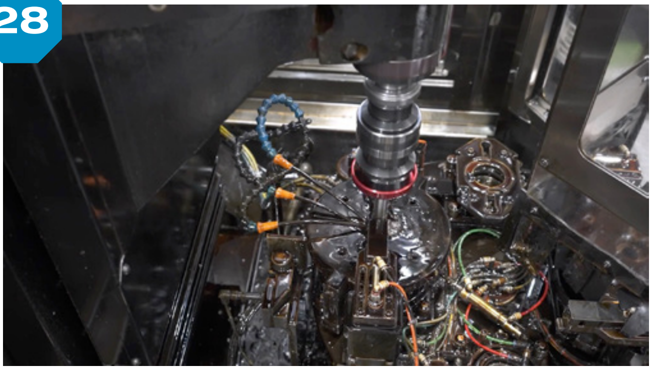

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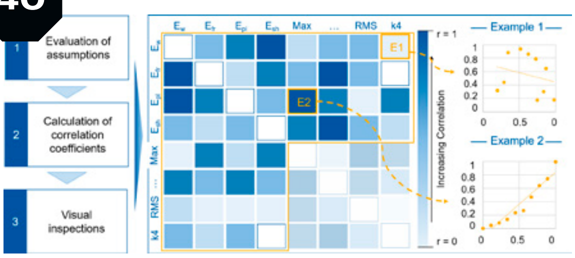

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Photo courtesy of Gleason

gear TECHNOLOGY

GT VIDEOS

Buffalo Gear Upgrades Equipment with Helios Gear

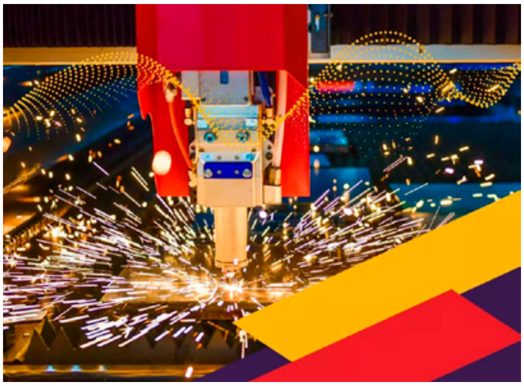
The Helios team recently installed a Hera 350 CNC Gear Hobbing Machine at Buffalo Gear in Buffalo, NY. See how Buffalo Gear's capabilities have expanded with the upgrade.

geartechnology.com/media/videos/play/281

EVENT SPOTLIGHT

Fabtech 2024

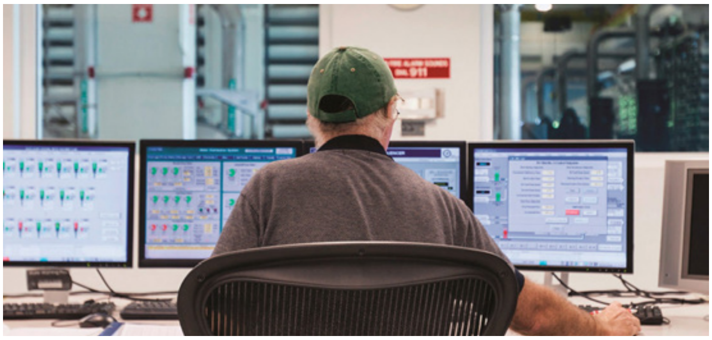
Fabtech (Orlando, FL) provides a "one-stop-shop" for metal forming, fabricating, welding, and finishing trade show. Attendees can meet with 1,300+ suppliers, discover innovative solutions, and find the tools to improve productivity and increase profits. There is no better opportunity to network, share knowledge and explore the latest technology.



geartechnology.com/events/5075-fabtech-2024

AS SEEN IN *PTE*

Technology and Reports Help Optimize Operations



Digital Transformation. IIoT. Industry 4.0. While they may seem like trending buzzwords, the technologies are critical to operations being efficient and competitive, and reducing unplanned downtime. Every industry strives for maximum efficiency; be that manufacturing, oil & gas, or water/wastewater. For capturing production data, the days of the clipboard and manual data analysis are gone.

powertransmission.com/articles/10015-technology-and-reports-help-optimize-operations

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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 40 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 *mwg42@hotmail.com.*

THE GEAR INDUSTRY'S INFORMATION SOURCE

geartechnology.com

Candy Store for Editors

Me with Mike Larson of Hainbuch America at the unveiling of Hainbuch's new robotic workholding automation solution.

Senior editor Aaron Fagan with Titan Gilroy of the Titans of CNC.

Rethink Robotics returned to IMTS with seven new collaborative robots.

A classic candy store offers a dazzling display of lollipops, gumballs and every variety of sprinkled, dusted chocolate and chewy, gummy delights. The bright colors and sugary sweet smell are designed to make an eight-year-old's eyes bulge, mouth water and tongue hang out.

IMTS is just like that, but for technical trade journalists. The show provides an immersive display of manufacturing technology and a seemingly unlimited supply of experts (some of them also colorful) to talk about applications of that technology.

So, yeah. For a week in September, we were like kids in a candy store (we tried very hard not to drool, though—it's so unprofessional).

We each came back with stacks of business cards—new contacts and old friends—and notepads full of ideas about the articles that will fill our pages over the course of the next year. We saw innovative new technology, product launches and advances in the art of gear manufacturing.

And although a lot of that information we can get from company press releases, the true insights come from the one-on-one conversations with the experts—people who have experience with projects like the ones you work on every day. That insight and knowledge is the engine that drives our content.

It boggles my mind that some of our competitors don't send editors to this show. When you read *Gear Technology*, you can count on the fact that we have direct insight into the challenges gear manufacturers face as well as the technology and solutions being used by companies like yours to help overcome them.

Many of you recognize the value of a show like IMTS, and you make the effort to go and experience the candy store for yourselves. You can read longtime industry veteran Dan Carleton's take on the show in this issue's Addendum column (page 56).

But we understand that not everyone can make it to a trade show like IMTS. So it's our goal to take what we learned and bring it back to you, both through direct articles about the technology as well as features that make use of the ideas and insights we gained on important trends.

I can't promise that our coverage will give you the full Willy Wonka experience, but I can promise you'll get at least some of the flavor.

Publisher & Editor-in-Chief
Randy Stott, Vice President Media
geartechnology.com

Weiler Abrasives

LAUNCHES PRECISION EXPRESS PROGRAM FOR GEAR GRINDING WHEELS

Weiler Abrasives has launched its new Precision Express program that cuts lead times for gear grinding wheels from months to days. The program is designed to help gear manufacturers in industries such as automotive, energy and aerospace improve quality, increase consistency and deliver on time to their customers—for added peace of mind.

"We know not having the right gear grinding wheel can lead to extensive lead times, quality issues and idle machines. Precision Express is our answer to the industry challenge of customers waiting months for a gear grinding wheel," says Kyle Thompson, sector manager for industrial production Americas, Weiler Abrasives. "We prioritize on-time delivery of our precision gear grinding wheels so our customers no longer have to wait months for a grinding wheel, which could delay their operations."

Precision Express matches an in-house profiling cell with a broad range of on-hand stock, cutting wheel manufacturing and delivery lead times from months to days. Even when gear manufacturers see a spike in demand or need a custom profile at a moment's notice, Weiler Abrasives can provide consistent availability and delivery.

In addition, Weiler Abrasives' high performance gear grinding wheels feature proprietary V59 bond technology that ensures exceptional results and addresses customers' unique needs with flexibility and precision. The advanced formulation of V59 bond technology provides superior grain retention, improving wheel life and grinding efficiency. Dynamic porosity lowers grinding temperatures through increased coolant efficiency and greatly reduces part surface damage from heat distortion while aiding in exceptional material removal rates—allowing for a reduction in grinding cycle times. The extended wheel life delivered with V59 bond technology also improves profile retention and reduces dressing frequency. The V59-Max performance bond combines high-performance ceramic and aluminum oxide abrasive grains with superior V59 bond technology to deliver the maximum cut rate, longest wheel life and superior form holding ability.

With a sizable stock inventory of over 120-wheel blank sizes and specifications at Weiler Abrasives' North American headquarters in Pennsylvania, custom wheels can be produced within two weeks. Available sizes range from as small as 6 in. up to 24 in. in diameter and from 1/2 in. to 9 and 1/2 in. thick. These are among the most common wheel styles and sizes used in the industry. The state-of-the-art Precision Express wheel profiling cell allows for wheel speed testing to ANSI B7.1 safety standards, which is 1.5 times the maximum operating speed labeled on the wheels, ensuring the ultimate safety of the product for the consumer.

weilerabrasives.com/Precision-Express

ANCA

HIGHLIGHTS GEAR TOOL TECHNOLOGY AT AMB 2024

At AMB 2024 in Stuttgart, ANCA recently presented a range of innovations and partner solutions.

From blank to a finished high-quality tool, all on one machine—ANCA's ultimate single setup solution for complete machining of cutting tools, including blank preparation, was shown on the MX7 Ultra. This technology ensures a seamless process that optimizes efficiency and productivity, allowing you to manufacture a wide range of tools below 0.2 Ra with reduced cycle time.

Equipped with a P-axis and a steady rest from ANCA's longstanding partner Arobotech, the MX7 Ultra enables integrated blank preparation, peel grinding and geometry grinding in a single clamping. This allows users to simplify their processes, shorten throughput times and reduce complexity in production. A solution with 38 kW spindle power for tools up to 32 mm diameter.

ANCA's GCX machine and gear tool technology addresses the complexity of gear tools manufacturing, this offering includes features for the design of gear cutting tools, manufacturing and integrated tool measurement, as well as providing the skiving machine setup parameters.

Tradeshow visitors discovered how this configuration enables short setup times, simulation and monitoring, plus quality enhancing features like the ANCA Motor Temperature Control (MTC) or integrated balancing (iBalance) for long-time grinding profile accuracy within ±0.0015 mm. This turnkey package facilitates easy entry into the gear tools sector while ensuring top-quality results.

anca.com

LK Metrology

EXPANDS MOBILE SOLUTIONS

All 34 portable measuring arms offered in 6-axis touch-probing and 7-axis multi-sensor variants by LK Metrology, Castle Donington, are now supplied as standard with a 4.5 in. diameter mounting ring to allow the unit to sit on a larger base, rather than that provided by the previous 3.5 in. ring. The result of having this extra stability is that the new Version 3 Freedom Arms are capable of measuring to higher precision. A mounting ring adapter can be supplied if an existing user already owns an LK tripod or stand with a 3.5 in.

mount. Mechanical, magnetic and vacuum fixing alternatives are available.

As previously, the new mobile metrology solutions are based on a lightweight carbon fiber tubular construction. Feedback of position is provided by absolute rather than incremental rotary encoders and the arms are available in three accuracy categories—classic, select and ultimate. Each is now capable of significantly higher accuracy measurement of size, position and form, whether using a tactile probe or laser scanner. Probing accuracy is certified to ISO 10360-12 and functionality is guaranteed up to 40°C.

Notable is that the 6-axis arms are workshop hardened, having full IP54 protection from water splashes and the ingress of dust and particles, delivering reliable, repeatable, 3D inspection and measurement in harsh industrial environments. Provided also is enhanced *RDS v6.4* software running on Windows for communicating with the arm via Wi-Fi or USB. It offers improved monitoring of parameters such as ambient temperature, stress on the articulating joints, and base vibration, displacement, tilt and inclination. An operator alert function in the software warns the user if an arm is not fully IP54 protected.

The 7-axis Freedom Arm v3 is not IP54 rated but is able to deploy a laser scanner and a tactile probe to enable multisensor metrology. An OLED touchscreen display provides the operator with convenient fingertip control, raising inspection productivity by avoiding having to go back and forth between the arm and a computer. A pair of rechargeable, hot-swappable battery packs with Ethernet connection for probe and laser scanner is available for use in environments where Wi-Fi is not allowed.

lkmetrology.com

Unisig

OPERATING SYSTEM STREAMLINES THE HUMAN-ROBOT INTERFACE

Unisig's next-generation operating system further improves the human-robot interface and slashes programming times.

The new operating system, featured on Unisig's UNE6-2i-750-CR small-diameter gundrilling machine, streamlines the setup of dozens of different part handling combinations to reduce new part setup times by 80 percent or more. The system significantly improves the communication between the machine's human machine interface (HMI) and the robotic controller. This enables centralized data storage or a single source of truth—the coding and data for the gundrilling operation and the program for the part handling are stored together for ease of recall.

Because it works within a parametric programming environment, the new operating system automatically adjusts its parameters to any dimensional part changes, without the need to manually calculate and enter in new parameters. Such intelligence eliminates the need to start over and create entirely new and independent programs, while greatly simplifying and shortening programming times for part families.

The UNE6-2i-750-CR gundrilling machine with integrated robot ships with a handheld programming console/teach pendant connected to the machine. Prior to the use of parametric programming, all part handling operations were pre-programmed using the pendant. Users can now enter and store all machine and robotic parameters in the machine HMI. This allows for a more centralized user experience and greatly reduces the depth of robotic experience required.

The machine HMI has built-in parametric selection guides, allowing users to toggle between data entry and the programming guides. Each data value, and its function, are graphically displayed in the on-screen programming guide. This prevents the guide from being misplaced and makes it available at all times, which is especially advantageous when periodically adding new parts involving large time gaps between them.

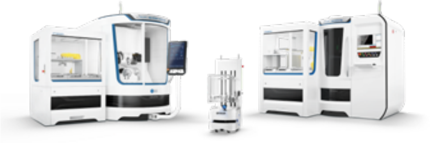
The UNE6-2i-750-CR with integrated robotic automation also features interchangeable part trays. The robot services both the machine's spindles and accommodates drilling of different diameters from each end. The optional lantern chuck system on this machine model allows workpiece loading into the rear of an automatic collet chuck to ensure accurate workholding, especially for uniquely shaped workpieces.

Unisig's UNE6 Series of precision gundrilling machines generate holes from 0.8 mm to 6.0 mm (0.03" to 0.24") in even the most challenging of materials. Such capability makes the machines well suited for a wide range of applications, including medical part manufacturing.

unisig.com

Walter

INTRODUCES AUTOMATED TOOL PRODUCTION SYSTEM



With the new Automated Tool Production (ATP) system, Walter now offers a comprehensive automation solution for cutting tools. ATP networks grinding, eroding and measuring machines from Walter, as well as upstream and down-stream machines from other system partners in the production process.

The ATP system from Walter consists of at least one robot cell accessible from the front (ATP Robocell) for the automatic loading and unloading of the machines and at least one autonomous, mobile transport robot (ATP AMR) for transporting the workpiece pallets and individual parts between the storage and processing stations. It requires no additional floor space, can be integrated into existing system layouts and is also suitable as an interface for machines from other manufacturers.

Walter customers can easily retrofit the ATP system into their existing production facilities without having to change the existing system layout and independently of the automation provider. Tool manufacturers whose production does not currently include Walter machines can also have the ATP system integrated into their existing production.

The ATP Robocell, which is accessible from the front, offers three access gates and therefore additional buffer spaces for production without waiting times or downtime. A separate removal station for the in-process exchange of individual tools between the measuring and processing machines enables automatic tool correction and therefore complete closed-loop processes. In the ATP Robocell, a multirange gripper contributes to the high flexibility of the system. It covers a large workpiece diameter range without changing the gripper unit and can exchange collets at the same time.

The system control is based on the OPC-UA data model Flames. This also includes a standardized communication model between the machines and the ATP AMR transport robot, as well as a control system for higher-level data and process control.

"We have developed this innovative system in close collaboration with partners. Our expertise in tool grinding, eroding and measurement and the expertise of our partners in automation now offers customers an automation solution that is state-of-the-art in every respect," explains Simon Kümmerle, strategic product manager grinding technology at Walter.

grinding.com

GF Machining Solutions

DEVELOPS NEXT GENERATION WIRE EDM MACHINE

With the goals of increased flexibility and reduced maintenance in mind, GF Machining Solutions developed its next generation CUT S 400 Dedicated wire electrical discharge machine (EDM) that improves the overall production of aerospace jet engine turbine disks, in particular for cutting their fir tree blade patterns. With advanced features and capabilities, the new machine allows manufacturers to cut a wider range of turbine blade diameters and do so with fewer production interruptions due to typical EDM setup and maintenance issues.

While dedicated is in its name, the CUT S 400 Dedicated gives manufacturers the flexibility to create the

complete range of popular jet aircraft engine disk diameter sizes with one machine. Geared toward those disks made from nickel-based or waspaloy alloys used in the "hot" critical side or the "cold" noncritical side of an engine, the new wire EDM handles disks measuring from 160 mm up to 680 mm in diameter.

The machine can accommodate this wide range of disk sizes thanks to its new, more robust rotary/tilt axis that easily manages heavier part loads without risk of deflection. A new additive manufactured smaller lower head nozzle size also provides additional room for smaller disk diameters while allowing for the use of various types of wire and wire guide diameters.

According to Eric Ostini, manager of business development at GF Machining Solutions, the aerospace industry continues to design and develop jet engine disks, but there remain legacy engines still requiring replacement parts. "With that said, the CUT S 400 Dedicated increases the range capability for supporting not only existing disk designs but also for those older ones still in use," he said.

Besides increased part size flexibility, many of the machine's new technological advancements make required maintenance easier and less frequent, which in turn, reduces the amount and duration of non-cut time and helps lower cost per part. These advancements are evident in the machine's casting, tank design and filtration system that help combat problems caused by EDM particles/residue generated by long hours of disk production cutting.

For faster, easier cleaning, the casting of the CUT 400 S Dedicated is designed so that tank water constantly runs down the interior sides of the work envelope, keeping them wet and preventing EDM residue from drying and hardening. This sticky residue also plays havoc with an EDM's filter and drive systems. To prevent the residue from making its way inside these systems, water also constantly circulates through the new machine's upper and lower heads.

Not only does the machine's tank always remain wet, it also has no sharp corners within its interior. Instead, GF Machining Solutions curved all the corners to eliminate crevices that make residue cleaning difficult. While cleaning these crevices there is also an increased risk of damaging the interior panels. Additionally, the tank is designed to channel water flow with EDM residue directly to the bottom of the tank, helping prevent residue from being dispersed throughout the work envelope.

To streamline machine filter maintenance, GF Machining Solutions increased the capacity and number of filters on the CUT S 400 Dedicated. They also incorporated quick releases along with an air purge system that removes water from the filters to reduce their weight, making them easier and quicker to remove. Along with filter enhancements, the machine's pumps are readily accessible and do not need to be removed for cleaning.

Also featured on the CUT S 400 Dedicated is the GF Machining Solutions Intelligent Spark Protection System (ISPS), which is part of the recently released Uniqua control. This system makes it possible to not only recognize exactly where the sparks of a wire EDM are happening during the process, it can also measure and identify the position of each spark along the length of an EDM's wire.

Knowing the exact location of a spark allows the system to automatically adapt to prevent wire breakage, especially beneficial during long cuts and unattended operations, and contributes to the reduction of surface integrity issues.

gfms.com

WAFIOS and Gehring

OFFER E-MOBILITY INNOVATIONS FOR HIGH PERFORMANCE PRODUCTION

The medium-sized mechanical engineering companies Gehring, Nagel and WAFIOS as well as Lambda Resins GmbH will be presenting their latest developments in the field of e-mobility at the Reutlingen E-Mobility Days 2024 (RED). The renowned specialist forum, initiated by WAFIOS and held this year for the first time on the new e-mobility campus, will take place from October 15–17, 2024 and is regarded as the central platform for innovations in e-mobility.

Around 12 coexhibitors will also be on site to present a wide range of e-mobility solutions. Top-class presentations by experts on the latest trends and developments in electromobility will round off the program.

Gehring and WAFIOS will be presenting comprehensive turnkey production lines and individual exhibits for the manufacture of electric motors at the REDs. These include high-precision stators and bent pins produced on the latest CNC bending machines.

Dr. Uwe-Peter Weigmann, CEO of WAFIOS, explains: "With its hairpin bending technology, which is fully controlled via CNC axes, WAFIOS combines maximum flexibility with high production output for the first time. This makes it possible to produce hairpins with different geometries and wire dimensions using one production system in automatic mixed operation."

Since April 2021, Gehring and WAFIOS have been combining their expertise to offer the automotive industry turnkey production lines for the manufacture of electric motors worldwide. The two companies rely on innovative technologies and their many years of experience in automotive manufacturing.

A special highlight at the trade fair will be the presentation of two FMU E 40 machines from WAFIOS and a SpeedFormer. One of the FMU E 40 machines will be used to demonstrate the development of hairpins in a continuous hairpin, while the other machine will showcase a new slide feed and HQ bending, a new bending technology. To produce the shaft winding, WAFIOS is drawing on its well-known expertise in meander production in the tube sector and developing it further based on the latest hairpin bending technology. SpeedFormer demonstrates the latest advances in bending technology, such as the production of different geometries without changing tools. In addition to the broad portfolio for hairpins, the BMF 60 busbar machine will also be on show. It presents mechanical stripping and can be integrated into automated systems.

The SpeedFormer, a transfer bending system, combines three proven bending processes from the fields of wire and tube bending in one system for the first time. This system enables complex bending processes with overlapping geometry elements and sets new standards in the series production of hairpins. Tobias Single emphasizes the advantages of this technology

"Our SpeedFormer makes it possible to produce hairpins in just 1 to 1.7 seconds in mass production—a significant improvement on the six to eight seconds previously required for prototype and small series production. The HQ bending process is also used. With the new bending process, we can produce a significantly smaller roof bend on the hairpins. Accordingly, smaller outer diameters of winding heads or stators are possible."

"The fundamental basis for small or large series projects is the prototyping of stators. In Gehring's Tech Center, individual processes or entire process chains are therefore run freely in advance as qualification," explains David Gossen, sales employee at Gehring. The knowledge gained later facilitates the transformation to the series process and reduces the commissioning time. In many cases, customers only request individual stator products.

"In order to reduce costs and throughput times, new production approaches have therefore been developed in the technical center," says Dr. Andreas Wiens.

Gehring will also be presenting the new Gehring Inspection System (GIS), a new measuring technology that can be used both inline and stand-alone. "By making processes more stable and reducing reject rates, we are improving the holistic production of hairpin stators," says Marcell Wardin, director of sales and marketing.

wafios.com/red


Skiving of rings and shafts
Skiving³:
machine, tool and process
Gear skiving machines LK 180/280 and LK 300/500
LIEBHERR
Gear Technology

Cutting-Edge Clean

A look inside how this Texas-based company is improving air quality, efficiency, and morale as it scales production

Aaron Fagan, Senior Editor

The importance of clean air in manufacturing is often underestimated, yet it's one of the critical elements that can impact both production efficiency and employee well-being. This is particularly true in facilities that rely heavily on CNC machining, where oil mist and coolant byproducts can create significant air quality challenges. Wolfram Manufacturing, based in Austin, has addressed this challenge head-on by integrating advanced mist collection systems into its operations.

For Wolfram, a rapidly growing high-precision manufacturing firm, maintaining a clean, efficient workspace is as important as producing quality parts. Specializing in industries like aerospace, defense, and oil & gas, the company operates in a high-stakes environment where machine uptime and employee productivity are paramount. However, managing the oil mist produced by their machines had long been a persistent issue. That is until they discovered a solution that changed the game: 3nine mist collectors.

Specifications

Suitable for cabin size: <353 CF
Air flow: 600 CFM
Operating conditions: <122°F
Power supply: 30/15 A, 230/460 V/3/60 Hz
Motor rating: 1.5 kW
Rated current: 5.6 A (230 V), 3.6 A (460 V)
Weight: 154 lbs
Height: 45”
Diameter: Ø 25.2”
Inlet pipe: Ø 6.3”
Sound level: <65 db (A)

The oil mist eliminator Clara by 3nine is suitable for just about any type of machine tool with a cabin size not exceeding 353 CF (10 m^3). The Clara effectively cleans the oil mist formed during parts processing and delivers clean air into the workshop, along with recycling almost all of your oil/coolant for reuse.

3nine is a Swedish company that develops solutions for the purification of processed air for the metalworking industry. The technology is based on centrifugal separation, using a disc stack which produces an extremely high degree of purification in a very compact format. Disk stack technology, also known as a disc stack centrifuge or separator, is a separation technology that uses centrifugal force to separate solids and liquids based on their density. The technology differs from traditional technologies such as rotating filters, electrostatic filters and mechanical filtration solutions by physically separating out the oil particles from the air instead of collecting them in filters. This allows for the immediate reuse of expensive cutting fluids and reduces maintenance.

A Breath of Fresh Air in CNC Machining

Stepping into Wolfram Manufacturing's facility today, you wouldn't know it was a place where heavy-duty CNC machining takes place. The air is clean, and the shop floor is free from the usual haze of mist that characterizes many machine shops. This hasn't always been the case, however.

"At our previous facility, you'd open the door to the shop, and you could immediately see and smell the coolant mist," says Kirby Martinez, optimization manager at Wolfram. "It wasn't just an inconvenience, it was a growing concern for us." This mist wasn't just a visual issue; it also posed a potential health hazard, not to mention the constant need for cleanup and maintenance that came with it. Employees often complained about the sticky residue that coated surfaces, leading to discomfort and reduced morale.

Wolfram initially attempted to address the issue with traditional ventilation systems. These systems helped to an extent, but they were far from a comprehensive solution. "Ventilation would reduce the problem, but it never really solved it," Martinez explains. "We needed something more targeted, something that could eliminate the mist at its source."

Enter 3nine. After extensive research, Wolfram decided to invest in 3nine's advanced mist collectors. These systems, which work by separating oil mist and coolant particles from the air, promised not only cleaner air but also increased efficiency. The technology operates by capturing mist at the point of origin—right at the CNC machines—and filtering it out before it spreads through the workspace. This was exactly the solution Wolfram needed.

Cutting Costs, Reducing Downtime, and Improving Efficiency

The benefits of the 3nine system were immediate. In fact, the first unit that Wolfram installed had such a profound effect that the company quickly expanded its use across the facility.

"We started with just one unit to test it out, but we quickly realized we needed more," says Chris Swaim, director of strategic initiatives at Wolfram. "The results were clear. Not only was the air cleaner, but we also started seeing reductions in downtime and maintenance costs."

Operating Principle

1. **Permanent media—The oil mist enters the disc stack where 99.9% of the fluid particles are separated from the air down to 1µm.**
2. **H13 HEPA filter—The particles smaller than 1µm, will be collected by the final stage HEPA filter.**
3. **Fluid Recovery—The separated cutting fluid is returned to the machine tool for reuse.**
4. **Self-Cleaning—The disc stack is automatically and continuously cleaned with the CIP (Clean in Place) system using clean cutting fluid from the machine tool.**

The design of the 3nine system offers significant advantages over traditional mist collection systems. Unlike bulky ventilation units that require extensive piping and large floor space, the 3nine collectors are mounted directly on top of the CNC machines. This space-saving design was crucial for Wolfram, particularly as they moved into their new facility.

"Our current space has a drop ceiling, which helps keep the temperature down, but it also limits how we can position large equipment," says Martinez. "The compact size of the 3nine units allowed us to make the most of our available space without compromising our cooling systems."

The space savings are just one part of the equation. The 3nine mist collectors also reduce the need for constant cleaning, allowing workers to spend more time on productive tasks rather than wiping down surfaces or changing filters on older systems.

Before installing 3nine, filter changes were frequent, time-consuming, and expensive. Now, filter changes are minimal, and the units themselves are incredibly efficient. "We've cut down our filter change costs by over $4,600 a month," Swaim notes. "That's significant, especially when you're talking about scaling operations."

Air Quality and Employee Morale: An Unexpected Benefit

One of the most unexpected benefits of the 3nine mist collectors has been the noticeable boost in employee morale. While air quality may not be the first thing that comes to mind when thinking about job satisfaction, it's something Wolfram's team has come to appreciate deeply.

"There's definitely a difference in the atmosphere on the shop floor," says Martinez. "You never fully get rid of the smell in a machine shop, but not seeing or breathing in that visible mist makes a big difference."

In fact, Wolfram's employees have reported feeling more comfortable and less fatigued since the installation of the new system. There's a psychological aspect to it as well: stepping onto a shop floor that's clean and clear of mist creates a sense of pride in the workspace. Employees are more focused and productive because they aren't dealing with the discomfort that used to come from the mist and the odor.

This morale boost has had a tangible effect on Wolfram's overall productivity. "Happy employees are productive employees," Swaim emphasizes. "When people feel good about where they work, they're more engaged and motivated. That translates into higher output and better quality."

Visitors to the facility have also noticed the difference. "When someone walks into a hazy shop, it leaves a negative impression," Martinez says. "But now, when visitors come through, they're impressed by how clean and clear everything looks. It's a point of pride for us."

Transforming Shop Conditions

One of the key challenges in gear manufacturing is maintaining a clean and safe working environment. Traditional air filtration systems often fall short, allowing oil mist and other contaminants to settle on machinery and surfaces, leading to increased cleaning time, machine wear, and potential health hazards for employees. However, innovative solutions like the 3nine mist collectors are changing the game.

Nathan Byman, founder and president of Wolfram Manufacturing, offers a firsthand account of the transformative power of 3nine in his shop:

"3nine, at this point, is the end game of what we've found for air filtration. We have about 20 years working through different manufacturing environments, from old forging facilities that had machining on the shop floor where everything is charred and blackened. And you wipe the machines to see what colors they are through all kinds of manufacturing facilities that considered themselves clean and used a lot of different air filtration along the way and suffered all the consequences of just everything getting sticky and covered and harder to clean day to day.

"Fast forward, we're in a shop with bright epoxy floors and interior office tiling on the ceiling, and the only way it is possible to run a shop in that environment is with a system like the 3nines. So as far as I'm concerned, we have found the end game, and it's the only thing we'll be using going forward."

Byman's experience illustrates the profound impact that air filtration can have on not just air quality but the entire shop environment. His team has moved from working in dirty, oily spaces to clean, efficient conditions where the air is free from mist, allowing for better machine performance, a safer working environment, and less downtime spent cleaning.

The Numbers Behind the Success

Wolfram's investment in 3nine mist collectors has proven financially sound. By using their Production Management Software, OnTakt (*ontakt.com*), to track downtime costs from previous systems, the leadership team demonstrated the ROI of the new collectors even before purchase, confirming their value both in improved air quality and overall efficiency.

Here's a breakdown of the financial impact:

- **Cost per unit:** Each 3nine unit costs approximately $13,000, a figure that might seem high at first glance but quickly proves its value in terms of cost savings and improved efficiency.
- **Filter change savings:** Prior to installing 3nine units, Wolfram was spending upwards of $4,600 per month on filter changes for traditional mist collection systems. The 3nine units require far fewer filter changes, slashing these costs by about 90 percent.
- **Reduced cleaning:** With the mist largely eliminated, Wolfram's cleaning staff now spends about 25 percent less time maintaining the facility. This translates to significant labor savings—around $800 per month.
- **Downtime reductions:** Machine downtime due to mist-related issues has dropped dramatically. With each 3nine unit saving approximately two hours of machine downtime per month, Wolfram estimates they save thousands in lost productivity each year.

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A 3nine filter in service at Wolfram Manufacturing with clean epoxy floors and a white drop ceiling.

The Numbers Behind the Mist

- **Cost of each unit:** $13,000
- **Monthly filter savings:** $4,600
- **Monthly cleaning savings:** $800
- **Total monthly savings:** $5,400
- **Payback period:** 19 months

In total, Wolfram estimates the 3nine units save them roughly $5,400 per month across the facility. This means that each unit pays for itself within about 19 months—an incredibly short payback period given the lasting impact on the facility.

"The return on investment was clear from the start," Swaim says. "We didn't just gain a solution for air quality; we gained a tool for efficiency and cost savings."

Scaling Up with Confidence

Wolfram Manufacturing is in growth mode. As the company continues to expand its operations to meet increasing demand, it plans to stay ahead of potential challenges—particularly air quality concerns—by continuing to invest in 3nine mist collectors.

"We're adding more machines all the time," says Martinez. "With every new machine, we're installing a 3nine unit right alongside it. It's a critical part of our strategy as we scale up."

This forward-thinking approach has positioned Wolfram not only as a leader in its industry but also as a model for modern manufacturing. By embracing technology that improves both operational efficiency and employee well-being, the company is setting a new standard for what a manufacturing facility can be.

A Blueprint for the Future of Manufacturing

Wolfram Manufacturing's success with 3nine mist collectors serves as a powerful example of how modern technology can solve age-old manufacturing problems. By prioritizing air quality, the company has not only improved the working environment for its employees but also boosted productivity, reduced costs, and optimized its operations for future growth.

As more manufacturers look to scale their operations while maintaining high standards of quality and efficiency, Wolfram's experience with 3nine offers a valuable blueprint. By adopting innovative solutions like advanced mist collection systems, companies can create cleaner, more efficient, and more productive workspaces—ultimately driving success in an increasingly competitive marketplace.

"In today's world, it's not enough to just produce good parts," says Swaim. "You have to create an environment where people want to work, where operations run smoothly, and where every investment counts. That's what we're doing with 3nine."

For more information about 3nine oil mist eliminators, contact *Shanti.Kachele@3nine.com*.

3nine.us

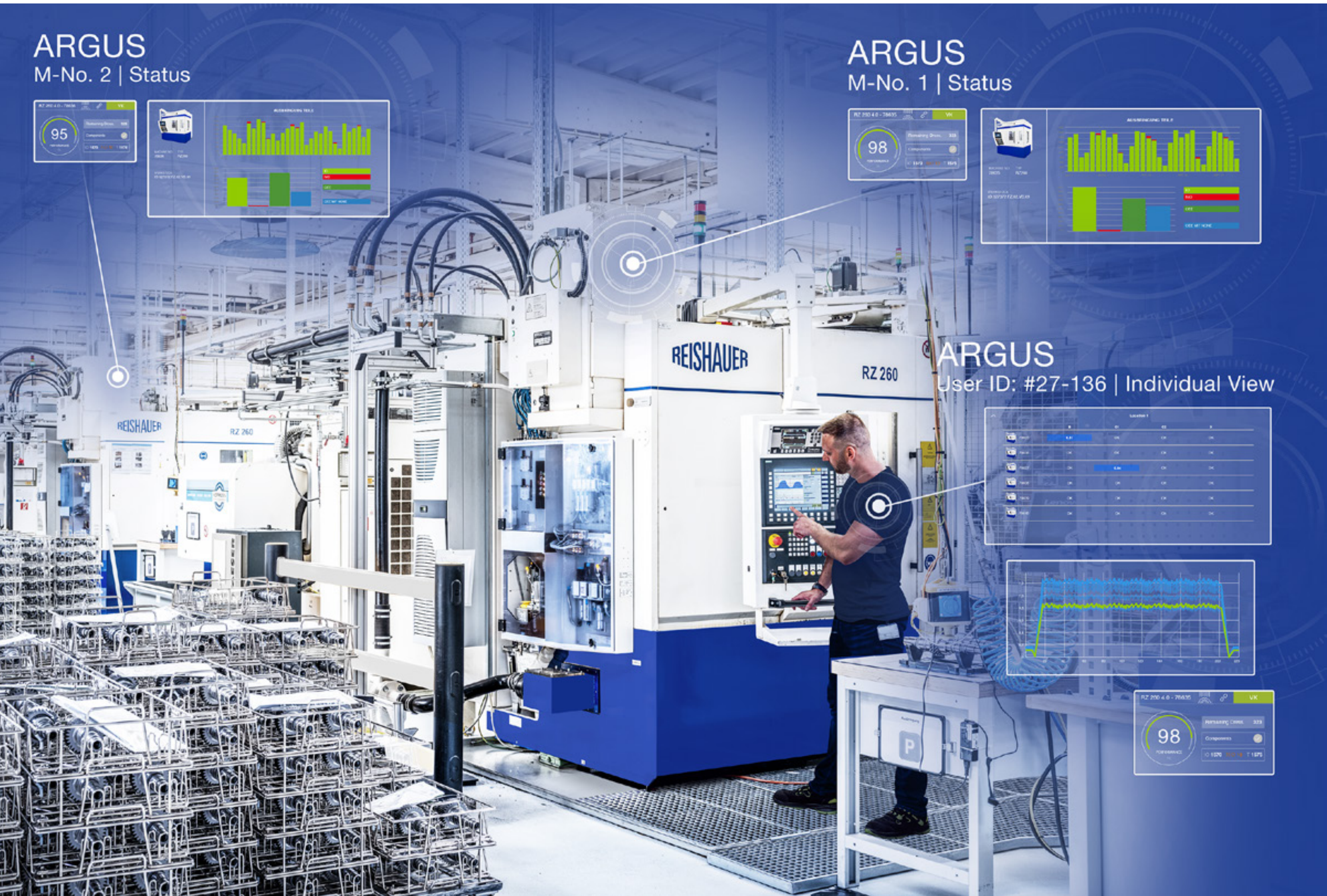
Digitization of Hard Fine Machining of Gears in a Production Environment

The goal is to optimize processes further and extend tool life to meet increasingly higher quality standards while reducing production costs

Walter Graf, Senior Project Manager, Reishauer AG

ZF-Brandenburg exemplifies modern manufacturing processes utilizing digital technologies. Integrating machines and production technologies into the digital world, where machines connect to the cloud and algorithms assist in assessing machine statuses, is already standard practice here. Operators, planners, and managers are always networked with all systems in real time, making ZF-Brandenburg a pioneer in digitalization best practices. Among other innovations, ZF employs the Argus Monitoring System from Reishauer to digitalize its machine tools in the hard fine machining of gears. This article by Reishauer AG summarizes the insights gained from digitization in the machine tool sector, highlighting the long-term collaboration between the two companies. ZF Getriebe Brandenburg GmbH, distinguished by a team of over 1,500 specialists, leads in producing exclusive manual and dual-clutch passenger car transmissions used in high-end German sports cars for maximum precision and performance. A crucial factor in the quality of these transmissions is the precise ground gears manufactured on machines from Reishauer AG, a Swiss pioneer in gear grinding machines.

A view of the ZF production environment.



Reishauer's ARGUS system is a groundbreaking innovation for monitoring processes and workpieces produced at ZF. This system enables the evaluation and optimization of the grinding process quality and the precise monitoring of machine components and grinding tool wear. The collaboration aims to leverage joint synergies by combining specialist production knowledge with the innovative power of digital solutions. Both companies are deeply committed to continuous optimization, resulting in a mutually beneficial partnership. ZF utilizes the ARGUS system to meticulously monitor processes and machine components in gear production, achieving significant advancements in its manufacturing technology.

What Will Gear Production Look Like in the Digital Age of 2024?

ZF Brandenburg revolutionized gear production by comprehensively implementing the ARGUS monitoring system. Today, almost 100 percent of all components are monitored directly, permanently, and seamlessly in real-time. This continuous monitoring guarantees an unprecedented level of safety in modern gear production. The ARGUS system monitors components and ejects potentially defective workpieces during the machining cycle, preventing quality issues in subsequent assembly stages. This proactive approach enhances process reliability and significantly reduces costs in later process steps. Process planners can react immediately to unexpected issues, such as frequency excitations. With 100 percent control provided by the ARGUS system, they can see exactly how each component is or was ground, recognize machine conditions, and identify problems in real-time. This allows them to eject faulty components from the machine or block critically identified parts in the process flow before installation in gearboxes, thus preventing faults that previously led to costly dismantling measures. The ARGUS system enables efficient detection of grinding worm breakages caused by local overloads during pre-machining fluctuations and easily detects rare large breakages due to collisions. One of the primary reasons ZF acquired the ARGUS system was to address challenging vibration problems. Shortly after implementation, with the expertise of Reishauer, ZF developed the ability to detect potential sources of vibration in specific working areas of the grinding worms. Calibration of the process monitoring was optimized to remove components that could potentially cause unwanted noise (NVH) in transmissions from the process chain. This optimization resulted from analyzing large amounts of data in the ARGUS web application, ensuring a higher quality of the final product and enhancing overall production efficiency.

> **"Thanks to the extensive database, it is now very easy to define and set precise and valid process limits."**
>
> —Denny Macholdt, ZF Production Planner

Production planner Denny Macholdt showing pride in his achievement.

The Impact of the ARGUS System on Gear Production at ZF Brandenburg

The ARGUS web application is accessible through any web browser, and its user-friendly interface is a standout feature. Even an inexperienced user can identify problems in the production environment with just a few clicks. However, resolving quality-relevant issues requires expert knowledge. ZF Brandenburg employs quality engineers specifically for this purpose, which has greatly simplified and accelerated the implementation of ARGUS. Reishauer AG consistently provides its customers with qualified, long-term support for digital applications and technological tasks.

Production Before ARGUS

Before the introduction of ARGUS, quality problems were often identified only at the end of the production during the end-of-line (EOL) testing. Statistical process control within a low percentage range could only detect static or slow changes. This meant faulty gears were often installed in gearboxes before defects were discovered. To determine the source of a fault, gears from the defective gearbox had to be measured using tactile methods in the measuring room. For example, if a component fault was linked to a grinding worm breakage, all components ground on that particular day had to be identified. In such cases, the affected production lot had to be blocked, and all components might need to be checked 100%. The resulting high follow-up costs were significant. Although such events were relatively rare, anomalies detected during EOL testing led to dismantling costs that were substantially higher than if the grinding machine had already sorted out potentially faulty parts. After hard finishing, the process steps become significantly more cost-intensive. Considering the unnecessary number of process steps, the working time, and the material costs due to components that were not ejected, it becomes clear how cost-effective and productive the grinding process with ARGUS is.

With the help of the ARGUS process monitoring system, every user can access all relevant data on their machines at any time and from anywhere, allowing them to make informed decisions.

Data Evaluation, Analysis, and Operability

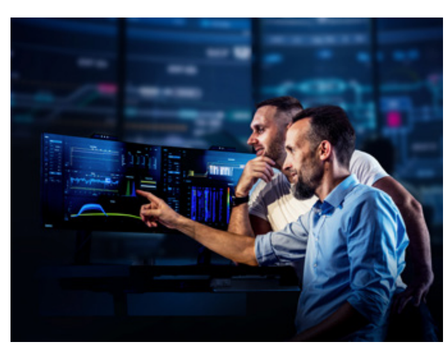
Today, the ARGUS web application enables planners to view the production process in real-time from a PC on the shop floor, in the office, or on a mobile tablet, regardless of location. One production planner commented, “The system allows us to think more deeply about the process and make more targeted decisions. With ARGUS, we can identify harmful frequencies and determine the speeds that should be avoided to ensure the process’s safety and quality.” Data analysis can identify error patterns and eliminate these potential problems directly on the machine. Once this step is taken, process optimization usually begins. In ARGUS, technology parameters can be easily linked to measurement data. This approach often reveals simple opportunities where small changes can quickly lead to greater effectiveness. Of course, this is always subject to the system’s inherently high process reliability.

“The ARGUS system enables us to gain deeper insights into the process and make more precise decisions.”—Denny Macholdt, ZF process planner.

Enhanced Machine Condition Monitoring

In addition to analyzing the grinding process, ARGUS excels in machine condition monitoring. With automatic component diagnostics (ACD), machine signals are constantly monitored and automatically evaluated to identify potential component failures. Autonomous test cycles take only a few minutes and record extensive data daily. These test cycles are designed with sensors to detect machine faults quickly. Cloud algorithms then display the collected data as a simple traffic light signal. A red light indicates that immediate action is required.

Before implementing ARGUS, ZF had to conduct complex measurement series and grinding tests to identify problems, such as profile form errors caused by a worn shift axis. This process required two to three employees and incurred significant costs. With ARGUS and ACD, it is now possible to immediately determine if a machine component is the cause of a problem, significantly reducing labor and downtime. ZF’s planning department rated the usability of the ARGUS system as very user-friendly. Two to three hours of training is sufficient for a machine operator to use the ARGUS system effectively and take data-based actions.



Reishauer’s inventor of ARGUS, Dr Christian Dietz and ZF’s Denny Macholdt.

Expertise and Collaboration in Gear Production

However, more detailed analyses, particularly the frequency analysis offered by ARGUS, require significantly more experience. ZF has gained this expert knowledge through its collaboration with Reishauer and by developing its internal expertise in process planning. This increase in in-house know-how includes appointing an NVH expert who exclusively handles machine vibrations. Since the digitalization of gear production at ZF, a division of tasks and collaboration between machine operators and process planners has been established. Planners focus on data analysis of large production batches, derive evaluation limits, assess trends, and take appropriate action. This division has led to considerable improvements in production.

Conclusion

ZF emphasizes that production has significantly improved with the use of ARGUS. The system's precise definition of limit values has increased the quality of manufactured parts. Defective parts are effectively identified and sorted out for subsequent processing, reducing the number of rejected parts and wasted production time. Additionally, the cost reduction due to the significant decrease in end-of-line (EOL) returns is quantifiable, as the number of returns has fallen markedly since the introduction of ARGUS. ARGUS also helps minimize tool costs by providing detailed insights into the condition of the tools. This insight allows using tools to their performance limits without prematurely removing them from the production process based on the potentially incorrect assumption that their service life is nearly exhausted after a predefined number of usage cycles.

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E.T. Hone Home

Gears manufactured by Forest City Gear are found in aerospace-related, medical, military, and other industrial applications, many of which demand high process capability where honing provides critical advantages in control and consistency.

An early decision to hone put Forest City Gear on a path to precision, earning a reputation for some of the best gears in the world and beyond

Phil Hanna, Product Manager—Machines/Gages, Sunnen Products Company

For more than 60 years, Forest City Gear has crafted a legacy of excellence in precision gear manufacturing, leveraging advanced techniques and cutting-edge technology to earn the business of customers as exclusive as NASA. At the heart of the company's technology-focused philosophy lies a long-time relationship with Sunnen Products Company, a leading manufacturer of honing systems, tooling, and accessories. The relationship helped Forest City set itself apart as one of the world's most precise gear makers, and now the company's parts are found on everything from fishing reels to the Mars Rovers.

Stetler and Evelyn Young started Forest City Gear in 1955 after Stetler's employer, Rynel Gear, was sold and liquidated. When a former Rynel customer approached Stetler with a need for high-quality gears, Forest City Gear was born. Since then, the company leadership was assumed by Stetler and Evelyn's son, Fred Young, who ran the company for nearly 50 years, continuing its traditions of high-tech precision and innovation. Fred's daughter, Kika Young, is now the company president. "Staying on the forefront of machine tool technology goes to our core values because it makes us a better partner for our customers," said Kika. "Likewise, Sunnen checks all the boxes we're looking for in a partner—communication, quick response, quality equipment."

Forest City Gear doesn't produce standard, off-the-shelf gears; they specialize in crafting custom gear solutions tailored to the unique needs of diverse industries. "Everything we make is custom, directly from a customer's design or CAD file," added Young. "Our company's strategic directive has always been: 'excellence without exception.' It boils down to always giving the customer a higher level of quality than specified and doing it without adding much cost or time to a job. Our automated vertical honing systems allow us to hit tight tolerances and produce precision finishes, easily and efficiently without adding production time."

About 30 percent of Forest City's work is aerospace-related, 5–10 percent medical, 5 percent military and the remainder are industrial or instrument work. Many of these applications demand high process capability where honing provides critical advantages in control and consistency, according to the team at Forest City.

Evolution: From Parts to Assemblies

The collaboration with Sunnen has allowed Forest City Gear to push the boundaries of gear manufacturing—delivering tight tolerances and exceptional surface finishes, to ensure that each gear meets the highest standards of quality and reliability. It has also helped Forest City expand its product line to gear assemblies where precision also plays an important role.

Forest City Gear's principal products are fine and medium-pitch custom gears, such as internal, spline, sprocket, helical, spur and worms/worm gears. Typical materials include 12L14, 1215, 4140, 8620, 9310 and various stainless grades, as well as aluminum, bronze, brass, Inconel, Hastelloy, titanium, plastics, wood fiber and powdered metal.

"We evaluated our Sunnen hones and how we used them over the years, and as the gear tolerance requirements got tighter, we started to take over more of the value stream," said Jared Lyford, Director of Operations, Forest City Gear. "We used to be more of a cut-teeth production, then we migrated to whole-part-complete, from raw material to finished part. Even after ID grinding, we needed to have more finite control of the bore tolerances, and that's where the Sunnen machines came in. They allowed us to meet the roundness and perpendicularity for both finished parts and in-process requirements for gear finishing."

Honing Makes the Difference

Forest City Gear's principal products are fine and medium-pitch custom gears, such as internal, spline, sprocket, helical, spur and worms/worm gears. The company works to quality levels as high as AGMA 15 (DiN 2-3). Part runs range from one to several hundred thousand. Maximum O.D. on most parts is 20", except for worms (5") and worm gears (16"). Typical materials include 12L14, 1215, 4140, 8620, 9310 and various stainless grades, as well as aluminum, bronze, brass, Inconel, Hastelloy, titanium, plastics, wood fiber and powdered metal.

Honing, a precision machining process, plays a pivotal role in ensuring the superior quality and performance of Forest City Gear's products. By employing two Sunnen SV Series vertical honing systems, as well as an SH-4000 horizontal hone, the shop achieves unparalleled accuracy and surface finish in its gears. This meticulous approach not only enhances the durability and reliability of the gears but also optimizes their performance in various applications.

Forest City Gear has used honing since the inception of its business. The company also tried hard turning, but found it more difficult to control quality, especially for micro finishes. "On bore-type gears, we have found that automated honing is a good way to give the customer tighter control of bore size, roundness, straightness, and finish," said Joel Miller, ID/OD Department Supervisor at Forest City. Miller is responsible for the honing, lapping and grinding duties at Forest City. "The customer notices the difference in a smoother, quieter, more efficient drive."

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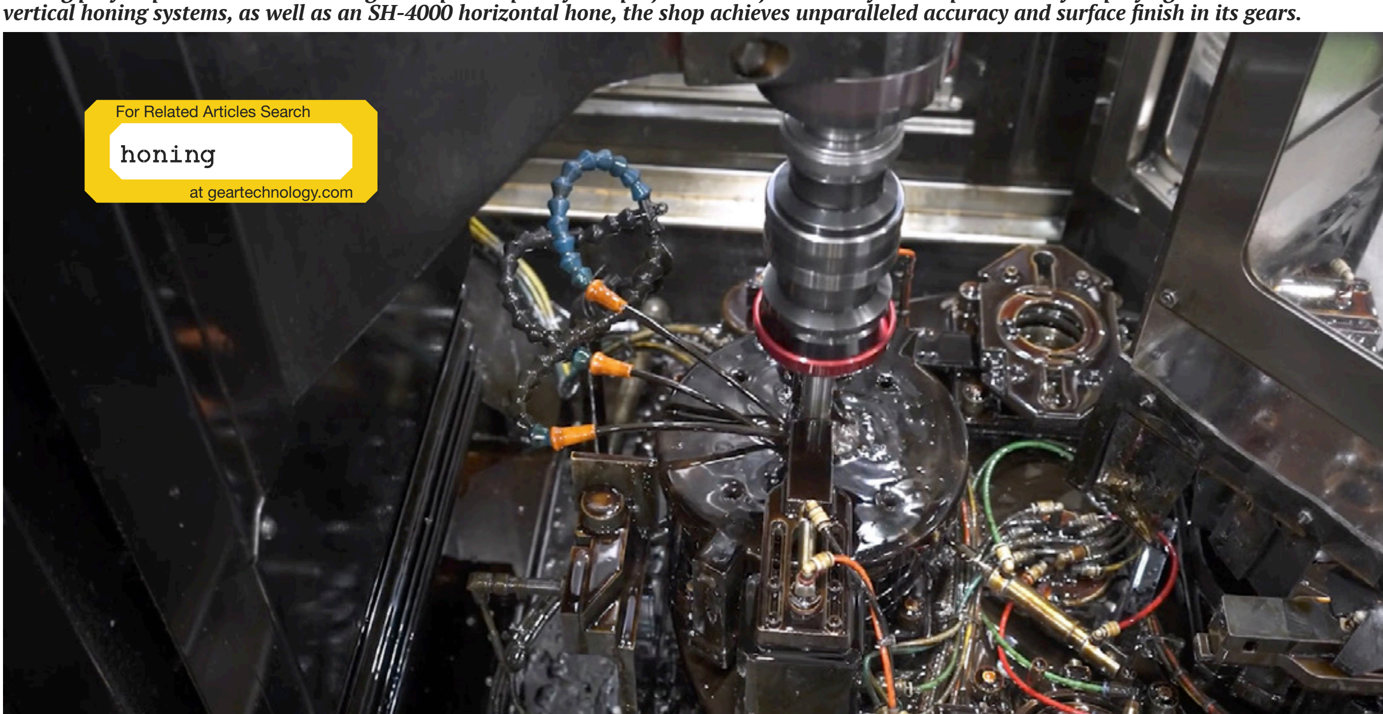

Forest City Gear needed to have more finite control of the bore tolerances, and Sunnen hones allowed it to meet the roundness and perpendicularity for both finished parts and in-process requirements for gear finishing.

"ID grinding is a fine process for gears with larger (>0.75 in.) bores and low L/D ratios (0.5:1), but our range of work includes smaller diameters and relatively deep bores," Miller explains. "When you start to reach an L/D of 2:1, honing has a real advantage in speed of material removal, and over 5:1 you might start to see deflection on a grinding spindle, exacerbating taper issues."

Forest City uses Sunnen's diamond-plated CGT tooling with the Sunnen MB30 honing fluid. "We've had excellent results with the diamond-plated tooling as far as consistent, cool cutting, holding size, and giving us long wear," added Miller. "And the Sunnen machines are tanks. We depend on them to be accurate and repeatable. We can run on Friday afternoon hitting split limit, come back Monday morning, turn the machine on and we're within 20 millionths."

Software Upgrade Delivers Efficiency and Flexibility

Forest City Gear had been using Sunnen SV computer controlled vertical honing systems since 2007, and when a new software update arrived in 2022 there were concerns. Fortunately, the new software is compatible with the older model honing machine, so a simple software upgrade was all that was needed. "The entire software upgrade only took about two hours," said Miller. "We were back up and running the same day."

The new Sunnen software proved to be a game-changer for Forest City Gear—making machine setups, operator training, and overall operational efficiency even more efficient. The new software introduced features such as intuitive user interfaces, automated processes, easy tool setups and enhanced compatibility. This allows operators to set up machines more efficiently, reducing the time and effort required for each setup.

"The intuitive nature of the new software reduced the learning curve for our operators," said Miller. "With the user-friendly interfaces and simplified workflows, operators can quickly grasp the functionalities of the software, requiring less time for training. This not only saved us resources in terms of training hours, but also enabled operators to become proficient more rapidly, contributing to overall productivity."

Through new software, Forest City gained access to advanced features designed to optimize various aspects of their operations. These include tools for process monitoring, data analysis, and predictive maintenance, among others. These features allow the shop to identify and address inefficiencies more effectively, leading to smoother operations and improved overall performance. "With this new software our operators can monitor which fixture is running and where we are in the part run," added Miller. "This gives us built-in consistency across all operators and allows one operator to run multiple machines."

Overall, the decision to upgrade to new Sunnen software appears to have had a significant impact on Forest City Gear's operations. By embracing Sunnen's advanced honing technology, the shop was able to enhance machine setups, expedite operator training, and streamline overall processes.

From its start, and through three generations of leadership, Forest City Gear has emphasized quality and precision in its parts and products. "We have always put a high value on machine tool technology, and we're very proud of that

New Sunnen software made machine setups, operator training, and overall operational efficiency more efficient for Forest City. The new software introduced features such as intuitive user interfaces, automated processes, easy tool setups and enhanced compatibility, allowing operators to set up machines more efficiently.

heritage," added Young. "In fact, we still have a photo hanging in the shop of my dad and a bunch of Forest City Gear folks with one of the Sunnen machines we purchased at IMTS."

Fred Young's passion for innovation not only established Forest City as a go-to gear maker, but it also brought new best practices to the gear making industry as he willingly shared his methods and techniques. Fred passed away in 2023.

"All of us at Sunnen enjoyed working with Fred," said Tom Dustman, Sunnen's Director of Sales, Americas. "He was a true manufacturing icon, constantly pushing the boundaries of what could be done to improve the quality of gears, and then sharing whatever he learned with the entire industry rather than keeping it as a competitive advantage. The synergy that was created by Forest City Gear and Sunnen working together helped both companies improve our capabilities and quality."

Through continuous innovation and a relentless commitment to machine tool technology, Forest City Gear has earned a reputation as a trusted partner for customers seeking top-tier gear solutions. By harnessing the power of honing technology from Sunnen Products Company, they continue to lead the way in precision gear manufacturing, driving success across a wide range of industries.

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Small Bevel Gears Made Easy

Production of small, high-precision bevel gears for robotics, power tools and other similar-size applications enters a new era

Uwe Gaiser, Director of Product Management and Bevel Gear Technology, Gleason Corporation

Gleason Phoenix 100C Bevel Gear Cutting Machine: fast, compact, efficient and purpose-built for smaller bevel gear cutting.

By 2030, the global robotics market size is expected to range anywhere from $160 billion to $260 billion. The world is expecting robots to do a lot of the "heavy lifting" going forward. But with demand pressuring supply for many of the essential components, new production technologies are needed to keep pace. Nowhere is this truer than for the smaller, high-precision spiral and hypoid bevel gears that play such a critical role in transmitting power and delivering precise, reliable movement in increasingly complex, multiaxis robotic systems. Yet, manufacturers of these gears have, up until now, had surprisingly few options available to help them ramp up production of this new generation of high-efficiency bevel gears—particularly in the increasingly common size range of 100 mm in diameter and smaller. Case in point: a technology still very much in widespread use to produce small bevel gears is a mechanical machine that dates to the 1960s: the Gleason No. 102 Generator. These tried-and-true workhorses can still be found by the many hundreds in even the most modern manufacturing environments, working dependably to cut the small spiral, hypoid and straight bevel gears that go into everything from power tools to lawn/garden and small industrial gearboxes to, yes, even advanced robotics.

While the 100C is easily applied to "legacy" production and the continued use of traditional solid body HSS cutter systems, it is ideally suited for today's most advanced inserted blade carbide cutter systems for Dry Power Cutting—and production two to three times faster than older machines.

Fitting Perfectly into Small Bevel Gear Production

The inherent limitations of these vintage mechanical machines make them particularly ill-suited to produce a new generation of bevel gears for robotics—and many other applications—where quality, flexibility, and, above all, speed, are paramount. The 102 Generators are, by nature, very time-consuming and difficult to set up and require operator skills that are in increasingly short supply. Changeover, whether for "high mix/low volume" or "low mix/high volume" applications and/or to accommodate fast-changing customer demand on the fly can take hours, even days on these older machines—a process that can be done with the press of a button and in a few minutes on today's modern CNC machines. Nor can they be networked into the quality inspection process that many manufacturers are today using to shorten the distance from optimized new design to high quality production part. Ensuring repeatable quality on a 102 is an operator-intensive process that requires repeated cycle interruptions for part quality checking and rechecking. These limitations aren't lost on the user, most of whom have transitioned to more modern CNC machines everywhere else in their facilities. Gleason has now developed a machine that is fast, compact, efficient and purpose-built for smaller bevel gear cutting: the Phoenix 100C CNC Bevel Gear Cutting Machine.

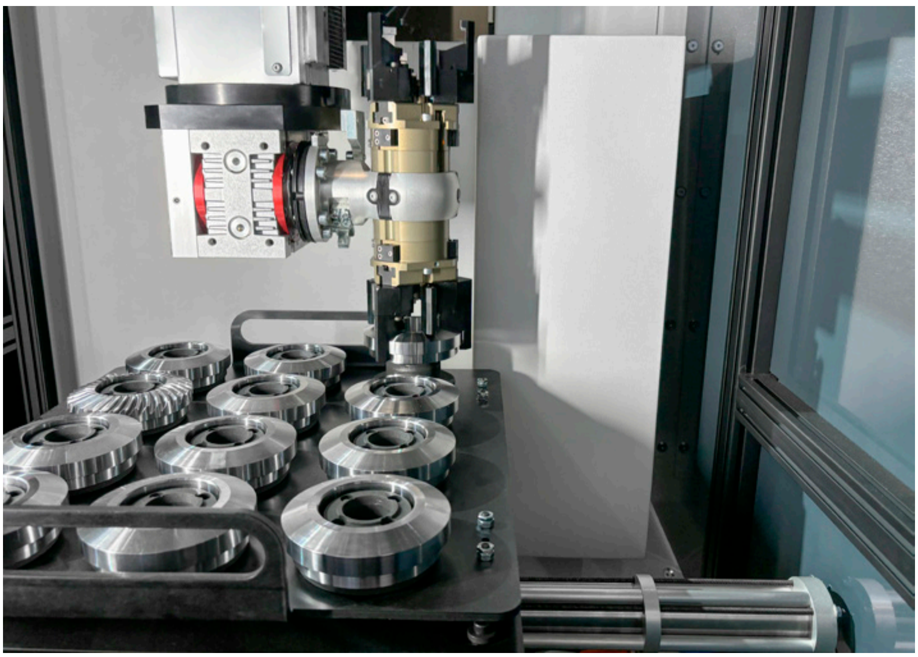
The 100C has been designed to fit seamlessly into the world of small bevel gear production: easily applied to "legacy" production and the continued use of traditional solid body HSS cutter systems and a myriad of pre-existing workholding systems, while ideally suited as well for the application of today's most advanced inserted blade carbide cutter systems for Power Dry Cutting at speeds two to three times faster than possible with older machines. Additionally, the machine can be equipped with very fast, fully integrated gantry-type load/unload automation, which easily interfaces with common palletized, basket-type and/or conveyor parts handling systems for higher volume applications. Even with its loader automation, the 100C's small footprint takes up only 65 sq. ft (6 m2) of precious floor space.

Scaled Down, Powered Up

In the case of the 100C, "downsized" doesn't mean "under-equipped." In fact, the machine offers many of the same features and benefits users have come to expect in the latest generation of larger Phoenix machines. For example, the powerful, high-speed direct-drive cutter and work spindles are designed to support almost every spiral bevel, hypoid and even straight bevel gear production application in its size range, including face milling and face hobbing, wet or dry cutting, low to high production volumes – all through application of all types of cutter systems. These, of course, include older-style solid-body HSS cutters, but also Gleason's latest solid-body carbide cutters and most advanced Pentac carbide stick blade cutter systems to achieve the extremely high speeds and greatly improved productivity of the Power Dry Cutting process. The 100C also saves time with an integrated brush deburr unit that automatically deburrs the workpiece in seconds right on the machine.

The 100C comes equipped with the latest Gleason bevel gear quick change tooling to help eliminate much of the costly non-productive time that was once required to change over different parts—while at the same time achieving high, repeatable accuracies. Note that the system is designed for the machine's 39-taper spindle bore; existing workholding for legacy parts with other taper requirements can easily be accommodated with a variety of adapters for the most common bore sizes.

Finally, when automation is used to load the gear blanks, an air-detect system ensures that the part is chucked and seated properly in advance of the machining cycle.



100C can be equipped with very fast, fully integrated gantry-type load/unload automation, which easily interfaces with common palletized, basket-type and/or conveyor parts handling systems for higher volume applications.

Working Smarter on Smaller Parts

Shorter cycle times and more efficient, error-free operation also result from Gleason's *GEMS* Machine User Interface software, which makes setup and changeover more intuitive and simpler to both learn and operate. This User Interface, coupled with the latest Fanuc CNC, provides several new process options and guides the operator intuitively through the workflows of the machine. Contrast that with the many hours, and vast experience, required for operators of older mechanical machines to change components like feed cams and change gears when setting up part-to-part. Since setup and operation are largely summary-driven, even new operators can be trained and operating the machine productively practically overnight.

These operating software and network capabilities allow easy integration of the 100C into any modern production environment. They can also interface the 100C into *GEMS* Closed Loop Manufacturing, which connects all process steps, from gear design to the final, optimized gear in a single system approach—for worry-free and intelligent gear production.

gleason.com

Shorter cycle times and more efficient, error-free operation result from Gleason's GEMS Machine User Interface, which makes setup and changeover more intuitive and simpler to both learn and operate.

A Focus on Gearboxes for New Robotic Applications

Mary Ellen Doran, AGMA Vice President, Emerging Technology

At the beginning of this year, the AGMA Robotics Committee published a white paper, *Gear Backlash in Robotics Applications*. The paper is available for download from the store on the AGMA website or reach out to me directly. A consensus was being built among experts that over the next 10–15 years, personal and collaborative robots will exceed the industrial robot market and be common in homes. As a committee, we wanted to address this change in the marketplace. The paper addresses the issues of gear drives in robotics. If this space grows exponentially, we should address intrinsic problems of backlash, wear, unpredictability, size, and high cost. Gear drives for robots that are in non-industrial settings will need to be different.

As a committee, we watched the developments in humanoid robots, understanding that this may be a new viable market for gear manufacturers. As a group, we guessed we would see fully developed prototypes in the next two to three years. We never expected the explosion of developments in the last six months. One after another we watched companies debut new products. If you have not been watching this space, here is a quick overview of companies and their systems.

It should be noted that bipedal robots are not new. In 2012, Boston Dynamics had Atlas, which they upgraded in 2016 to be electrically powered and hydraulically actuated. They have recently retired that robot in pursuit of a fully electrified version. Apptronik, another known leader in this space, debuted their general-purpose, humanoid robot, Apollo. The robot stands 5'8" tall and weighs 160 pounds. It can lift 55 pounds. Other newer players in this space are 1X Technologies, backed by OpenAI, which has a robot called NEO. NEO is a 66-pound humanoid robot that could be used to complete chores around the home. Tesla debuted their robot, Optimus at 125 pounds can carry 45 pounds and deadlift 150 pounds. Agility Robotics product is called Digit. It weighs in at 140 pounds and can lift 35 pounds. Digit is already moving boxes in a Spanx production facility in Georgia. Figure, which recently received more than $700 million in funding, is bringing a humanoid robot to market that is 132 pounds and can carry up to 44 pounds. It is being tested at the body shop at BMW's Spartanburg production facility. These are just a few of the many we have seen over the year.

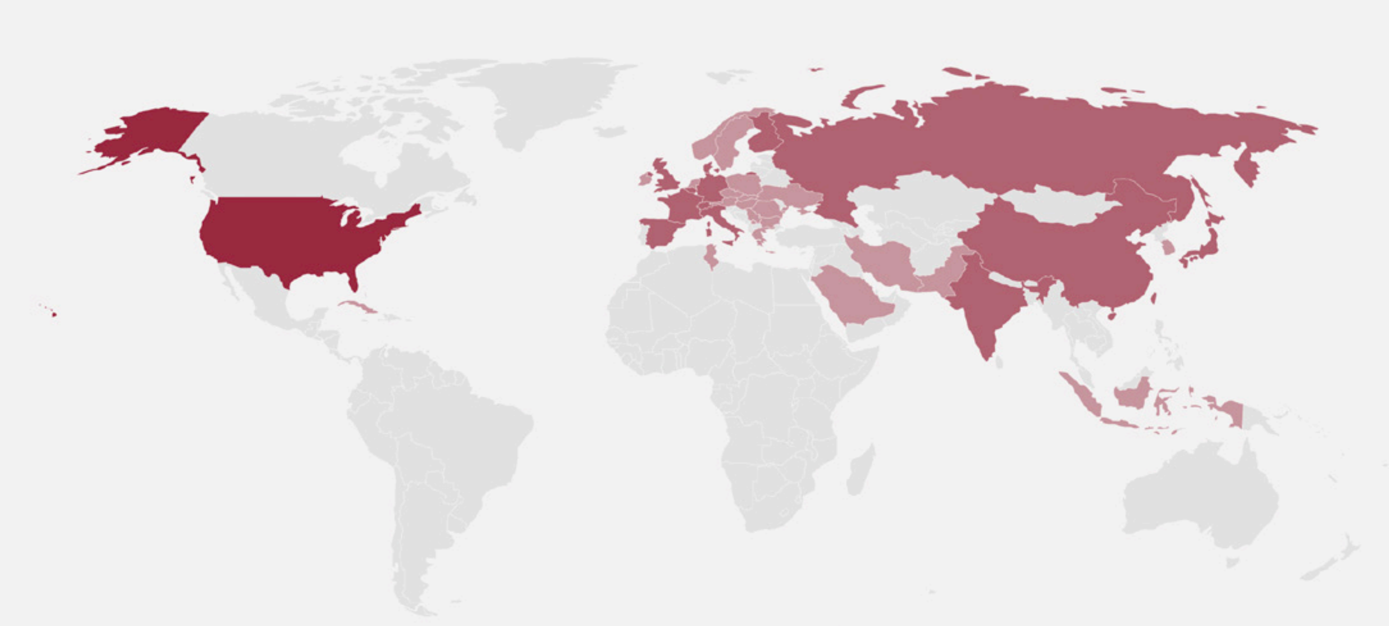
Apptronik's Apollo was demonstrated at IMTS 2024.

In July, AGMA Robotics Committee Chair, Robert Kufner discussed these developments with robot scientist Kel Guiren at the AGMA Emerging Tech event. In August, Morgan Stanley published an article citing that by 2040, the U.S. may have 8 million working humanoid robots. By 2050, analysts expect the number to rise to 63 million possibly affecting 75 percent of occupations, 40 percent of employees, and roughly $3 trillion in payroll.

While there are so many points of discussion on these new products, the focus for the AGMA Robotics Committee is the use of gears and gearboxes. We will be bringing presenters on this topic to the 2025 AGMA Emerging Technology Webinar Series. We hope to host more speakers on this topic at AGMA events, including the Motion + Power Technology Expo in October 2025. And, we are currently working on a second white paper, the working title is "The Near Future of Mechanical Drives for Humanoid Robots Safety." We welcome you to join us in these discussions.

Did You Know?

Todd Praneis, AGMA Vice President, Technical Division



Did you know that ANSI serves as the participating member for the United States at ISO?

Did you know that ANSI serves as the secretariat (committee manager) for ISO Technical Committee 60 (TC60), covering the subject of Gears?

Did you know that AGMA has been selected by ANSI to be the Technical Advisory Group (TAG) for ISO TC60?

Did you know that there are two subcommittees under ISO TC60, SC1 covering Nomenclature and Wormgearing, and SC2 covering Gear Capacity Calculations?

Did you know that the SC1 secretariat is managed by Switzerland (SNV)?

Did you know that the SC2 secretariat is managed by Germany (DIN)?

Did you know that there are currently 14 participating member countries and 22 observing member countries in ISO TC60?

Did you know that AGMA provides a technical expert—a "U.S. Delegate" to each ISO TC60 working group to bring the U.S. position and expertise to the international "table"?

Well, now you DO know! AGMA, and its member companies are busy helping develop, modify, and contribute to the international standards process. Without the dedication of our U.S. delegates and the shadow technical committees supporting them, the AGMA methods and processes would not be incorporated in these international standards. See below for a list of our dedicated U.S. delegates and the working groups that they support:

TC60/WG2	Gear Accuracy	John Rinaldo, Atlas Copco (Retired)
TC60/SC1/WG4	Gear Nomenclature	John Rinaldo, Atlas Copco (Retired)
TC60/SC2/WG6	Cylindrical gear rating	Robin Olson, Regal Rexnord
TC60/SC1/WG7	Wormgearing	John Cross, ASI Drives
TC60/SC2/WG12	Lubrication	Michael Blumenfeld, ExxonMobil
TC60/SC2/WG13	Bevel gearing	Claus Weyand, Regal Rexnord
TC60/SC2/WG14	Materials & HT	Carl Ribaudo, Timken (Retired)
IEC TC 88/ISO TC60 JWG	Wind Turbines	Brent Reardon, Consultant

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Investigation of the Interaction Between Process Signals and Modeled Thermomechanical Energy in Generating Gear Grinding

Eng. Mariana Mendes Wilfinger, Dr.-Ing. Mareike Davidovic and Prof. Dr.-Ing. Thomas Bergs

Introduction

Grinding is a high-performance machining process typically applied at the end of a manufacturing process chain, due to its ability to meet surface quality and workpiece integrity requirements. In gear manufacturing, generating gear grinding is a high-productivity variation of the grinding process. The high productivity results from the continuous process, where the workpiece is machined with a worm-shaped grinding tool. Due to its abrasive characteristics and the resulting high degree of material deformation, this process requires a large energy amount of energy input per volume of material removed (Ref. 23).

The energy generated during the grinding process can be categorized into thermal and mechanical energy. While the mechanical loads in the contact zone during the grinding process have a direct influence on the residual stress state of the workpiece surface, the thermal loads account for most of the generated energy. Thermal energy can be dissipated to either the chip, the environment, the cutting oil or the workpiece, which brings the risk of compromising the surface integrity through the occurrence of grinding burn. The extent to which process parameters can be manipulated without causing part damage is not entirely understood. This constraint not only limits the productivity of the process but also often makes it rather iterative, as the surface characteristics must be tested to assess whether the selected parameters are appropriate. Currently, suitable process parameters are defined by time-consuming trials or based on the operator's experience.

To guarantee an adequate surface integrity outcome in the parts finished by grinding, several energy characterization models have been developed for the calculation of energy and heat characteristics in the contact zone during grinding (Refs. 11, 14, 21). However, their direct application into generating gear grinding is often not viable, due to the complex contact conditions of the process derived from its intricate kinematics. More recent models are also able to describe the energy generation in the contact zone during generating gear grinding (Refs. 12, 19). The calculation of energy through such models offers a viable approach to understanding the energy generation in the contact zone, although it does not provide a means of directly accessing the influences of the energy on the process itself.

The fundamental relationships between energy and power in terms of machining processes indicate power as a relevant parameter for energy assessment. Power is a measure that can be assessed in real-time as a time-domain signal data extracted from the control of the grinding machine (Ref. 3). Moreover, the recording of spindle power signals during the process is a commonly found feature among modern grinding machines, allowing for in-process monitoring, without the necessity of installation of additional sensors. Thus, examining the relationships between the calculated process energy and the power signals on the spindles of the grinding machine may enable an indirect assessment of the heat in the contact zone, without the need for interactive evaluations. The approach developed in this research aims to aid a further understanding of the correlations between the energy generated during material removal and the power signals from the machine control during generating gear grinding. The approach is based on the development of a methodology for the investigation of correlations between machine spindle power signals and the calculated process energy in the contact zone, during the contact between tool and workpiece in generating gear grinding.

This paper was first presented at the 65th Conference "Gear and Transmission Research" of the WZL on May 22–23, 2024.

Nomenclature

$dCor$	[-]	Distance correlation
F_t	N	Tangential force
$\vec{F}$	N	Force vector
M_i	[-]	Mutual information
$p(X)$	[-]	Marginal probability of X (energy variable)
$p(X,Y)$	[-]	Joint probability function of X and Y
$p(Y)$	[-]	Marginal probability of Y (power variable)
P_c	W	Cutting power
P_p	W	Process power
$P_{s,i}$	W	Spindle idle power
$P_{s,t}$	W	Spindle total power
R	[-]	Ranks of X (energy variable)
r	[-]	Pearson coefficient
r_s	[-]	Spearman's rank correlation coefficient
S	[-]	Ranks of Y (power variable)
$\vec{v}$	m/s	Speed vector
v_c	m/s	Cutting speed
X	[-]	Energy variable
Y	[-]	Power variable

State of the Art

Despite the challenges posed by a complete understanding of the energy generation during generating gear grinding, both analytical and empirical models can provide a quantification of this metric. The energy generated in the contact zone can be correlated to the power in the spindle (Ref. 12), which in turn, can be measured by analyzing machine signals. However, since this relationship is not inherently straightforward, a detailed study of both power signals and energy is required to identify effective correlations. Therefore, within this chapter the current state of the art on both of those concepts is reviewed, focusing on methodologies for energy calculation and signal analysis in gear grinding. By investigating existing approaches and technologies, a foundation can be established for proposing a method to analyze correlations between energy consumption and power signal characteristics during generating gear grinding.

Energy in Generating Gear Grinding

As an abrasive process, the energy required in the grinding process is higher than in machining processes with a defined cutting edge (Ref. 20). This effect is derived from the large amount of material deformation that occurs during the cut, from the material that is removed and the one that remains in the workpiece, as well as the friction between the work-piece surface and the grains in the grinding wheel (Ref. 20). The total energy required to machine parts during grinding can be understood as a sum of process, machine and background energy (Ref. 11). The machine and background energies correspond to the share that is required for the machine to operate (hydraulics, cooling system, lighting, etc.). Meanwhile, the process energy corresponds to the share that is actively employed for material removal. For grinding, the process energy averages up to 20 % of the total required energy and is typically considered to be equivalent to spindle energy (Ref. 1).

The understanding of the energy involved in machining processes is often approached by a correlation with machine power, based on the principle that power is the rate at which work is done or energy is converted. Therefore, in cutting processes, energy is defined as the product of the distance to be traveled (cutting length) and the components of the resulting force acting in its direction, while power is defined as the product of the speed components and the resulting force acting in their direction (Ref. 9). These relations are useful in manufacturing since they allow for a more direct comprehension of the energy in terms of process parameters. In grinding, this association is given by Equation 1, in which the cutting power Pc is directionally proportional to the tangential force Ft. The cutting power is a share of the aforementioned process power (Equation 2) and, therefore, cannot be directly compared to the power which is observed in the machine spindle (Ref. 8). Nevertheless, the association between those is possible through Equation 3, in which the process power Pp is defined as the spindle total power, subtracted by the idle power on the spindle—the power which is necessary for the sole rotation of the spindle, without contact between tool and workpiece (Ref. 11).

$$P_c = F_t \cdot v_c \tag{1}$$

$$P_p = \vec{F} \cdot \vec{v} \tag{2}$$

$$P_p = P_{s,t} - P_{s,i} \tag{3}$$

Fundamentally, power can be understood as the rate of energy consumption. In terms of the grinding process, essentially up to 60–90 percent of the process energy can be converted into heat into the workpiece, depending on factors such as process conditions, grain and wheel bonding type (Ref. 11). This conversion effect leads to a recurring issue during grinding processes, the incidence of grinding burn, characterized as thermal damage in the workpiece surface. This incidence may lead to metallurgical phase transformations, tempering and possible rehardening of the surface layer (Ref. 15), as well as induction of residual stresses, which affects the fatigue strength of the material (Ref. 10). Since thermal damage like grinding burn concerns a wide combination of effects and intensities, it cannot be detected throughout the process immediately, but rather through tests and examinations carried out on the finished part. According to Malkin, the threshold temperature for the occurrence of grinding burn could be determined in terms of critical specific energy, which requires the definition of empirical coefficients based on the material pair (Ref. 15). Those findings indicate that there are means for in-process identification and control of thermal damage. Previously, Rowe also developed a model for predicting grinding burn threshold, based on the heat flux observed in the process, considering the energy partitioning between tool and workpiece (Ref. 21).

The detection of such thermal defects is further complicated due to the abrasive characteristics of the grinding process. Since the material removal is performed by grains with an undefined cutting edge, the heat generation in the contact zone cannot be directly assessed. For this reason, many models have been developed to estimate both the energy and heat in the process during grinding. For the case of generating gear grinding, this modeling is further hindered by the complex kinematic characteristics of the process, which leads to different contact conditions at each instant of the process (Ref. 22). Reimann developed a thermomechanical energy description model for generating gear grinding, in which the specific grinding energy is calculated based on parameters such as the cutting force, cutting speed, contact time, and contact zone area in the process, which are determined both analytically and empirically (Ref. 19). The model has been parameterized utilizing an analogy trial replicating the effects of the contact between tool and workpiece at one specific point of the gear flank and validated by the inspection of the presence of grinding burn (Ref. 19). Although the model provides a good description of the heat flux at one specific point by this approach, its application in different test cases is challenging due to its reliance on empirical factors from temperature and force measurements during trials. Furthermore, Linke developed a model to describe the energy in conventional grinding based on the stages of chip formation—friction, plowing and shearing, with a single-grain engagement approach (Ref. 11). The implementation of consideration of contact length in the model makes it more comprehensive to different process kinematics. However, it is not directly applicable to generating gear grinding, as well as it does not consider the influence of different grain sizes or geometries, nor the influence of the simultaneous engagement of multiple grains. Although both models can estimate the heat and energy in the contact zone, they either do not fully consider factors that are also relevant to the process or are not directly applicable to generating gear grinding. Considering this, Löhrer combined the findings of both models into an approach that considers the influence of the grinding wheel topography on the energy distribution at the flank during generating gear grinding (Ref. 12).

In the model developed by Löhrer, the energy calculation is done through the generating gear grinding simulation with the software *GearGRIND* (Ref. 12). With user input of the tool topography, process parameters and workpiece properties, the software can apply the process kinematics to obtain the generated energy. This is achieved utilizing a penetration calculation in which the workpiece and tool movements are discretized in cutting planes, to later be positioned with each other. Due to the process-specific kinematics, the tool profile penetrates the workpiece, as the cutting planes of the tool body are projected into those of the workpiece. If there is an overlap, the common cutting surface is then determined and removed (Ref. 7). For the original simulation of the contact, neither the grinding worm nor the gear rotated, but rather the gear was fixed in space while the tool followed a trochoidal motion, representing a combination of the gear and the tool motion which occurs in the actual process. For the energy calculation developed by Löhrer, in addition to the original approach, the topography curves of the grinding worm are also projected into each tool profile (Ref. 12). Subsequently, the rotational motion of the worm is implemented by changing the position of each tool profile during the trochoidal motion, which allows it to accurately represent the contact between the grains and workpiece surface through the rotational motion of the tool. Based on this foundation, the microinteraction characteristics of contact length l_c, grain cross-section area A_{cu} and grain penetration depth h_{cu} are calculated, as illustrated in the left side of Figure 1. In the schematic, the engagement path of a grain is represented by a line passing through the macro contact geometry. Through the simulation, the contact characteristics are calculated along the entire engagement for all the grains in contact, in the entire gear grinding process (Ref. 12). Thereby, it is

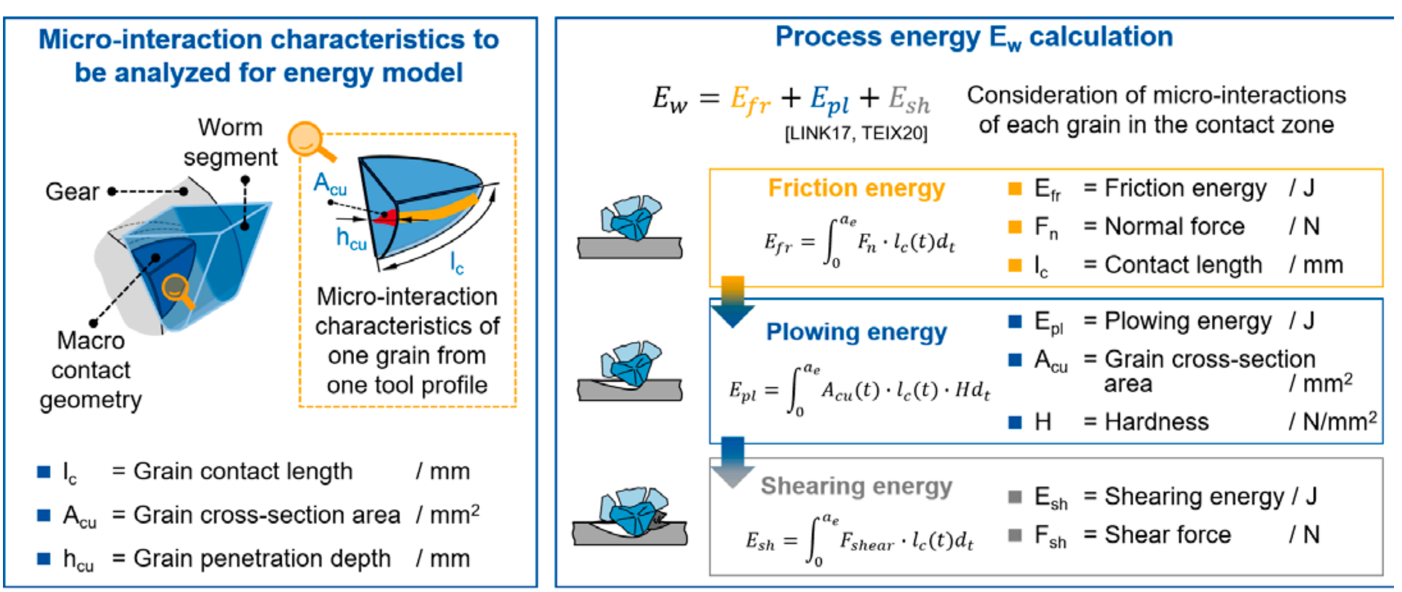


Figure 1—Approach for Process Energy calculation by Löhrer (Ref. 12).

possible to calculate the friction E_{fr}, plowing E_{pl} and shearing energy E_{sh}, and with that the process energy E_w, by using the equations described in the right side of Figure 1.

Signal Analysis in Grinding Processes

In grinding, material removal takes place through the engagement of grinding wheel grains with the workpiece, resulting in a contact zone significantly smaller than in defined cutting-edge processes like milling or turning (Ref. 2). Therefore, the assessment of process parameters using conventional measuring techniques is often not possible, due to the difficulty of accessing the actual contact area. These difficulties underlie the efforts which have been made to apply indirect monitoring methods to the grinding process through signal analysis, as a means of capturing and interpreting the dynamic behavior observed in the process. This chapter provides an overview of signal analysis, initially in the context of overall manufacturing processes, as well as specifically in grinding processes.

Within machining processes with a defined cutting edge, Tool Condition Monitoring (TCM) is a common application for signal analysis. For the process of gear hobbing, Hendricks investigated the suitability of using acceleration sensors for predicting component quality regarding tool wear (Ref. 6). The goal of the approach was to derive measures for increasing the process stability from the signal data. The evaluation of characteristic values extracted from the time and frequency spectrum of the signal allowed the recognition of patterns between acceleration signals and geometric quality deviations in the hobbed parts. For the process of milling, Drouillet also investigated tool life predictions by studying the spindle power signals of the process (Ref. 5). In this approach, the Root Mean Square (RMS) values of the signals in the time domain are evaluated by a neural network to predict the Remaining Useful Life (RUL) of the tool, presenting a strong correlation between the predicted and true values of the RUL.

In abrasive processes such as grinding, the stochastic characteristics of the contact between the grains of undefined geometry and the surface of the workpiece bring further complexity into such investigations. Pandiyan conducted a comprehensive review regarding monitoring of abrasive finishing process by using artificial intelligence. The review indicated that AE (Acoustic Emission) sensors are the most commonly employed for abrasive processes, due to their sensitivity in the high-frequency range, where most of the microcutting components are dominant (Ref. 17). Further analysis revealed that grinding burn, wheel conditioning and shatter vibration are common topics to be predicted when monitoring grinding processes (Ref. 17). Additionally, Mirifar developed an approach for prediction of forces and surface roughness in grinding, through the analysis of AE sensors integrated into the grinding tool (Ref. 16). In the approach, the signals were initially pre-processed, amplified and de-noised, and the peak values were used as input in feedforward neural network, which was able to predict the arithmetic mean roughness R_a and normal grinding forces F_N with an accuracy of 99 percent (Ref. 16).

To indirectly assess the process energy during generating grinding, the physical relationships between energy and power indicate the evaluation of power signals as a promising approach. On industrial grinding machines, the recording of time-domain power signals of the machine spindles is a commonly incorporated factory feature. Therefore, the evaluation of such signals also brings the advantage of not requiring the installation of external sensors such as accelerometers or AE sensors, with which the achievement of sensible results is dependent on the sensor positioning and distance to the workpiece (Ref. 17), hence, possibly leading to incorrect readings.

Objective and Approach

As described in the previous chapters, the understanding of the relationships between energy in the contact zone and spindle power signals in generating gear grinding shows potential for optimizing process parametrization. In that sense, the objective of this report is to develop a method for investigation of the correlations between process signal and calculated process energy in generating gear grinding, see Figure 2.

To achieve the proposed objective, the approach is divided into four phases. In phase 1, experimental trials are conducted for generating gear grinding of a pinion shaft, to gather the machine power signals. Those signals are then treated and analyzed in phase 2, where the main characteristic values which define the process are extracted, to be later compared with the process energy. This calculation will be performed based on the model of Löhrer (Ref.12) through the software *GearGRIND*. The model is described in phase 3. Finally, in phase 4, a method to investigate the correlations between the power signals and process energy gathered in the previous phases is developed.

Experimental Methodology

In the trials carried out for this study, generating gear grinding was applied to finish case-hardened pinion shafts made of 16MnCr(S)5, designed for use in transmission systems of electrical vehicles. The trials were performed as a part of the Incubator Technology Chain project, in which product, process and quality were acquired for the entire manufacturing chain of the pinion shafts. Before the generating gear grinding trials, the pinion shafts were prepared by a hobbing process with varying parameters. The variation of parameters during the gear preparation influences the initial geometry in the grinding process, and therefore, is presented in this chapter.

Experimental Setup

The grinding trials were performed on a Klingelnberg VIPER 500 KW grinding machine. The pinion shaft was centered and clamped between tips, as shown in Figure 3. During the process, the actual value of current in axes *B* (workpiece rotation), *C* (grinding worm rotation), *X*, *Y* and *Z* (grinding worm translation) was recorded. Because current and power are directly related if the voltage is constant, and the detectable power signal of the grinding spindle has a lower resolution than the current signal, the spindle current has been measured. The signals were recorded throughout the entire grinding process of each pinion shaft at a sampling rate of f_s = 60 Hz. As a tool, a ceramic bonded grinding worm manufactured by Krebs & Riedel was used, with characteristics shown at the bottom left of Figure 3. To prepare the grinding worm for the grinding process, its dressing was performed using a diamond disk dresser.

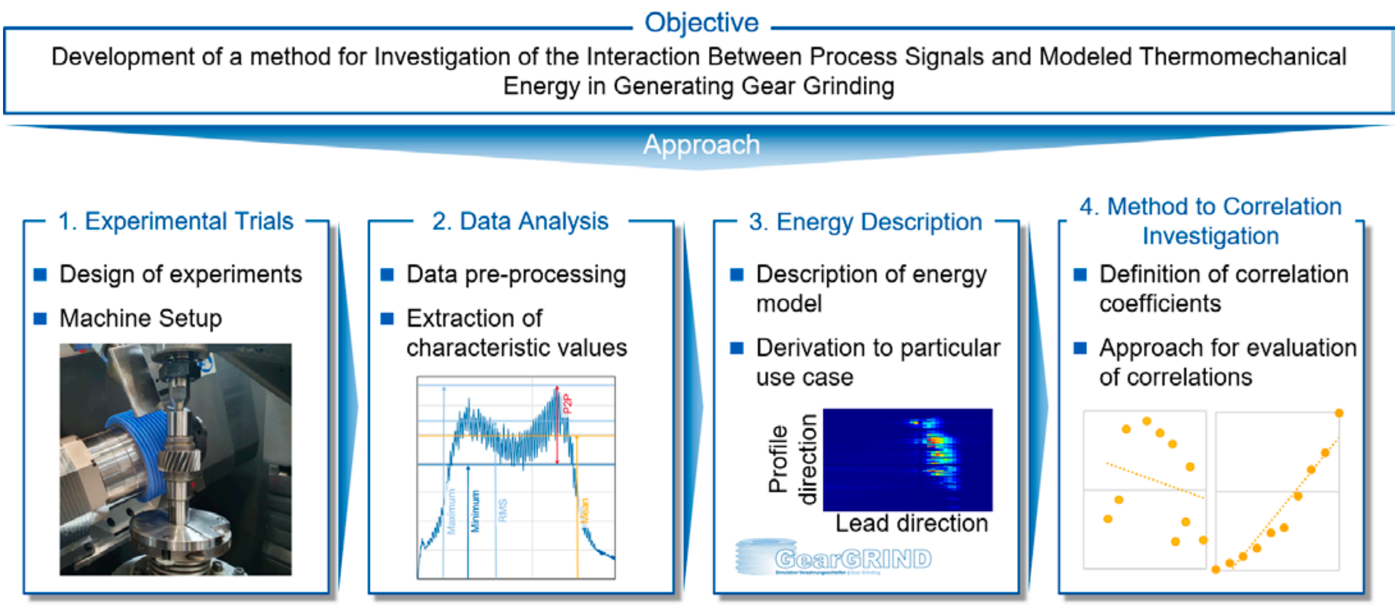


Figure 2—Objective and approach of the research.

Figure 3—Experimental setup.

Design of Experiments

The design of the experiments is shown in Figure 4. As previously mentioned, before grinding the gears are prepared by a gear hobbing process (shown on the left side of Figure 4). The energy calculation detailed in this research only takes the grinding process into account, however, the grinding stock in the first pass is defined by the parameters used during the gear preparation. Therefore, the variation of the parameters in this stage must also be considered. For both the gear preparation and the grinding, a reference and a productive parameter set were applied. For the gear preparation, the cutting speed v_c was kept constant between both variations, while the feed was varied between f_a = 1.5 / 2.0 mm, and f_a =3.0 / 4.0 mm.

During grinding, material removal was performed through a five-stroke strategy, which divided the total grinding stock into five cuts, aiming to reduce the risk of grinding burn in the final part. The first three strokes concern the roughing operation, while the finishing is performed in the next two, each with different parameters. Generally, the first stroke acts as an equalization pass, in which there may not be full contact between the tool and the workpiece, to level the surface. With the model considered in this research, the energy of each stroke is calculated separately, therefore, each stroke can be considered as a different input for the energy calculation. Across the grinding process, the cutting speed v_c, infeed ΔS and axial feed f_a were varied as shown in the center and left of Figure 4. While the cutting speed varies between the reference and productive variations, the infeed and axial feed are varied between the roughing and finishing steps.

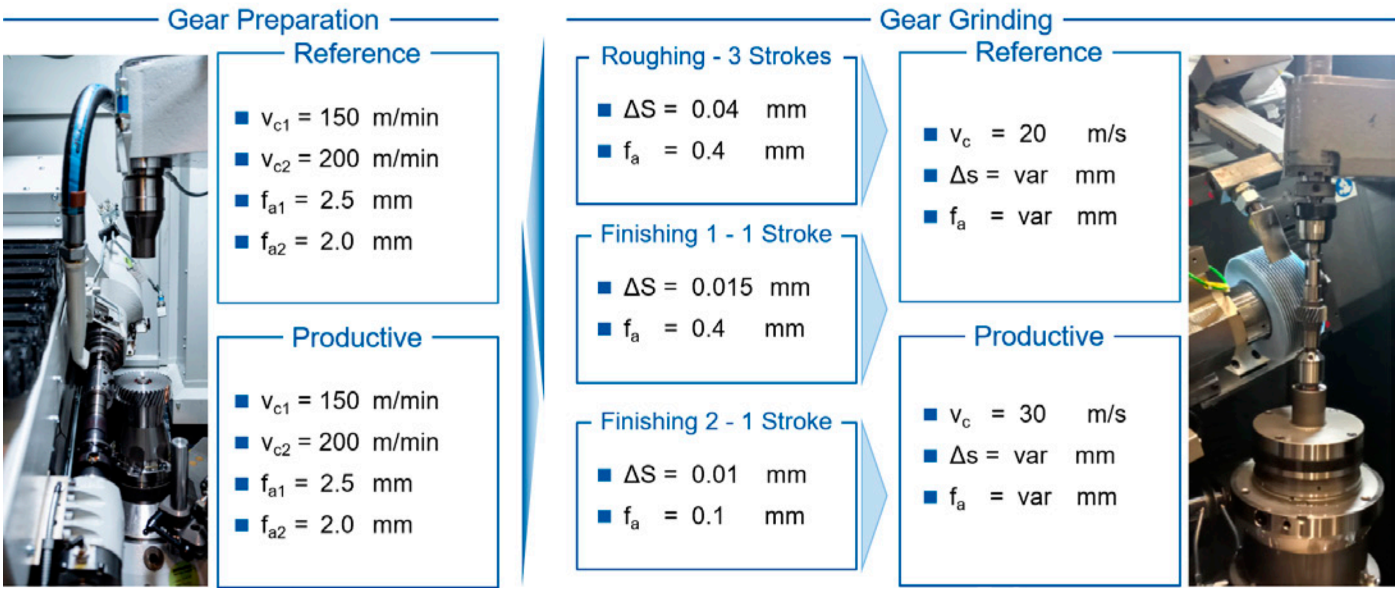


Figure 4—Design of experiments.

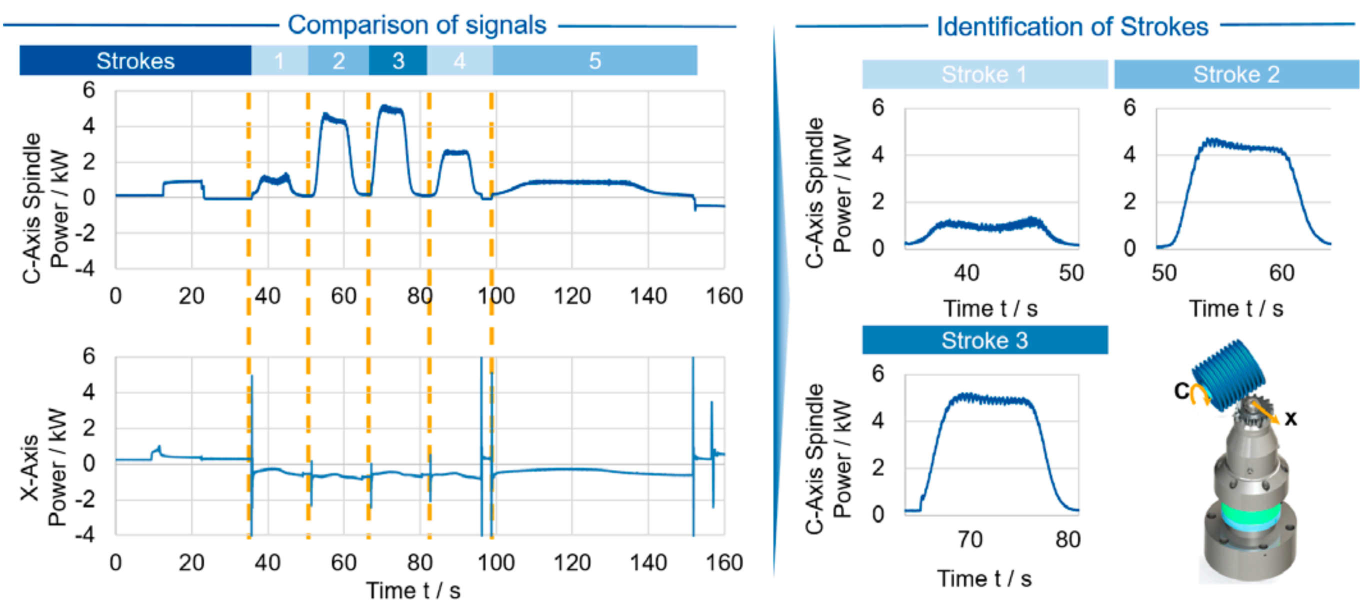


Figure 5—Identification of the stroke intervals in the tool spindle signals.

Treatment of Process Signals in Generating Gear Grinding

After the execution of the trials, the next step of the approach is evaluating the acquired signals, to extract from them characteristic values which can be compared to the process energy. For that evaluation to occur, the signals from the entire process must first be evaluated in terms of the process strategy, to understand which sections of the signals are relevant for the analysis.

The raw signals obtained from the trials contain valuable information about the process, however, evaluating them directly presents challenges. Initially, the large amount of data not only makes the evaluation complex but also poses limitations in terms of storage and processing. Additionally, the entire signal contains regions that are not representative of the process, when there is effective contact between the tool and workpiece. Therefore, to facilitate the recognition of patterns in the signal, it is first necessary to extract values that can be associated with the energy.

The actual values of current in the entire process were extracted from the machine control. The first step to evaluate these results in terms of energy is to convert the measured current into power, given its relationship to the voltage. The result of this conversion for all the C-axis (tool rotation) and X-axis (tool radial translation) is shown in Figure 5. On the left side of the figure, the signals for the X- and C-axis are compared. On the signal recorded from the X-axis, the presence of peaks at the points where contact starts on each stroke could be identified. Those peaks were then taken as a reference for the distinction of the beginning of each stroke, as shown by the vertical dashed lines. The end of the interval of each stroke, however, was taken as the moment when the value of the beginning of the stroke was reached again (not depicted in the diagram). As a result, each stroke was then distinguishable as shown to the right of Figure 5.

Typically, signal processing requires applying a filtering process to extract realistic values from the signals. However, the power signals during the trials were acquired at a frequency rate of f_s = 60 Hz, significantly lower than common frequency rates in data acquisition (typically 60 kHz to 1 MHz for AE sensors, for example). Therefore, a further reduction of the signal is not necessary.

With the signal pre-processed by identifying the regions containing different strokes, it was then possible to characterize the signal by extracting time-domain characteristic values. For this approach, Maximum (Max), Minimum (Min), Median (med), Mean, Peak to Peak (P2P), RMS, Kurtosis (Kurt), K4, Skewness (Skew), Variance (Var) and Krest factor (Krest) were calculated for future comparison to the calculated energy. In the center of Figure 6, a visual representation of a few of the characteristic values for the first stroke of eight repetition trials with the reference parameters of grinding is displayed. In this case, the stroke occurred in the time interval between 36 and 48 seconds from the beginning of the process. Through the plot to the right of Figure 6, it is possible to see the scatter between the calculated values, which indicates the reliability of the current measurements and suggests a viable source of data for further comparison with the generated energy during the process. Therefore, the extracted values can be used as input for the investigation of correlations with the generated energy during the process. Each of those values was then calculated for every stroke, and each of the parameter sets described in the section "Experimental Methodology" to later be used as an input in the approach developed in the section "Development of an Approach for Investigation of the Correlation Between Process Signal Data and Process Energy."

Description of Process Energy Calculation Model

With the power signals for the machine's main spindles evaluated and characterized in the previous section, the next step of the approach is the calculation of the process energy in each setup of the design of experiments. As mentioned in the previous chapters, this research is based on the model developed by Löhrer, which allows the calculation of the energy over each contact point between tool and workpiece, in one axial position of the gear gap. The model is developed utilizing a penetration calculation considering measurements of the tool topography. The application of the model is summarized on the left of Figure 7.

For applying the model for the process investigated in this approach, the first step is to characterize the grinding worm in terms of its tool topography. For this purpose, the topography of the grinding worm is measured using a laser scanning microscope Keyence VKX-1000, following the same approach detailed by Löhrer (Ref. 12). Hence, a fraction of the worm with a large enough size to provide a representative description of the topography—in terms of grain size and distribution—is scanned by the microscope. The resulting measurement is then evaluated using the software *MountainsMap*, to extract several two-dimensional curves, contained in a plane parallel to the tool surface. To extract curves that may be accurately incorporated into the tool profiles that represent the grinding worm in the simulation, each curve must be parallel to and equidistant from the others.

On the right side of Figure 7, it is possible to see the results which were achieved by Löhrer when applying the model to the generating gear grinding of a 20MnCr5 gear, with the properties and parameters displayed to the right of the figure (Ref. 13). With these parameters, the influence of cutting speed and axial feed on the process energy per area E_w' (shown in lightest color) was investigated. The results are also compared to those obtained with the empirical model of Reimann (Shown in the darkest color), and for this reason, this analysis is limited to one point on the gear pitch circle, as defined in the analogy trials developed by Reimann (Ref. 19). Within both results, it is possible to see a direct relationship

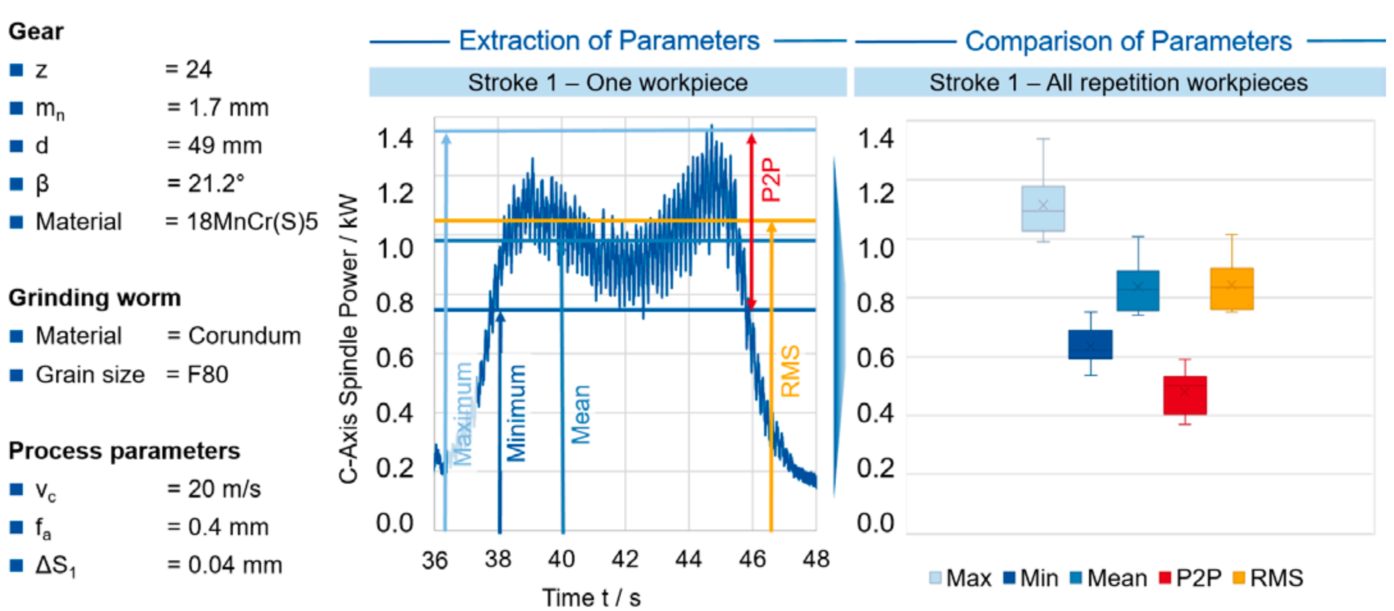


Figure 6—Approach for evaluation of power signals in the tool spindle axis.

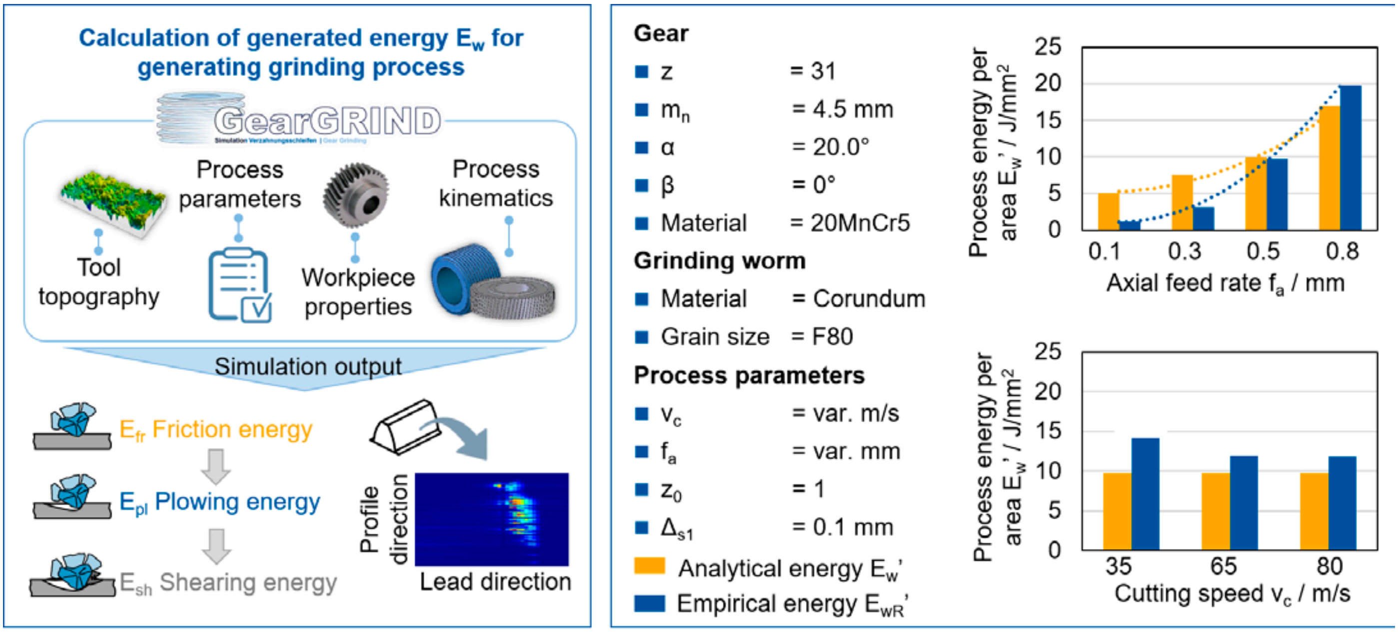


Figure 7—Application of the energy model developed by Löhrer (Ref. 13).

between axial feed f_a and energy, although no relevant effect can be seen by the variation of cutting speed v_c. According to Löhrer, this behavior likely comes from the fact that the v_c is not considered for the construction of the macromovements in the simulation with *GearGRIND*, and consequently, it is not considered for the calculation of the microinteraction characteristics (Ref. 12). Physically, this can also be explained by the fact that, although cutting forces increase with an increase of the cutting speed, and thus the process power consumption, the contact time also decreases, which may become too short to dissipate the power into the generated energy E_w (Ref. 13). Therefore, in a further analysis of the energy considering process signals, similar behavior can be expected, considering that the power is directly correlated to both the forces and the speeds in the process, through Equation 1 and Equation 2.

Besides the calculation of the generated energy, a particular characteristic of the model developed by Löhrer is the consideration of the different energy shares coming from the distinct chip formation mechanisms (friction, plowing and shearing energies) (Ref. 12). Given the different interactions between the grains and the workpiece during each stage of material removal, each of these shares may represent a different effect on the thermal and mechanical loads of the cutting process. According to Malkin and an analysis performed by Löhrer, nearly all the friction energy E_{fr} is conducted to the workpiece as heat, while the shearing energy E_{sh} presents the lowest conversion into heat to the workpiece of all three energy shares (Refs. 12, 14). Thus, if most of the generated energy E_w corresponds to E_{sh}, the majority of this energy will likely be applied to material removal, and not converted into heat to the workpiece. These interactions suggest the relevance of also considering each different share of generated energy (E_{fr}, E_{pl}, E_{sh}) as a different variable input in the approach for investigation of correlations between the calculated energies and characteristic values extracted from the power signals, as described in the following chapter. Therefore, through the model developed by Löhrer, the process energy in terms of the energy shares must be calculated for each stroke, and each set of process parameters described in the section "Experimental Methodology." The achieved results will be then considered as input for the approach developed in the next section.

Development of an Approach for Investigation of the Correlation Between Process Signal Data and Process Energy

Once the values of the generated energy in each of the grinding strokes are obtained, as well as the characteristic values of the power signals from the respective trials, the next step is the investigation of correlations between both results. As detailed in "Energy in Generating Gear Grinding," in generating gear grinding, there is no clear analytical relationship between power signals and energy in terms of process parameters. Therefore, the need for an alternative approach to recognize correlations between variables obtained from the acquired signals and calculated energy using statistical correlation techniques arises. The approach developed in this research seeks to study correlations based on the steps described in the previous chapters, as shown in Figure 8.

In the section "Treatment of Process Signals in Generating Gear Grinding," the extraction of characteristic values from the spindle power signals was described, as shown in the upper left of Figure 8. Each set of process parameters and each grinding stroke result in a vector of characteristic values that will be used in the comparison. In the section "Description of Process Energy Calculation Model," the energy calculation through the model developed by Löhrer (Ref. 12) was described, as well as each energy share which will be evaluated in the comparison, as shown in the bottom left of Figure 8. This chapter then details the development of the approach to compare how the variables extracted for each grinding stroke through the previous steps are correlated through all the trials described in the section "Experimental Methodology."

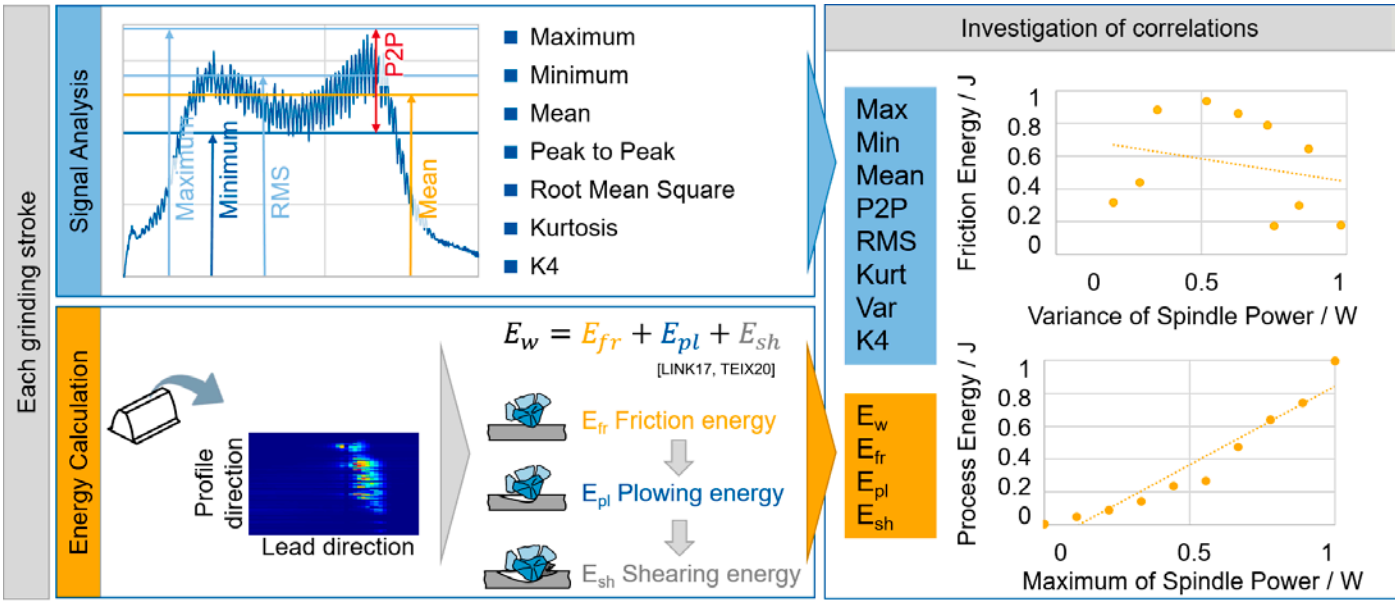


Figure 8—Approach for investigation of correlations between process energy and spindle power.

Considering the stochastic nature of tool and workpiece engagement in generating gear grinding, as well as the insufficient understanding of the influences of power signals in the process energy E_w, it is challenging to estimate the nature of the correlations that are expected to be found with this approach. Although linear correlations are easier to identify, nonlinear correlations may also be present in the data, as well as multivariate correlations resulting from the combination of different variables. Therefore, an approach to this investigation must meet the requirements of being able to recognize different kinds of relationships, be flexible regarding the assumptions that must be met by the data distribution and be prepared to consider the presence of outliers. Initially, this is achieved by considering a combination of different correlation coefficients in the analysis. The coefficients will be calculated for each combination of variables obtained by comparing the signal characteristic values and the calculated process energy shares. Since it is not relevant to investigate the correlation between the signal characteristic values among themselves, the coefficients will be calculated for each combination of one energy variable, and one power variable.

A common coefficient applied for correlation investigations is the Pearson correlation coefficient r (Equation 4) (Ref. 18), with which essentially the covariance between two variables, divided by the product of their standard deviations is calculated. By calculating this coefficient, a value ranging from r = -1 (perfect negative linear relationship) to r = +1 (perfect positive linear relationship) is obtained. For Pearson to be applicable, it is necessary that both variables are normally distributed, and the data is homoscedastic. Such requirements may not be met by all the variable combinations that are evaluated in this approach. As well as the fact that this coefficient is sensitive to the presence of outliers, means that the evaluation of other coefficients is also necessary.

$$r = \frac{\sum i(x_i - \overline{x})(y_i - \overline{y})}{\sqrt{\sum i(x_i - \overline{x})^2}\sqrt{\sum i(y_i - \overline{y})^2}} \tag{4}$$

When compared to Pearson, a second coefficient which is less sensitive to the presence of outliers, besides not requiring the normal distribution of the data due to its non-parametric nature, is the Spearman's Rank Correlation Coefficient r_s (Equation 5) (Ref. 18). Through the calculation of this coefficient, it is possible to measure the strength and direction of a monotonic relationship between two variables (whether linear or not), through a value between r_s = -1 (perfect negative linear relationship) and r_s = +1 (perfect positive linear relationship). The calculation is done utilizing ranking the data points for each variable and subsequently calculating Pearson's correlation coefficient on these ranks.

$$dCor^2(X,Y) = \frac{dCov^2(X,Y)}{\sqrt{dVar^2(X) \cdot dVar^2(Y)}} \tag{5}$$

Although both r_s and r provide a useful overview on linear and monotonic relationships, for a most robust approach, the calculation of the Distance Correlation $dCor$ (Equation 6) is also considered, as it applicable for complex data where the relationship may not be apparent. The calculation of $dCor$ allows for the detection of both linear and non-linear relationships between two or more variables, without any assumptions about the distribution or dimension of the data, by providing a value between $dCor$ = 0 (independence) and $dCor$ = 1 (perfect dependence). This coefficient is obtained by calculating standardized distances between points in the data, and thereby determining the statistical independence of these distances.

$$dCor^2(X,Y) = \frac{dCov^2(X,Y)}{\sqrt{dVar^2(X) \cdot dVar^2(Y)}}$$

(6)

Finally, to achieve an approach that is not only based on coefficients from which it is possible to understand the strength and direction of a relationship, the Mutual Information M_i (Equation 7) is also included in the analysis (Ref. 4). The calculation of this metric allows for the quantification of the amount of information gained about one variable by observing another, by effectively measuring the degree of mutual dependence between them. The calculation of Mutual Information involves the estimation of the probability distributions of each variable, and their joint distribution, therefore, it doesn't require any assumptions about the data distribution.

$$M_i = \sum p(x,y)\log\left(\frac{p(x,y)}{p(x)p(y)}\right)$$

(7)

By calculating the correlation coefficients, an evaluation of the relationships between the characteristic values from measured power signals and calculated energy can be made. However, for this evaluation to yield meaningful results, it is initially necessary to ensure that the correct assumptions about the data for the calculated coefficients are fulfilled. Secondly, it is necessary to evaluate whether the results obtained from the calculations are relevant to the overall analysis. To achieve that, the approach shown on the left of Figure 9 is developed.

In step number 1 of the procedure, a preliminary exploration of the variables is performed, to guarantee that the assumptions made for the calculation of each correlation coefficient are valid. In this step, the linearity, normality and homoscedasticity of the variables will be evaluated to validate the application of each coefficient. With that investigation, it is possible to understand which correlation coefficients can be calculated in step 2 for each relationship between variables. The coefficients will be calculated for each variable combination, yielding a different strength of correlation for each. To evaluate the relevance of the correlations between each variable combination, in step 3, the results will be visually inspected, as exemplified on the center and right sides of Figure 8. Through the heat map shown in the center, it is possible to compare the strength of correlations between each combination, thus allowing us to quickly assess which combinations are strongly (darkest color) or weakly (white) correlated. In this evaluation, the combinations between the total generated energy E_w—as well as the energy shares E_{fr}, E_{pl}, and E_{sh}—and the characteristic values extracted from the power signals, will be observed. Subsequently, through the selection of the most strongly correlated variable combinations, a visualization of the scatter plots of each combination allows for the identification of which kind of relationship (positive or negative, strong or weak, linear or nonlinear) is found between them, if any. Thereby, the application of this method is expected to reveal underlying patterns between power signals and process energy in generating gear grinding, and with that, bring a foundation for identifying the energy generation through real-time measurements of spindle power signals.

Summary and Outlook

The energy generation in generating gear grinding is a critical mechanism in terms of the surface integrity of the parts. The assessment of generated energy in the process remains challenging due to the intricate characteristics of the process kinematics and grain engagement. To provide an improved understanding of the energy generated during generating gear grinding, Löhrer developed a model that allows for the calculation of process energy E_w with consideration of the microinteraction characteristics of the grain engagement. The model can describe the energy generation along the entire grinding process (Ref. 12); however, it doesn't provide the means for direct on-time assessment of the conditions within the contact zone. This research takes advantage of the power signal measurements obtained from a grinding machine during the process, to derive an approach for understanding the energy generation in the process utilizing a real-time assessment based on power signals.

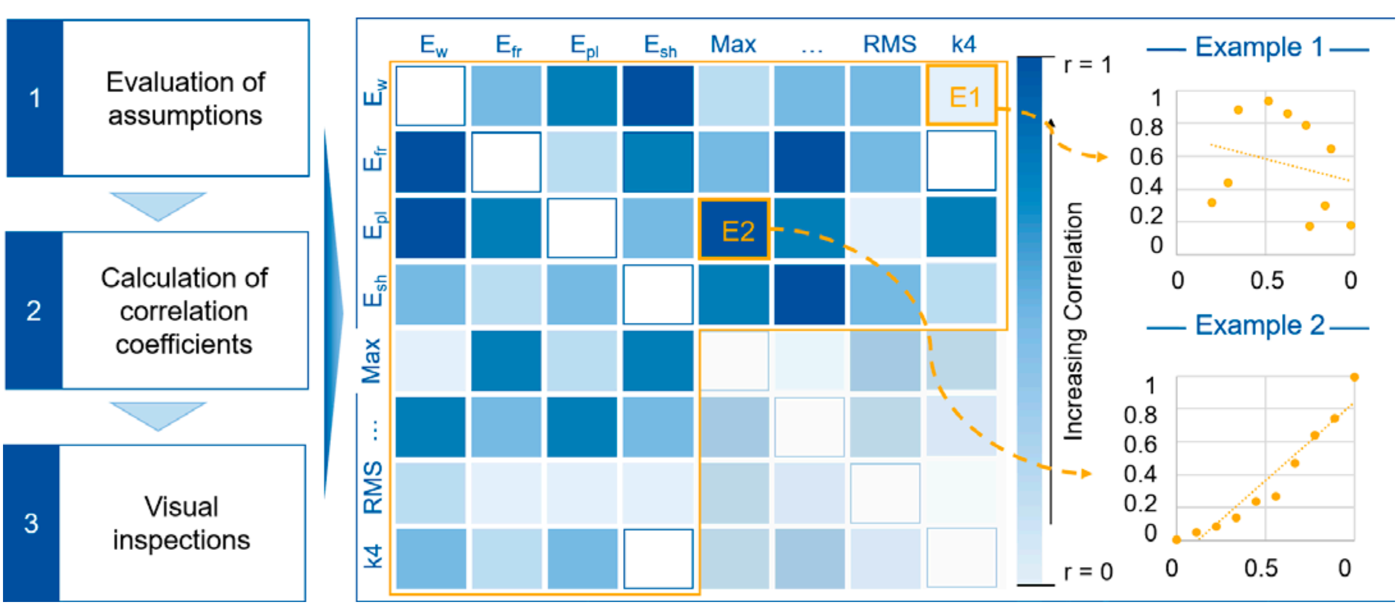


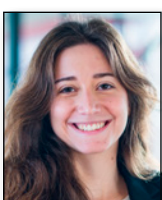
Figure 9—Approach for investigation of correlations between process energy and spindle power.

The objective of this work was to develop an approach to investigate the interactions between process signals and calculated process energy in generating gear grinding. To achieve this objective, the approach was based initially on the execution of experimental trials of generating gear grinding, to acquire the signals of machine spindle power during the process. The acquired signals were then analyzed considering the process strategy, and the relevant characteristic values were extracted from it, to allow a direct comparison with the calculated energy. Furthermore, the energy model developed by Löhrer was described through the simulation in the software *GearGRIND*. Thus, the process energy E_w as well as the energy shares of friction energy E_{fr}, plowing energy E_{pl} and shearing energy E_{sh} were considered in the approach. With the analysis of power signals and description of the process energy, it was then possible to develop an approach for the investigation of correlations between the two by applying statistical correlation coefficients.

The next step of the research is the application of the energy model developed by Löhrer to the process conditions in which the signals were extracted. Then, through the developed correlation approach, it will be possible to understand the effects of the calculated energy on the real-time power signals, and subsequently establish a connection between them. That understanding will allow the development of real-time process monitoring techniques, to assess the energy generation in generating gear grinding. With that, it will be possible to predict the occurrence of thermal damage without the need for iterative steps during the process parametrization.

Acknowledgment

The authors gratefully acknowledge financial support by the German Research Foundation (DFG) for the achievement of the project results within the project: DFG EXC2023/1—B1.II.



Mrs. Mariana Mendes Wilfinger
concluded her studies in Mechanical Engineering at the University Senai Cimatec in 2023. Since then, she has been a research assistant in the Department of Gear Technology of the Laboratory for Machine Tools (WZL/MTI) working in the gear manufacturing group, focused on hard finishing processes, in particular generating gear grinding.

Dr.-Ing. Mareike Davidovic studied mechanical engineering with a focus on production technology at RWTH Aachen University. After leading the Gear Hard Machining Research Group since early 2019, she became Chief Engineer for Gear Manufacturing at WZL/MTI in November 2021. In 2022, she completed her Ph.D. on the topic of bevel gear grinding.

Prof. Dr.-Ing. Thomas Bergs is a Member of the Board of Directors of the Fraunhofer Institute for Production Technology IPT where he leads the Process Technology Division and is the Institute head of Manufacturing Technology Institute MTI at the RWTH Aachen University. His ongoing research activities are in networked adaptive production.

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Klingelnberg

WELCOMES 22 YOUNG APPRENTICES

Starting a career is something special for every young person. In August 2024, Klingelnberg once again welcomed 22 young apprentices who started their training in various professions. During the orientation week in early August 2024, the trainees had the opportunity to demonstrate their teamwork skills in the climbing park in Hückeswagen, Germany, attend a first aid course, and learn about the company's values.

"We are very much looking forward to working with the new group of trainees," said Michael Schwarzer, human resources manager at Klingelnberg. "As a globally active engineering company that also provides apprenticeship opportunities, we are happy to invest in the careers of future skilled workers and thus in our own future viability. The reasons why up-and-coming professionals chose to train at Klingelnberg are often similar. Many trainees had already completed a school internship with us beforehand and gotten to know the company."

Robin Müller, a future electronics technician for industrial engineering, explained: "My interest in Klingelnberg was sparked by Mr. Schwarzer after the company supported our school by providing physics experiment sets. The three-week internship here then completely convinced me to apply."

Lukas Bonk, an apprentice industrial mechanic, chose to train at the mechanical engineering company because of its good reputation. He noted: "My goal is to continue learning and developing my professional skills after my apprenticeship."

Leon Ruben Niedermeier was also attracted by the company's reputation: "I heard so much about the company that I applied to become a warehouse logistics specialist. I am convinced that I will not only learn, but also have a lot of fun at work."

Leon Kool, a future cutting machine operator, hopes to be hired after his training and appreciates the opportunities for further training at Klingelnberg. "The excellent training opportunities were one of the reasons I chose the company," he explained. "After my apprenticeship, I plan to complete my vocational baccalaureate and possibly take the master craftsman's exam."

Maximilian Mengel opted for the dual apprenticeship as an industrial clerk because he had the opportunity to complete his vocational baccalaureate at the same time as his apprenticeship. "After I finish my apprenticeship, I can also imagine studying for a professional degree," he reflected.

klingelnberg.com

Liebherr Gear Technology

OPENS NEW LOCATION IN MEXICO

Liebherr Gear Technology has opened a new location in Querétaro, Mexico. This expansion will allow Liebherr to further improve the service and be closer to customers in this region.

(Left to right) Miguel Cisneros, General Manager Mexico, Felix Scholz, Managing Director, Walter Friedrich, Representative/Consultant.

The subsidiary in Querétaro, Mexico, specializes in the service and sales of gear-cutting machines, gear-cutting tools, measuring technology, and automation systems. This location plays a central role in supporting Mexican customers and offers comprehensive services.

The company's new location in Mexico brings numerous advantages. With improved availability, Liebherr can respond to customer needs more quickly and effectively. Local teams are well-acquainted with the demands of the Mexican market and are available to support customers with their expertise and experience. Additionally, Liebherr is expanding its product range by not only bringing proven products and services but also by developing special offerings tailored specifically to the needs of customers in Mexico.

liebherr.com

CONEXPO-CON/AGG

RELEASES WORKFORCE DEVELOPMENT E-BOOK

CONEXPO-CON/AGG is excited to announce the release of its latest e-book, "4 Steps to Hiring and Retaining the Best Workers", designed to help construction business owners attract and retain the best skilled talent. This free comprehensive guide offers strategies and tips proven to help companies find, hire, and develop the right employees, ultimately enhancing productivity and maintaining high-quality standards.

"We understand the critical importance of skilled and reliable workers in the construction industry," said CONEXPO-CON/AGG show director Dana Wuesthoff. "Our new e-book provides valuable insights and practical advice to help construction business owners overcome staffing challenges and build a strong, dedicated workforce to move their businesses forward."

The e-book covers:

- Proven recruitment strategies to attract top talent
- Effective retention techniques to keep employees engaged and satisfied
- Common hiring mistakes and how to avoid them
- Development plans to enhance team skills and boost productivity
- Tips for how to reduce turnover rates

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Ceratizit

PROMOTES WILT TO MANAGING DIRECTOR U.S. CUTTING TOOLS

Ceratizit Group's board of directors announced the promotion of Troy Wilt from national sales manager to managing director of Ceratizit USA, Cutting Tools Division.

"Since joining our team, Troy has played a pivotal role in Ceratizit's continued growth in the U.S. market," says Dan Cope, president of the Americas for Ceratizit. "His strategic vision and deep industry knowledge have been instrumental in fostering strong relationships with customers and peers which is the kind of leadership that will build on our current success."

A graduate of Miami University in Ohio, Wilt began his career in 1989 at a cutting tools distributor, where he spent nine years developing a deep understanding of the industry. In 1998, Wilt moved into a sales position with a major cutting tool manufacturer and served customers in West Central Ohio. His exceptional sales acumen and commitment to customer service led to significant growth in his region, resulting in the territory being split three times within five years to better manage increased demand.

Driven to lead, Wilt moved into sales management, where he continued to excel and drive growth. In 2015, he took on the responsibility of managing a global aerospace original equipment manufacturer (OEM), gaining valuable international experience and expanding his expertise in the cutting tool market. Wilt joined Ceratizit in 2021.

Wilt puts his more than 30 years of experience to work as managing director for Ceratizit USA effective immediately.

"I am committed to leading the organization towards continued growth and innovation," says Wilt. "I am passionate about fostering a culture of excellence and collaboration and dedicated to delivering cutting-edge solutions that meet the evolving needs of Ceratizit's cutting tool customers."

cuttingtools.ceratizit.com/us/en.html

Rego–Fix

ANNOUNCES PARTNERSHIP WITH OMEGA TMM FOR INNOVATIVE PRESETTING SOLUTION

Rego–Fix has partnered with tool measuring and management solution company Omega TMM for the creation of Orion powered by Rego–Fix – a tool measuring machine using Rego–Fix's powRgrip toolholding system with Omega TMM's presetting technology.

Orion powered by Rego–Fix was created based on customer requirements that demanded reliable, innovative and precise tooling to ensure the best and most satisfying experience possible with an easy-to-use and robust tooling system.

The Rego–Fix powRgrip toolholding system creates simple, heatless toolsetting in under 10 seconds using a hydraulic press to insert special shallow-tapered collets into holders with a matching taper. Its superior clamping force, vibration damping and precision with toolholder-to-collet and collet-to-tool shank interfaces provide extreme accuracy and high-quality tooling from high-speed milling and drilling to coolant-free cutting.

Rego–Fix is a Swiss manufacturer of premium toolholding systems from toolholders and clamping collets to clamping nuts and accessories. Inventor of the original ER collet, Rego–Fix helps manufacturers achieve toolholding excellence in fast-paced industries including aerospace, automotive, computers, communications, consumer electronics, heavy duty equipment and medical devices. From its U.S. headquarters in Whitestown, Indiana, the company provides sales and support to customers across North America.

Omega TMM is the only U.S. manufacturer of tool presetters in the world and exports tool measuring machines and solutions to countries across the globe from their U.S. headquarters in Fairport, New York. In addition, the company's wholly owned foreign enterprise is located in Nanjing, China, which offers sales and service support for the Asian marketplace.

"We are excited to partner with Omega TMM in creating a unique and easy-to-use presetter that utilizes the innovative powRgrip toolholding system," said Bill Obras, general manager Americas at Rego–Fix. "Our powRgrip delivers fast, high-quality precision with adjustable tooling that goes hand-in-hand with Omega TMM's cutting-edge presetting technology."

regousa.com

OCTOBER 30–31

Advanced Engineering 2024

Advanced Engineering (Birmingham, U.K.) has rebranded to celebrate the evolution and new developments in industrial manufacturing. Sectors include aerospace, automotive, defense, composites, marine, rail, energy, medical and more. To ensure that visitors and exhibitors can still easily find relevant contacts, Advanced Engineering exhibitors will now be categorized by the services, products and solutions offered. They will have the opportunity to highlight all of the sectors they work in, removing any limitations created by the specific show zones. Advanced Engineering will welcome back a full speaker program with representatives from some of the leading companies in U.K. manufacturing including GE, Shell, ZF, Bosch, Siemens, 3M, IBM, Airbus and more.

geartechnology.com/events/5081-advanced-engineering-2024

NOVEMBER 6–7

Aachen Conference on Gear Production 2024

Although gears have been indispensable components in various areas such as mechanical engineering, the automotive industry and industrial gear production for many decades, increasing requirements and current market developments are constantly presenting the drive technology sectors with new challenges. The aim of the Aachen Conference on Gear Production is an exchange of knowledge and experience between engineers who work in or are responsible for the design, development, production, assembly and application of gears.

geartechnology.com/events/5101-aachen-conference-on-gear-production

NOVEMBER 12–14

Smart Production Solutions (SPS) 2024

With its unique concept, Smart Production Solutions (SPS) covers the entire spectrum of smart and digital automation – from simple sensors to intelligent solutions, from what is feasible today to the vision of a fully digitalized industrial world. SPS, located in Nuremberg, Germany, is an innovative platform for the automation industry with topics on control technology, electric drive systems, HMIs, software, sensors and mechanical infrastructure. Whether keynote, expert lectures or panel discussions, SPS 2024 brings together high-profile speakers across a wide variety of channels, providing additional exchange opportunities beyond physical boundaries.

geartechnology.com/events/5106-smart-production-solutions-sps-2024

NOVEMBER 19–22

Formnext 2024

Formnext (Frankfurt, Germany) is an entire platform for companies from the world of additive manufacturing. Here, a veritable who's who from the realms of design and product development, industrial tooling, production solutions, quality management, and measurement technology comes together with leading providers in basic materials and component construction. It will also explore clever ways in which AM can be integrated into process chains in industrial production. In addition, top international speakers and other experts will be on hand to engage conference attendees in in-depth discussions at the highest technical level.

geartechnology.com/events/5104-formnext-2024

DECEMBER 3–4

CTI Symposium Berlin 2024

CTI Symposium Berlin offers keynote speeches, panel discussions and technical presentations on future powertrain technologies. This includes the exchange of experiences, R&D results and opinions with leading representatives of automobile manufacturers, suppliers, engineering consultants as well as officials. Topics include passenger cars, commercial vehicles, electric motors, transmission components, AI in powertrain development, thermal management, supply chain, powder metallurgy and more. While net zero emissions can be achieved with different drive systems and primary energy carriers, all solutions have one thing in common: CO_2-neutral mobility based on renewable energy sources.

geartechnology.com/events/5105-cti-symposium-berlin-2024

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A Scoot Through IMTS 2024 with a Gear-Industry Veteran

Dan Carleton, Gear Gear, Inc.

I limped up to the counter at the Scootaround rental site at McCormick Place and rented one to get around the show with speed and agility without challenging my knee problems or causing any foot pain. I highly recommend this tool for the ability to get around the show to anyone, handicapped or not.

Dan Carleton with senior editor Aaron Fagan.

I have been to many IMTS and EMO shows over my fifty years in the industry; yet the 2024 show proved to be a thrilling and confusing event that left me tired and looking forward to a future that will surpass even my meager manufacturing dreams. At the first manufacturing technology show I attended (even before McCormick Place was built), I was in my early twenties and gobsmacked by the huge milling machines with tool changers that were operated by tape drives—no CNC for the old school. Well, the 2024 show proved to be deep in the new school.

There was an exciting emphasis on showing students and youth in general how the manufacturing technology of the future is evolving. This evolution was evident in the Student Summit section on the lower level of the East Building, where NASA, community colleges, the American Precision Museum, and a few forward-thinking large manufacturers had booths to attract students and other future engineers, service technicians, managers and machinists to the new schools of manufacturing thought.

But future thinking wasn't limited to the Student Summit section of McCormick Place. Upstairs in the East Building were large displays of revolutionary inspection tools, like laser scanning of gear blanks and a race car, plastic fillers to make precision positive models of keyways and splined bores, and simplified Coordinate Measuring Devices that cost less than similar ones did even five years ago.

I cruised over the long bridge from the East to the North Building which featured gear making and gear inspection. I stopped to renew old friendships with pals from Gleason, Liebherr and DVS Technologies as well as from Galdabini and Balance Systems. There were many suppliers from consolidated groups such as Taiwan and India and even a company from Native America.

Across the hall in the South Building, I found even more HUGE exhibits, and still managed to run into old friends from various parts of the industry. From Nidec to Fanuc to Fives to Mazak my scooter powered me through large machining, grinding and controls exhibits. Around the corner from Fanuc, I came upon the entrance to the West Building via a bridge over the main entrance to the show.

The West Building was wild. Besides the tooling, cutters and workholding, the positive deposition of materials from carbon fiber to titanium was a fascinating look into the future. The complexity of the demonstration pieces was indeed amazing. The ability to directly deposit an amazing array of materials in even tiny spaces with thin tubes, tiny passages and blind canyons will free the designers of the future to create the cities, machines, and space travel vehicles to take us flying into a world that we can only imagine from 2024.

Rest assured I have never felt the same way when leaving either IMTS or EMO in the past: as an exhibitor, I always left exhausted from delivering the endless sales pitches; and as a visitor, I was always irritated by my sore feet and inability to see every part of the shows. But after my time at IMTS 2024 was over, and I packed up and headed home to Michigan, I only felt regret that I couldn't go another round with the show the next day!

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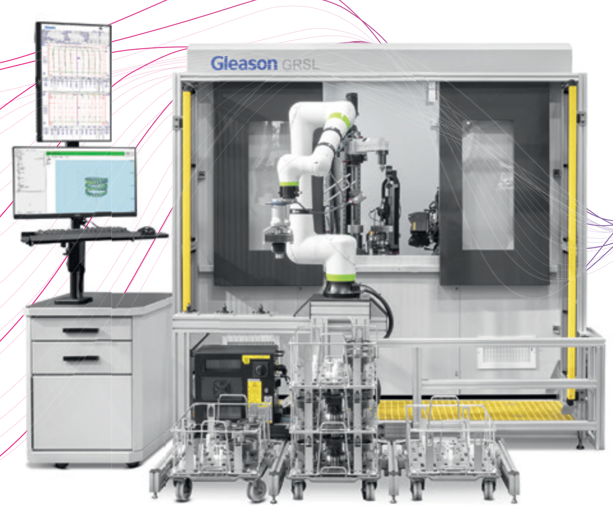

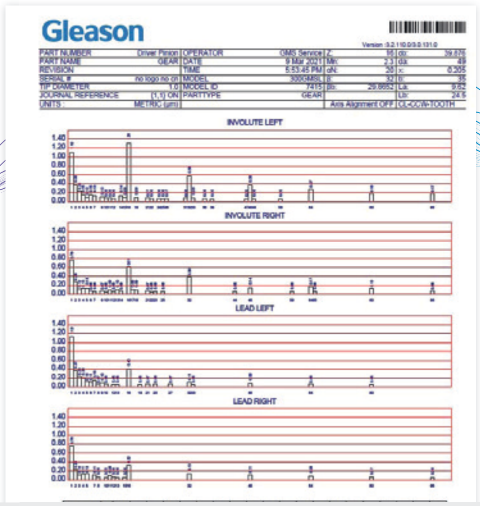

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