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SEPTEMBER/OCTOBER 2023

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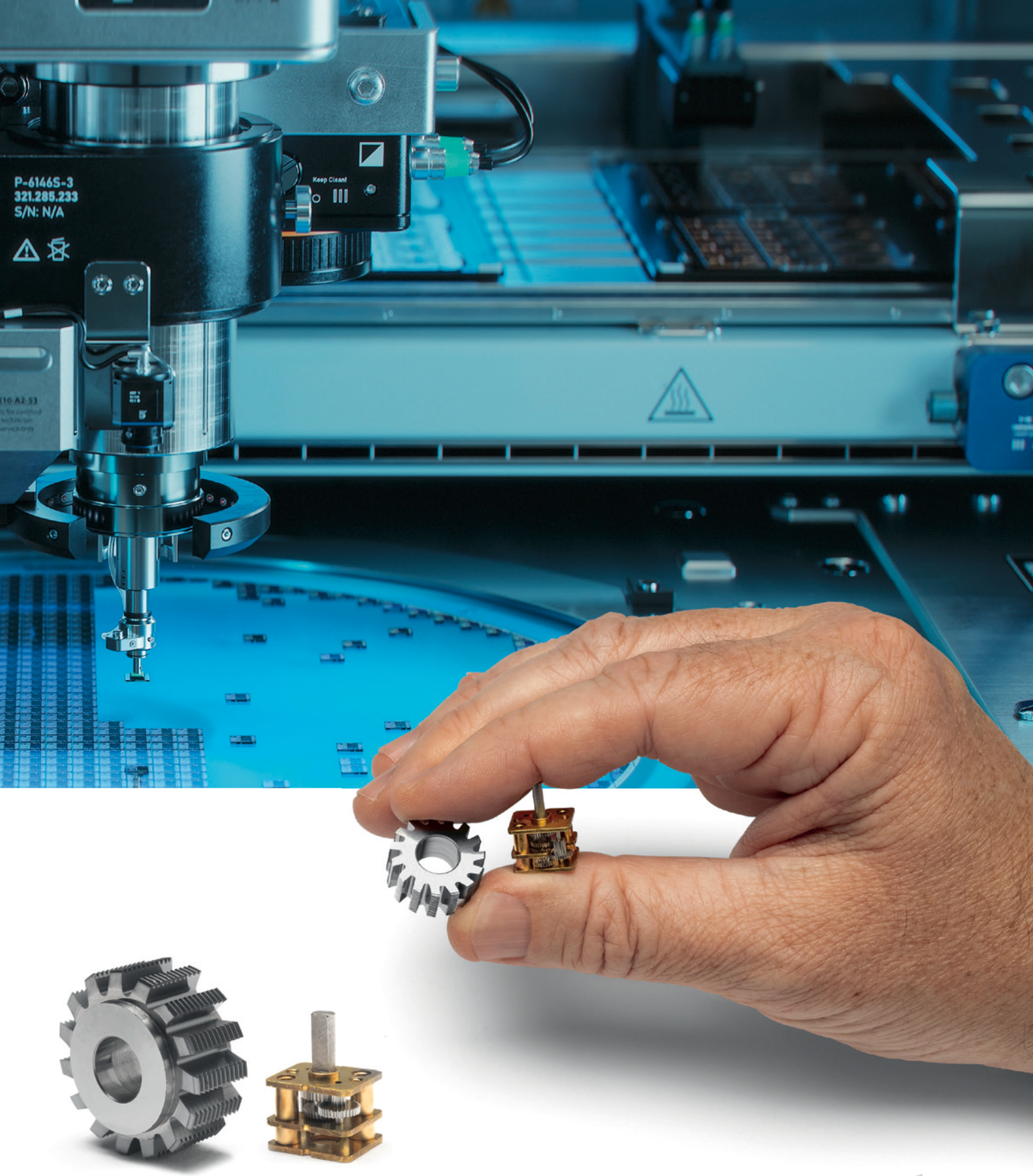

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Vol. 40. No. 7

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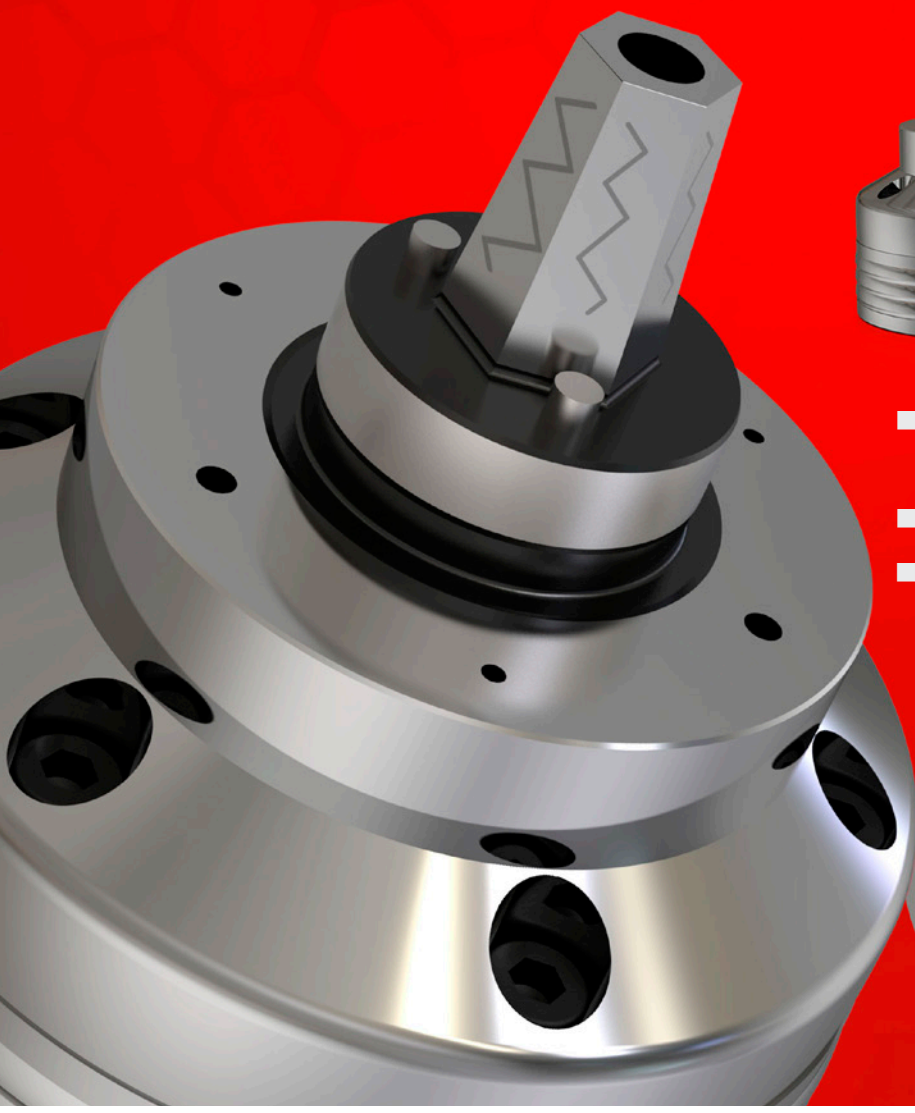

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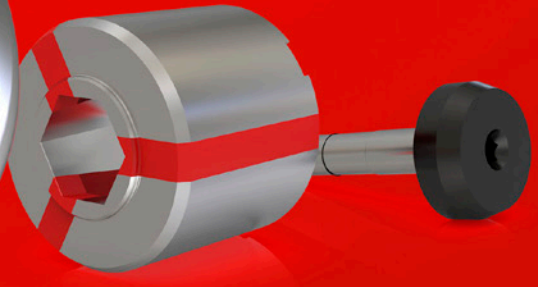

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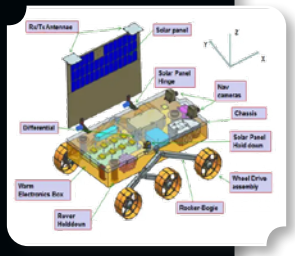
GT Revolutions

Bevel Gears India's Role in the Chandrayaan-3 Moon Landing Mission

On August 23, 2023 at 12:32 UTC, India's Chandrayaan-3 mission made a successful landing on the southern part of the moon near the crater Manzinus. After carrying out all of the Indian Space Research Organization (ISRO)–planned investigations and explorations on the lunar surface and before the start of the two-week lunar night, the Pragyan rover was put into sleep mode on September 2nd, 2023, and the Vikram lander on September 4th. We were able to catch up with Mushtaq Jamal, vice president of engineering and business development at Bevel Gears India Pvt Ltd (BGI), to discuss BGI's role in this monumental achievement for India. [Special thanks are due to Divya Sudarsanan, Content Editor for Gear Technology India, for helping facilitate this interview.]

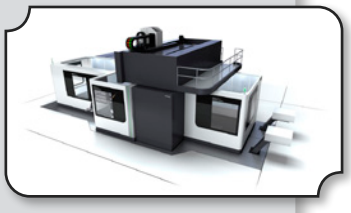


geartechnology.com/blogs/4-revolutions/post/30470-bevel-gears-indias-role-in-the-chandrayaan-3-moon-landing-mission

GT Videos

Inside the DMG Mori Portal Series

Automobile manufacturers can develop ever more sophisticated car body molds because they can rely on 5-axis portal machines as the backbone of automotive tool and die making. The aerospace industry achieves unprecedented part quality thanks to full technology integration of milling, turning and grinding, ensuring maximum passenger safety. Thanks to 5-axis technology in large format, portal machines ensure that hydroelectric power can be converted into energy. Mechanical engineering also benefits worldwide from portal machines from Pfronten, which repeatedly demonstrate their performance in demanding machining operations such as gear production. DMG Mori has more than 1,400 Portal machines installed worldwide.



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Michael Goldstein founded *Gear Technology* in 1984 and served as Publisher and Editor-in-Chief from 1984 through 2019. Thanks to his efforts, the Michael Goldstein *Gear Technology* Library, the largest collection of gear knowledge available anywhere, will remain a free and open resource for the gear industry. More than 38 years' worth of technical articles can be found online at *geartechnology.com*. Michael continues working with the magazine in a consulting role and can be reached via e-mail at *michael@geartechnology.com*.

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Publisher & Editor-in-Chief
Randy Stott

Since our founding in 1984, *Gear Technology*'s goal has been to improve your knowledge, bringing you the best possible technical information about gear design, manufacturing, inspection, heat treating and much more. We keep you informed about the business of gear manufacturing, including the trends and technologies that will shape your companies in the coming years.

Traditionally, we've done so through the articles in these pages. Not only do we provide the best technical articles from around the world, but we also provide the insight of an editorial team that's spent decades in our industry. Today, you can browse more than 39 years of those articles online at geartechnology.com (in the Michael Goldstein *Gear Technology* Library).

Since 2015 we've also brought that knowledge to you in person, via our "Ask the Expert Live" presentations, the next edition of which will take place at our booth (#3136) at AGMA's Motion+Power Technology Expo (October 17–19 in Detroit).

This year, rather than focusing on gear basics or the more technical aspects of gear design and manufacturing, we've decided to address some of the issues that you've told us are most significant to you—the things you're struggling with, the questions you're hoping to find answers for, and the troubles that keep you up at night.

Here's what we have on schedule this year:

The Future of Gear Manufacturing, Tuesday, October 17, 10:30 a.m, featuring:

- Joel D. Neidig, Director of R&D, ITAMCO
- John Perrotti, Chairman and CEO, Gleason Corporation
- Prof. Dr.-Ing. Karsten Stahl, head of the Institute for Machine Elements and Director of the Gear Research Center (FZG) at the Technical University of Munich
- Carlos Wink, Chief Engineer, Eaton Mobility Group

Manufacturing of Gears for Electric Vehicles, Tuesday, October 17, 2:30 p.m., sponsored by Reishauer, featuring:

- Pascal Diggelmann, Head of Application Technology, Reishauer
- Dr. Hermann J. Stadtfeld, Vice President Bevel Gear Technology, Gleason
- Dr. Oliver Winkel, Head of Application Technology, Liebherr

Automation for Job Shops, Wednesday, October 18, 10:30 a.m, sponsored by Schafer Industries, featuring:

- Rob Cherba, Automation Sales Manager, Liebherr Automation
- Geoff Dawson, Director of Michigan Regional Sales, FANUC America
- Ryan Finfrock, Engineering Manager, Schafer Industries
- Gerd Walter, COO, Creative Automation

Solving the Skilled Workforce Challenge, Wednesday, October 18, 2:30 p.m., sponsored by Forest City Gear, featuring:

- Kika Young, President, Forest City Gear
- Mary Ellen Doran, Executive Director, AGMA Foundation
- Kris Ward, Sr. Director, Strategy & Business Development, SME
- Megan Schrauben, Executive Director, MiSTEM Network

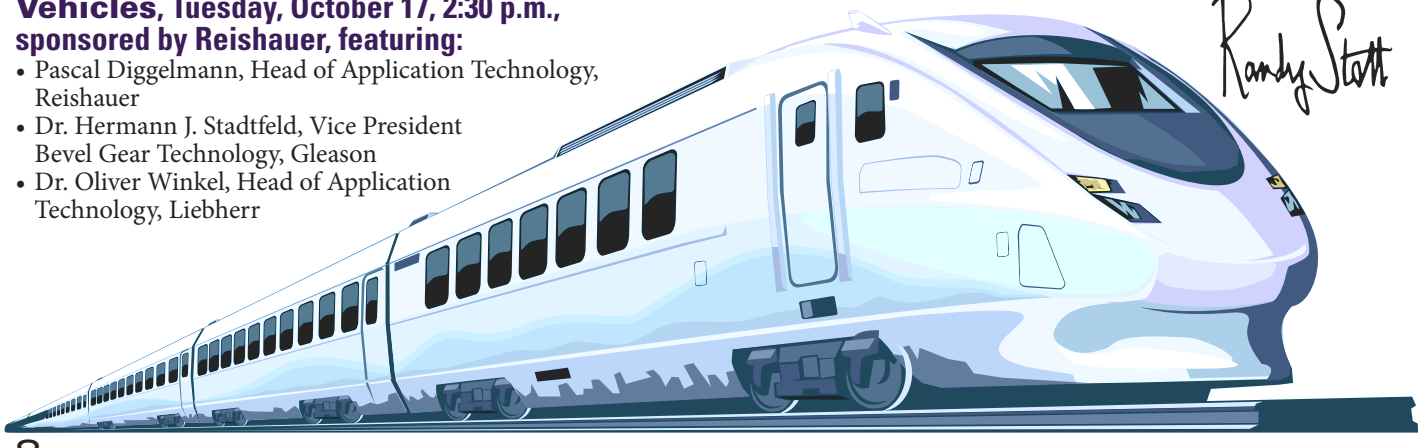
As you can see, we have lined up some of the top minds in our industry to help our audience learn as much as possible about these key topics. Our editors will serve as moderators, but we're also looking for participation from you, the industry. We hope you'll come and ask questions, too.

But that means you've got to be there. It's not too late to make plans to attend MPT Expo. Besides "Ask the Expert Live," there are plenty of reasons to attend, including AGMA's Fall Technical Meeting, AGMA's in-person educational sessions, and of course, the show itself.

Most of you reading this are probably within driving distance. So come to MPT Expo. Hop in your car, book a flight, or board the next train. Register at *motionpowerexpo.com*.

The Knowledge Express is leaving soon. Don't miss out!

Randy Stott



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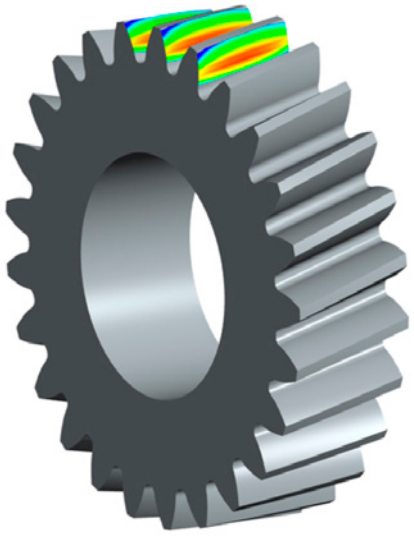
KISSsoft

OFFERS LTCA FEATURE IN SOFTWARE UPDATE



The loaded tooth contact analysis (LTCA) is crucial in understanding the deformation of gears and its impact on various factors such as noise generation, contact patterns, contact shocks, and torque variations. With the contact analysis feature in *KISSsoft,* users can calculate tooth contact under specific torque and speed levels, thereby assessing the performance of gears and gearboxes. LTCA forms the foundation for a robust microgeometric gear design, including lead and profile modifications. In this web-demo, users will gain insights into parallel axis and coaxial gearboxes, focusing on the following aspects:

- Loaded tooth contact analysis
- Stiffness calculation for teeth, shafts, bearings, housing, planet carrier, and gear body
- Analysis of system deformation and its impact on gear contact patterns
- Designing lead modifications for optimal strength and contact patterns
- Designing profile modifications for optimal behavior in terms of power, NVH (noise, vibration, and harshness), efficiency, and contact temperature
- Optimization of modifications for duty cycles

kisssoft.com

Digital Metrology Solutions

TRACEBOSS PLUS SOFTWARE COMBINES SURFACE ROUGHNESS AND CROSSHATCH MEASUREMENT AND ANALYSIS

Digital Metrology Solutions, provider of measurement software, consulting, and training, has introduced *TraceBoss+* (*TraceBoss Plus*) software, integrating surface texture and crosshatch measurement in a single package.

"Last year Digital Metrology's *TraceBoss* software changed how people see, save, and understand data from surface roughness gages," said Mark Malburg, president of Digital Metrology. "Since then, we've had many requests to add crosshatch measurement to the software, as well as the ability to view torn and folded metal, a key indicator of how a honing process is running. *TraceBoss+* adds both functions, as well as introducing new tools to analyze, save, store, export, and output all of these results together. This complete toolset greatly helps anyone working with engine components to see their data and explore their surfaces."

TraceBoss+ software interfaces with most portable surface roughness gages. A user can take a measurement, view the results and graphics full screen, save data, and reload it for comparison and statistical process control. It reports most common roughness parameters, showing briefly whether a surface passes or fails user-provided limits.

The built-in crosshatch functionality lets a user acquire an image of surface texture from any USB equipped microscope. Simple tools make it nearly instantaneous to obtain the crosshatch angle, while zoom and pan functions let an operator navigate through high resolution image data to review the cleanliness and consistency of honing processes.

Perhaps most importantly, the crosshatch angle information is added to the parameter results, so the data and image can be output along with surface roughness data in a single file. All of the data can also be printed in a concise, easy-to-share report.

"When we released *TraceBoss,* we knew we'd given surface roughness gage users a powerful tool for understanding surface texture," said Malburg. "Now, *TraceBoss+* goes many steps further, putting surface roughness, angle, and quality analysis in one easy interface."

digitalmetrology.com/solution/tracebossplus/

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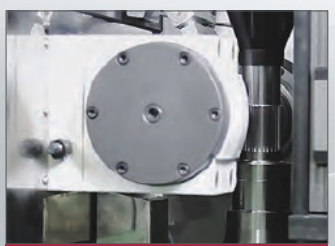
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Kapp Niles

PROVIDES DIGITAL SOLUTIONS FOR THE CLOSED LOOP

With Closed Loop, Kapp Niles offers a system that enables the integration of machining and measuring machines. By using Closed Loop, efficient processes and optimized production are realized. This tool helps companies to improve the quality of their workpieces and to make their processes more efficient. With automated corrections, it significantly reduces the reject rate. Furthermore, Closed Loop is flexible and compatible with machines from other manufacturers, which makes an investment in a new infrastructure unnecessary.

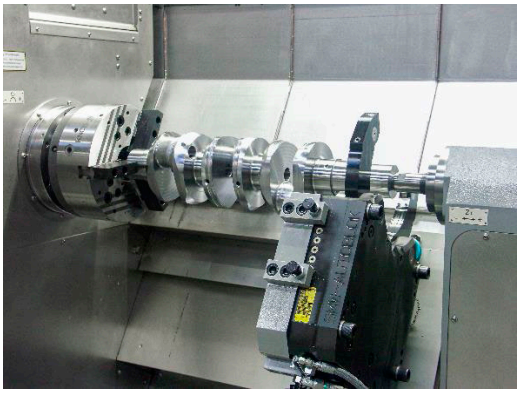
The Kapp Niles system offers standardized transmission via GDE (Gear Data Exchange) of correction values, including parameters such as profile angle deviation ($f_{H\alpha}$), flank

line angle deviation ($f_{H\beta}$), tooth width, ball dimension and two-ball dimension (Wk). Through seamless integration into existing processes, Closed Loop enables different machine types to work together efficiently.

kapp-niles.com

WFL

OFFERS COMPLETE MACHINING OF CRANKSHAFTS IN SMALL SERIES



As the energy sector continues to advance, efficient and high-precision methods of producing components are a crucial

aspect. One area that requires special attention is the machining of crankshafts. WFL Millturn Technologies is responding to this need by offering ground-breaking solutions for the complete machining of crankshafts in small series.

A Millturn provides the best alternative to conventional production methods for the complete machining of crankshafts, including deep-hole drilling of oil ducts or gearing. Based on many years of experience and the use of flexible and multifunctional complete machining centers, WFL can produce prototypes and small series of crankshafts efficiently. Whether for high productivity rough turning or precision prefinishing—all crankshaft geometries can be completely machined in a Millturn from WFL.

The complete machining of crankshafts requires maximum accuracy and reliability. Conventional methods use several steps to machine crankshafts, with various specialized machines and processes coming into play. While this approach delivers high output, it lacks flexibility and is therefore only suitable for large series. The production of crankshafts is a highly complex and relatively inflexible process both on highly specialized machines designed for series production and on all-purpose machines for small series and prototypes.

The use of Millturn complete machining centers together with efficient technologies allows WFL to combine the entire machining process in one machine in just a few clamping operations. WFL machines can handle all the steps required to produce a crankshaft. A single machine carries out milling, boring, turning, deep hole drilling and measuring–from the blank to the nearly finished product. In addition to significantly reducing the production time, this also enhances the quality and precision of the crankshafts. Final heat treatment and the grinding of the crankshaft bearing and crankpin are the only separate processes.

Complete machining eliminates the time-consuming process of moving between different machines and the set-up time this involves. This significantly boosts production capacities and reduces overall costs. At the same time, the machine's high level of precision minimizes the risk of errors and ensures the consistent quality of the crankshafts thanks to measurements carried out in the machine.

The potential for savings is considerable when machining crankshafts in a Millturn compared with conventional production on multiple machines. A 60 percent saving can be achieved in the process chain thanks to complete machining, and this figure is even 80–90 percent for the set-up time.

Machining crankshafts is a demanding process that not only requires perfect tools but also relevant software to be successful. WFL's cycle packages make crankshaft machining especially simple and cost-effective. These cycle packages contain cycles for pre-roughing crankshaft bearings and bearing grooves, a web milling cycle, and rounding of oil holes with a radius cutter or corner rounding end mill.

wfl.at

Grob Systems

HIGHLIGHT 5-AXIS MACHINING CENTER AT SOUTHTEC

Grob Systems, Inc. will be highlighting power skiving applications on its G550T Mill/Turn Universal Machining Center at Southtec Booth #829 located at the Greenville Convention Center in Greenville, SC, from October 24–26, 2023. The G550T is part of the Grob 5-Axis Turning Centers Line, capable of machining a part by milling and turning in a single setup, saving time, costs and floor space.

Southtec attendees will see live continuous machining Power Skiving demonstrations on the G550T. The Grob-cycle power skiving NC user-cycle produces spur and helical internal and external gears at defined angles. Demonstrations will show how having the right machine, tools, software, and feeds/ speeds maximizes productivity by producing precise gears, faster in one operation for challenging applications, including EV. Power skiving is up to 10x faster when compared with shaping (internal gears), and up to 4x faster vs. hobbing (external gears).

The G550T Mill/ Turn 5-Axis Machining Center offers optimized milling and turning performance for a broad range of part materials, and is equipped with a Siemens 840D SL control, 14,500 rpm spindle, and an HSK-T100 tool interface. For maximum stability and machining performance, the G550T features a powerful mill-turn table with t-slots arranged in a star shape. Three linear and two rotary axes permit 5-sided machining, as well as 5-axis simultaneous interpolation, with a swivel range of 230 degrees in the A-axis and 360 degrees in the B-axis. The drive design is based on two symmetrically located ball screws and weight compensation in the Y-axis, and wear-free torque motors in the A and B axes.

The G550T's unique machine concept includes a horizontal spindle position that permits the longest possible Z-travel path and optimum chip fall. The arrangement of three linear axes offers maximum stability by minimizing the distance between the guides and the machining point (TCP). The G550's

tunnel concept allows the largest possible component to be swiveled and machined within the work area without collision - even with extremely long tools.

The Grob 550T is also ideally designed for automated solutions. Grob's automation technology ranges from pallet and part handling/ storage systems to highly flexible, turnkey manufacturing lines. Attendees can discuss the configuration that optimally suits their needs.

grobgroup.com/en/

Big Daishowa

INTRODUCES THE BIG CAPTO C3 SERIES

Big Daishowa has introduced the C3 program, an expansion of the Big Capto tool holder line, designed to increase efficiency and precision for small lathes.

The C3 series of Mega New Baby chucks has a clamping range of .010–.630 in. with a maximum rpm of 30,000. These make excellent choices for drills, reamers, taps, and finishing end mills. Ultra-slim and strong, they provide reliable gripping for even the smallest workpieces.

The Big Capto C3 square holders for turning applications come in left and right orientations. The turning application holders—C3-180-BH16R-2058 and C3-180-BH16L-2058—are monoblock holders. Their insert clamps are tough and reliable, adding on to the already inherently high rigidity of monoblock holders. The resulting higher rigidity minimizes vibrations and movement during cutting, improving accuracy and efficiency.

The new square tool holders are available in 90-degree and 180-degree types. The 90-degree type offers a variety of orientations, including perpendicular to the workpiece. Its compact design also allows for work in spaces that are tighter or have limited clearance. The 180-degree type, meanwhile, allows the tool to machine harder-to-reach areas of the workpiece.

Due to the limited space for smaller lathes and mill-turn machines with C3 clamping systems, integral C3 turning adapters are compact and rigid with both left- or right-hand units for most common turning

geometries. C3 boring bar holders also are available to clamp 6-, 8-, 10-, or 12-mm boring bars. All turning tool holders feature through-spindle coolant. Tool assembly device, Kombi Grip (model KG32R), makes an excellent addition to work on C3 tools outside the machine, and cleaning of internal C3 clamping units is quick and efficient using Big Capto spindle cleaner SC-C3.

us.bigdaishowa.com

Weiler

PRESENTS NEXT GENERATION ABRASIVES

Weiler Abrasives recently announced the next evolution of abrasives—Tiger 2.0 zirconia alumina and aluminum oxide cutting, grinding and combo wheels. Designed for demanding metal fabrication industries like shipbuilding, pressure vessel and heavy equipment fabrication, these abrasives help cut through inefficiencies, safety issues and labor shortages that prevent companies from doing their best work.

"We understand that our customers' production environments are ever-changing and many are challenged with doing more work with less labor. We listened to their feedback to determine what they want and need in their abrasives," said Tony Hufford, category manager—Metal Fabrication at Weiler Abrasives. "The result is wheels that offer fast cut-rates with extended life that we developed through countless hours of trials and validation to provide the best product to market."

In addition to offering fast cutting speed, Tiger 2.0 wheels last up to 40 percent longer to increase efficiency in operations' cutting and grinding applications. The wheels feature an award-winning blotter design that includes a patent-pending Optimum Use Line. The line is a visual indicator that helps the operator use the wheel to its full

life. This innovation reduces changeovers, allowing for greater productivity while also reducing waste and abrasive spend. In some cases, users experience three times more efficiency than with their previous abrasives.

Tiger 2.0 grinding wheels feature anti-chipping technology, an advanced bond formulation that reduces uneven edge wear and chipping to improve safety and the user experience and extend wheel life.

Tiger 2.0 wheels are available in Type 1, Type 27 and Type 28 options. These wheels range in size from 4 to 9 inches and are intended for use on portable angle grinders.

weilerabrasives.com/tiger-2.0.

EMAG

LASERTEC WELDING MACHINE PROVIDES ROTOR SHAFT SOLUTIONS

Sales of electric cars are on the rise—and at an enormous pace worldwide. The International Energy Agency (IEA), for example, estimates that 14 million e-vehicles will be sold this year, representing a 35 percent increase in sales compared with the previous year. This means that they already account for almost one-fifth of the total car market. As a result, production planners are focusing on the manufacture of key components of the e-motor, such as the rotor shaft. They are looking for innovative solutions

"from a single source," with which the component can be machined particularly efficiently and reliably in ever larger quantities.

EMAG LaserTec ELC 6 laser

welding machine provides joining, preheating, and welding processes. These processes are compactly combined on an assembled rotor shaft with its rotary table system ensuring optimum cycle times.

Advances in e-mobility, including hollow designs of components, allow great freedom in design, lighten the weight and lower material costs for assembled rotor shafts. At the same time, this "heart" of the electric motor must withstand particularly high loads, as motor speeds of up to 20,000 rpm are now possible. Compared to a camshaft in a combustion engine, for example, this value is many times higher! Thus, the production of assembled rotor shafts is always about manufacturing tolerance—even minimal imbalances must be avoided at all costs because they would endanger the service life of the engine. In addition, the process must result in a highly stable component.

In this context, what is the most efficient way to reliably produce increasing quantities in the face of an expanding market? One answer to this question leads directly to the innovative technology of EMAG LaserTec, because the company, based in Heubach near Aalen, has an impressive track record with laser welding, which is indispensable in "building" the two-piece rotor shaft.

EMAG LaserTec knows the entire production sequence of the respective components and develops the complete process chain on this basis. On the customer side, the planning of new or the expansion of existing production facilities is therefore massively simplified. In addition, the whole process is based on EMAG's modular mechanical engineering.

emag.com

PBC Linear

DEMONSTRATES COBOT FEEDER AT FABTECH

PBC Linear (Pacific Bearing Company) recently demonstrated deeper CNC integration for its Applied Cobotics Cobot Feeder at Fabtech 2023, in the Universal Robots (UR) Booth #B17063 in Chicago, September 11–14.

The Cobot Feeder, a CNC machine feeding application kit that delivers and stages parts to be placed into a machining process, received UR+ partner certification earlier this year. It includes a base storage-and-retrieval unit with a UR cobot pedestal, an enclosed steel rack dunnage tower with a 17-tray capacity that safely stores up to 50 pounds of material, an HMI touchscreen display for easy lift control, Ethernet IP, Modbus, and standard UR cobot communications. By reliably loading and unloading dunnage trays that a UR cobot can consistently access, this versatile CNC machine-tending tool provides a standardized platform for storing, staging, and delivering parts into a position that the UR cobot can reach for loading and unloading.

The Cobot Feeder demonstration combines a UR10e with a Flexxbotics FlexxCNC to control the process of loading and unloading trays of PBC Linear FL-12 bearings into a pneumatic vise. The modular, flexible, and easily re-taskable Cobot Feeder empowers one machinist to do the work of up to eight while also increasing the amount of raw materials available to cobot machines tending workcells.

"By increasing the amount of raw materials to a workcell, the Cobot Feeder's 17-tray, high-density, part-storage solution enables a machining, welding, stamping, forming, or deburring center to operate for longer periods of time without human interaction, significantly increasing productivity by up to 300 percent or more," explains Beau Wileman, Applied Cobotics and 3D platform product manager, PBC Linear. "In many cases, this means a cobot workcell operating eight hours a day during normal business operations can continue to work through shifts two and three, providing lights-out operation around the clock. This considerably increases the cobot workcell's productivity, while overcoming the 'labor gap' in machine tending manufacturing operations."

pbclinear.com

MOTION + POWER
TECHNOLOGY EXPO®

American Gear Manufacturers Association®

Formerly Gear Expo

EVERY GEAR IS HERE

OCTOBER 17–19, 2023 DETROIT, MI

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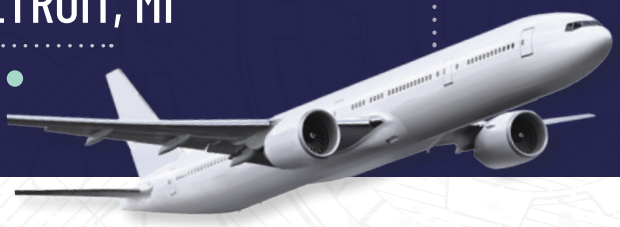


Motion + Power Technology Expo is the center of gear manufacturing innovation. Come learn where the industry is headed, find new ideas for your business, collaborate with leading gear professionals, and discover specific ways to improve your gear operations.

Every gear and every learning opportunity is here. Education sessions include:

- Basics of Gearing
- Integration and Trade-Offs in Gear and Bearing Systems
- Reverse Engineering: Why, When, and How – Avoiding Pitfalls and Litigation
- Why Bearings Are Damaged
- Involute Spline Design and Rating
- Modern Automated Gear Quality Assessment Technology
- Materials Selection and Heat Treatment of Gears

Two Ways to Join the Industry at MPT Expo:

Sign up to Exhibit or
Register as an Attendee

LEARN MORE AT:
MOTIONPOWEREXPO.COM/GT

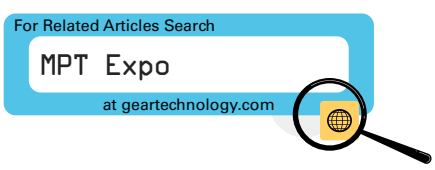
Three Days in Motown—Every Gear Is Here

Resources to help you get the most out of your Motion + Power Technology Expo experience

Aaron Fagan, Senior Editor

AGMA's Motion + Power Technology (MPT) Expo is a biannual trade show—running this year from October 17–19 at Huntington Place in Detroit—designed to serve the gear and power transmission industry, representing the full spectrum of professionals involved in the life of a gear, gearbox, or other power transmission device—from design to manufacturing, testing, heat treating, and more. You will find equipment and materials suppliers to make gears; gear and gear drive manufacturers; and every imaginable industry-adjacent supplier from software to tooling, lubrication to bearings, and much more.

MPT Expo is not only a trade show with a comprehensive exhibition hall representing the whole power transmission supply chain, but also an educational and networking event that keeps apace with the standards and the vanguard of the industry alike. To help you plan your experience, what follows is an interview with AGMA Director of Meetings & Events Leah Lewis, a sneak preview of exhibition booths to visit, and a complete list of panelists and details for *Gear Technology*'s 5th biannual "Ask the Expert Live" discussion in Booth 3136. We look forward to seeing you in Motown!



AN INTERVIEW WITH LEAH LEWIS, AGMA DIRECTOR OF MEETINGS & EVENTS

Please share something special we can look forward to at this year's Motion + Power Technology Expo.

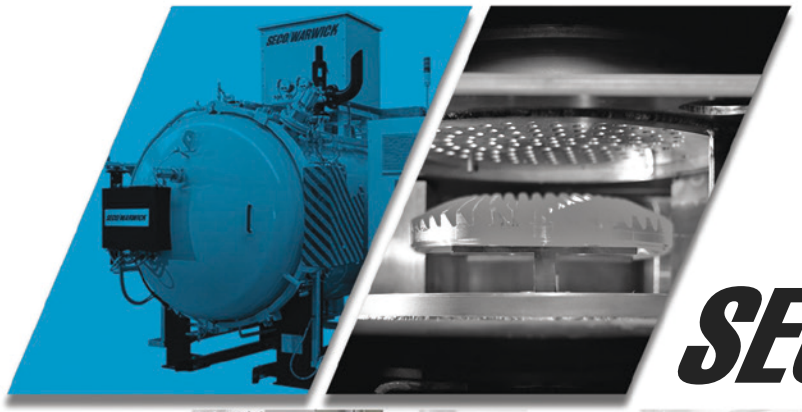
The first I would want to highlight is the curated tours. We are working with our exhibitors to customize a show-floor experience for attendees on different topics like software, robotics, and automation. For people who are coming to the show and don't know who to see or where to start, you'll have a customized list of exhibitors you can visit based on certain topics. You'll just scan a QR code—that can be found on flyers or strategically placed signage—to get the information, and then you can have access to a self-guided walking tour of the show floor at your own pace. And if people want more of a customized experience, it's something that AGMA staff can help with as well.

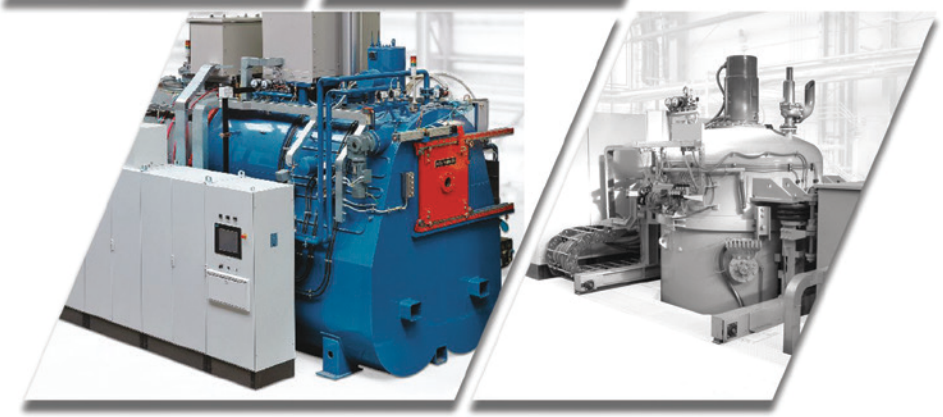
That's very cool because it can be overwhelming at shows. What are some additional things that may be new or unusual about this year?

I would say one of the biggest kind of features that attendees have been interested in is the Town Hall on Electric Vehicle Standards which is taking place on Thursday, October 19 at 8:00 a.m., and it's basically an open dialog on EVs and how they are impacting the gear industry. It's an opportunity for AGMA to share what we're already doing in the space—primarily where standards are concerned, but also education and advocacy for the field around EV, but also kind of opening the floor to attendees and our members to listen and learn on what AGMA should be doing in this space. We want to open the dialog to the industry and hear what the industry needs in this space because it's changing very rapidly and AGMA wants to be a key player when it comes to leading the industry in this.

The AGMA Technical Division Executive Committee recently restructured to project-based groups for standards development. The EV space is changing so rapidly that those kinds of structural changes will help meet those dynamic demands.

I mean, it goes back to why AGMA was founded over 100 years ago, which was to develop standards in the gear industry. And as electric vehicles become more of a mainstream technology, we want to own that role as the





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Motion + Power Technology Expo Booth Previews

ANCA—Booth 3232

ANCA is delighted to be part of the MPT Expo where the company will showcase its latest products, services, and industry solutions. A mere 30 minutes away from ANCA's American headquarters in Wixom, MI, the ANCA team is excited to showcase its technology right here in the company's home state. Here's what you can expect from ANCA at MPT Expo:

Cutting-Edge Products and Services

Visit their booth to experience firsthand their latest CNC grinding machines and technologies. ANCA will have a GCX linear machine on the stand demonstrating its state-of-the-art process for gear power skiving.

Expert Insights

Engage with their experienced professionals who will be available on-site to discuss how ANCA can help address your grinding needs and goals, now and into the future.

"We are thrilled to be a part of Motion + Power Technology Expo this year," said Russell Riddiford, President at ANCA Inc. "This event provides a fantastic platform for us to showcase our latest innovations and connect with industry leaders. We look forward to meeting and interacting with both existing and potential clients to discuss how ANCA can provide tailored solutions to meet their grinding needs."

anca.com

Cincinnati Gearing Systems—Booth 3213

Located in Cincinnati, OH, Cincinnati Gearing Systems (CGS) is a recognized leader in precision component gear manufacturing and design engineering. More than just a gear manufacturer, CGS offers customers over 100 years of experience in producing high-quality, reliable, and cost-effective component gearing and gear units for a wide range of power transmission applications. Configurations include epicyclic gear units, multiple pinion gear units, parallel shaft designs, vertical and horizontal offsets, dual and single input, single and double helical, and hybrid designs. CGS has in-house full-service manufacturing, design engineering, testing, and heat-treating capabilities. Whether it is a clean-sheet design or a standard design, CGS is the single source to satisfy your specific gearbox requirements.

Fracking Gear Unit

- Gas Turbine to Pump Drive
- Double helical gearing, epicyclic configuration
- 16,000/1,455 rpm @ 5,500 hp
- High efficiency, low noise replacement for traditional diesel engine pumping solutions

facilitator of standards when it comes to gears in electric vehicles. It should be an interesting conversation and we definitely want attendees to come ready to listen and learn and share. It's not just going to be a presentation by us, it is going to be primarily open dialog for the industry to come, share their knowledge, and share what AGMA can be doing to help them in this space. Because there are still a lot of unknowns, right?

Yeah. It affects the full stack, from design right through to the operator. Everybody needs to be involved in the conversation.

Definitely.

Are there any other opportunities attendees might not necessarily know about?

Yeah. One other thing to highlight. We are collaborating with ASM International to hold a "Women in Manufacturing and Engineering" breakfast, which is taking place on Tuesday, October 17, at the show. It'll be right before the show floor opens and will be a really nice way to kick off the week. It's an opportunity for us to kind of celebrate the women who are in our field. There's going to be a panel presentation with women in the industry sharing their experiences: how they got into the industry, how to become a leader in the field, how to differentiate themselves, and how to advocate for themselves. It'll be a good opportunity and it is open to men and women. It's not just limited to women, but it's kind of an opportunity to meet, network, and bring people together to encourage more women to get into manufacturing and engineering.

That's fantastic. Is there a final message that comes to mind when you think of addressing the *Gear Technology* readership directly?

I think I would just highlight that this is an event that's going to bring the whole industry together. So even if you're not in the market for a specific product or service right now, you just kind of want to see what's out there. Walking the show floor is a great way just to kind of see the latest and greatest innovations in the industry. There are a lot of emerging technology vendors that are offering new software and automation tools. It's not just gear manufacturing on the show floor. It's the entire power transmission solution that you will find on the show floor. We're really excited to showcase a lot of great technology. Our Solution Center presentations are going to be published soon, so some of our exhibitors will be doing special presentations to showcase some of their products and specialties. I think above all of that, it's just a really great place to network and meet people. Products and services aside, there are a lot of great networking events where you can meet people, talk to people, talk about solutions, and just really kind of build your own network of peers in the industry.

motionpowerexpo.com

agma.org

Hydrogen Compression and Expansion Services

- Expander to Generator Drives
- Parallel Shaft Single Helical API 617 Integral Gear Unit
- Expander casing flange mounted to gearbox
- Expander wheel integrally mounted to pinion shaft with Hirth connection
- 33,000/3,000 rpm @ 2,000 hp
- Used in the plastics production process

Faster Machining Processes

With the installation of the new Liebherr CNC shaper cutter, CGS has significantly reduced the machining time for double-helical gears. This machine doubled previous cutting speeds.

The correction measurement in the machine substantially increases the quality of the gear; and due to the electronic helical guide, CGS can shape every helix angle without the need for additional tooling.

The new Kapp Niles gear grinder has automatic onboard checking and the capability to grind internal gears up to a 30-degree helix angle both left hand and right hand.

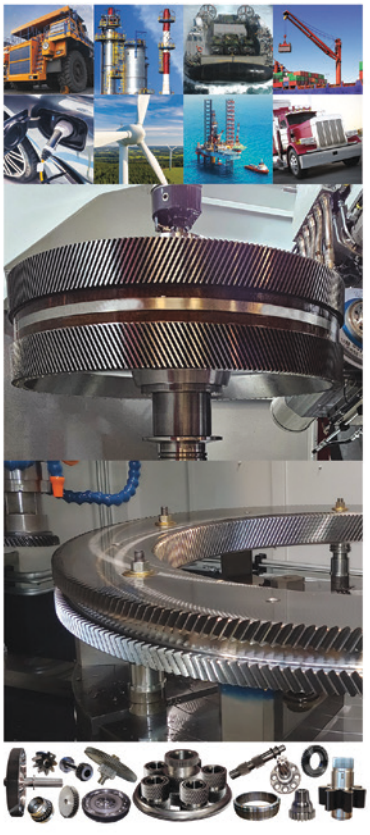
cincinnatigearingsystems.com

Cincinnati Steel Treating—Booth 3213

Located in Cincinnati, Ohio, Cincinnati Gearing Systems (CGS) is a recognized leader in precision component gear manufacturing and design engineering. More than just a gear manufacturer, CGS offers customers over 100 years of experience in producing high-quality, reliable, and cost-effective component gearing and gear units for a wide range of power transmission applications. Configurations include epicyclic gear units, multiple pinion gear units, parallel shaft designs, vertical and horizontal offsets, dual and single input, single and double helical, and hybrid designs. CGS has in-house full-service manufacturing, design engineering, testing, and heat-treating capabilities. Whether it is a clean-sheet design or a standard design, CGS is the single source to satisfy your specific gearbox requirements.

Component Gearing

Cincinnati Gearing Systems is IATF 16949 certified and has over 30 years of experience in producing custom component gears for various automotive and off-highway Tier 1 and Tier 2 customers as well as leading-edge electric drive applications still in development. From pinions, spur gears, and helical gears, to powertrain shafts, Cincinnati Gearing Systems can be your one-stop shop for all your component gearing needs. With over 100 years of gear manufacturing experience with our own heat-treating facility, Cincinnati Gear offers full-service precision gear manufacturing for prototypes, production, and high volume.



Transportation

- Internal Combustion Engine
- Electric Vehicles
- Off-Highway
- Automotive
- Powertrain

Military and Commercial Marine

- Mobile Power Generation
- Land, Surface, Subsea
- Shipboard Power
- Main Propulsion

Industrial

- Power Generation
- Industrial Gases
- Wind Energy
- Oil and Gas
- Mining

Faster Machining Processes

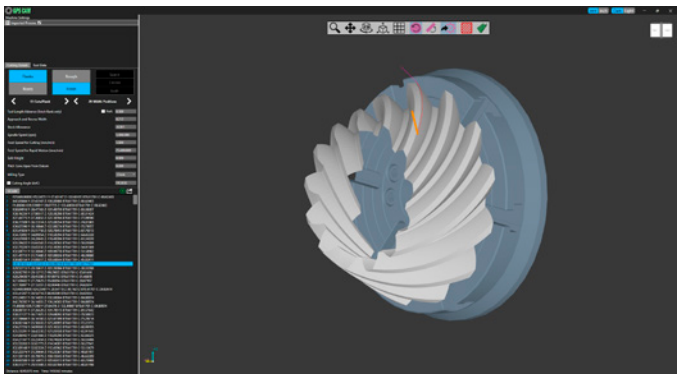
With the installation of the new Liebherr CNC shaper cutter, CGS has significantly reduced the machining time for double-helical gears. This machine doubled previous cutting speeds. The correction measurement in the machine substantially increases the quality of the gear; and due to the electronic helical guide, CGS can shape every helix angle without the need for additional tooling. The new Kapp Niles gear grinder has automatic onboard checking and the capability to grind internal gears up to a 30-degree helix angle both left hand and right hand.

steeltreating.com

Dontyne Gears—Booth 3019

Dontyne will be promoting improvements to design in the new *Gear Production Suite 5.8* release and the new *GPS* CAM module which has enabled smaller companies or those requiring small batch runs to move production onto more flexible 5-axis CNC machine centers.

This intuitive hypoid design tool, launched in *GPS 5.7*, allows flexible design options and ensures complete conjugacy of the teeth through the mesh cycle before the appropriate micro geometry is applied, and has had immediate benefits for our customers. After



meeting at PRI 2021, Tubeworks, based in the USA and involved in motorsport, has become an early adopter of our Hypoid software design package. The CAD file can be exported to any CAM package, or, for a more secure approach, the G-Code can be automatically generated from the designed surface using our *GPS* CAM module. They were able to produce components in-house quickly and at a low cost. Jayson Miles, CEO of Tubeworks commented "This has been a dramatic improvement on our previous approach using gear functions in our CAD system. Not only does it allow more design flexibility, meaning we can optimize our design, but we can roll check the contact in seconds to ensure it is constant over the mesh cycle. The software has helped reduce our development cycle for hypoids from weeks to days."

In collaboration with Collins Aerospace based in Wolverhampton, UK, Dontyne has developed a dish cutter simulation for the fast production of Coniflex bevel forms on a 5-axis machine using its *GPS* CAM module for the *GPS 5.8* release. This approach uses a fixed tool, so it is not as versatile as the end-mill option but does allow more rapid production and higher volumes. Dontyne has been able to validate the result by producing test pieces on the Okuma at its Dontyne Gears facility in Washington, UK. Dontyne would like to thank the team at Collins Aerospace for their help on the project and look forward to furthering collaboration soon.

dontynegears.com

EMAG—Booth 2813

EMAG invites you to Booth 2813 where machining experts will be available to answer questions and talk about new advances in automated gear and shaft manufacturing.

See EMAG's K 160 Horizontal Hobber in Action

Horizontal hobbers aren't just for making shafts. Thanks to integrated automation and part size flexibility, they also work well for manufacturing high volumes of automotive pinions and gears. And, if your operation is looking to replace aging manual hobbing machines, EMAG's long-bed version of this multiaxis machine can handle long shafts and heavy gears. Like the standard K 160, it comes with direct-driven performance drives, user-friendly and easy-to-program controls as well as built-in automation.

From Blank to Finished Component

Additional displays will cover the uses and advantages of laser welding and electrochemical machining as they relate to gear and shaft manufacturing. The EMAG Group is one of the few suppliers of manufacturing systems that cover the whole process chain—from soft to hard machining—for manufacturing gearbox, engine, chassis, and nonautomotive components. With a line of modular machines, EMAG offers various technologies and integrated automation on a standardized platform to reduce floor space and cost while maintaining world-class quality. Active in the automotive, oil field, power generation, and large equipment industries, EMAG is a trendsetter in the field of vertical turning and multi-functional production machines, allowing the customer to process workpieces in a single set-up.

The North American headquarters of the German-based company is in Metro-Detroit and is an important partner in the advancement of complete manufacturing lines. EMAG is ready to discuss a wide range of automated technologies including:

- Gear cutting and shaping.
- Profile and gear-generating grinding.
- Chamfering and deburring.
- Power skiving, turning, drilling, and milling.
- Laser welding, ECM deburring as well as PECM machining.

Stop by Booth 2813 and learn more about how EMAG can work with you to make your gear and component manufacturing more efficient, productive, and profitable.

emag.com

Forest City Gear—Booth 2809

Founded in 1955, Forest City Gear is a third-generation family-owned gear manufacturing company based in Roscoe, IL. By choosing to invest in the best technology available, Forest City Gear has developed into a world-renowned leader in fine- and medium-pitch gear development, manufacturing, and inspection. Forest City Gear is a member of the American Gear Manufacturers Association (AGMA), is AS9100D/ISO 9001:2015, ISO 13485:2016, ITAR certified, and Nadcap accredited for nondestructive testing.

FCG's high-precision capabilities extend to spurs, helicals, involute splines, sprockets, worms, and worm gears. These gears are trusted worldwide in everything from telescopes to tractors, artificial elbows to aircraft, military lasers to race cars, printers to medical examining tables, and power tools to dental drills.

They can even be found in outer space, most notably on the International Space Station and NASA's Mars exploration rovers.

All FCG projects fall under one of two value streams: Make Complete or Cut Teeth Only. Make Complete projects are designed in collaboration with the customer and processed from raw materials to finish. Cut Teeth Only is operational work, in which customers provide specs and gear blanks, and FCG cuts the teeth. With FCG's state-of-the-art facilities, continuous investment in the best machinery, and an inventory of more than 7,000 hobs and 5,000 shaper cutters, Cut Teeth Only gears ship out in ten days or less.

You can find FCG's brilliant Make Complete and Cut Teeth Only engineers at Booth 2809, ready to design and plan the gears you need. Cheers to gears!

forestcitygear.com

Helios Gear Products—Booth 3609

Helios Gear Products will feature hobbing solutions including the Hera 350 CNC gear hobbing machine and the MSR rotary magazine with automatic loading at the MPT Expo.

Hera CNC gear hobbing machines support micro- to coarse-pitch gear manufacturing applications with advanced technical features such as complete Fanuc CNC and direct-drive torque motors, X-axis linear scales, easy-to-use (and train) dialog programming, and versatile unified automation systems. With competitive pricing, domestic support from the expert Helios team, and a unique combination of technical capabilities in a small footprint, the Hera machines offer both job shops and end-product gear manufacturers world-class hobbing solutions.

Of the 8 sizes of Hera machines available, Helios will be demonstrating the Hera 350's ability to produce high-quality spur gears, helical gears, and other hobbed profiles with a maximum pitch rating of 4.23 DP. Jeff Kamps, Helios customer and President at Wisconsin Gear & Machine says, "We've cut our cycle times down from 4 hours to a half hour. It's really been beneficial for Wisconsin Gear. With the shortage of people, it's really made a big difference; we can still get a large volume of work done in a timely manner."

Advancing gear manufacturing productivity even further is the new MSR. This rotary magazine with automatic loading offers comprehensive, versatile automation by integrating manufacturing cells with operations such as gear generation, washing, deburring, and laser marking. The MSR features stackable workpiece towers that offer more capacity than rotary conveyors and is offered with a variety of robotic loading options to feed up to four machine tools at a time for fully optimized gear manufacturing operations.

heliosgearproducts.com

Klingelnberg America—Booth 3426

Höfler Cylindrical Gear Roll Testing Machine R 300—The Gear Noise Finder

The metrology on the Höfler Cylindrical Gear Roll Testing Machine R 300 provides a reliable way to determine the root causes of gearbox noise. Due to the short measuring time, it can be easily integrated into any manufacturing process and enables 100 percent quality control of the gears produced. The R 300 is designed for all roll testing processes that are relevant for evaluating the running

behavior and noise behavior of gears. These include the single-flank test, the structure-borne noise test, and torsional acceleration test, and the double-flank test. Depending on its equipment, the R 300 enables testing of gears and shafts, a particularly important factor for components from an electric vehicle drivetrain system (e-Drive). For testing the e-Drive intermediate shaft, Klingelnberg will demonstrate a process for roll testing both gears on the shaft in one test cycle. This saves time for a second loading and unloading and for retooling the machine and reduces test costs.

P 152—The Solution for Medium-Sized Gears

The increasing cost pressure on large components for wind power requires new technologies that will enable proven principles for high-volume and mass production of smaller components to be transferred over to large components. The newly developed Klingelnberg Precision Measuring Center P 152 closes the gap in the portfolio between the mid-sized and the large precision measuring center model series.

The latest addition to the family is capable of measuring components with a maximum outside diameter of 1 520 mm and workpiece weights up to 8,000 kg with the usual measurement precision. Despite this heavy workpiece weight, no special foundation is required. Klingelnberg has succeeded in scaling the technology concept of the small and mid-sized series to the larger component dimensions. The inherently rigid machine bed with its 3-point support plays a key role here. The bed design and floor support are so cleverly designed that even when loaded with heavy workpiece weights, the angular position of the individual machine axes to each other does not change significantly. The machine bed's 3-point support enables the integration of an active vibration platform into the machine bed. This means that even the low-frequency oscillations from the shop floor can be safely absorbed without the use of a vibration-isolating foundation. Consequently, all changes visible in the measurement results can be attributed to the component and are not induced by the ambient conditions.

klingelnberg.com

Liebherr Gear and Automation Technologies, Inc.—Booth 2800

Liebherr Gear and Automation Technologies, Inc. offers a complete gear technology and automation solutions program. Liebherr's machines include gear hobbing, shaping, skiving, chamfering, and gear grinding machines, as well as gear metrology solutions. These machines feature the LHGearTec control system, an intuitive interface that streamlines machine operation and efficiency. In addition, Liebherr manufactures gear cutting tools and clamping fixtures, to provide full turn-key gear machining. Liebherr automation systems offer a wide range of cost-effective, user-friendly, and high-quality solutions and offer the flexibility to expand retrospectively.

At the MPT Expo, Liebherr will introduce the all-new LC 400 M gear hobbing machine, for use in various applications. With box guideways designed for maximum stiffness, this machine is rated for module 8 mm hobbing, and coupled with quick change fixturing the machine is extremely versatile for job shops. Liebherr will also present the WGT 400 gear inspection machine, similarly flexible for a variety of gear applications, and best-in-class accuracy, from e-mobility to industrial gearboxes.

liebherr.com

Machine Tool Builders (MTB)—Booth 3206

Machine Tool Builders Inc. offers gear producers the optimum solutions for the widest range of applications. Examples of these many technologies will be on display at the MTB exhibit at MPT Expo, Booth 3206. Visitors will have the opportunity to experience the many benefits of these new solutions, including:

- The Hamai N70, a CNC horizontal hobbing machine, is the latest in the Hamai series, a highly respected Japanese global brand with thousands of installations worldwide. With the N70, Hamai has made a quantum leap forward for more economical, more dependable production of high-precision aerospace and automotive gears up to 70 mm in diameter, and shaft lengths to 250 mm.

  The N70 has been completely re-designed to pack more power and precision into a very compact package, with extreme rigidity and the capacity for gears up to Module 2.5. Most importantly, it's available fully automated to reduce nonproductive load/unload time to just three seconds. Equipped with the latest Fanuc controls, touchscreen, and Hamai's operator-friendly programming, the N70 is also exceptionally easy for even less experienced operators to run day in and day out.
- The SMG SH410 Vertical Hobbing Machine, for parts as large as 410 mm in diameter, and workpieces to Module 8. It's a powerful solution to meet the day-to-day demands and flexibility requirements of today's gear jobbers. The machine combines high hobbing and table speeds and rapid x- and z-axis travel, with high rigidity, high torque, high-precision worktable, and powerful work spindle to cut cycle times while delivering high-precision gear cutting even at high cutting loads. This productivity is coupled with a variety of options with the gear jobber in mind: various automation configurations; onboard chamfering/deburring; provisions for extra-long shafts to 650 mm; and even hard skiving. It's compact, highly rigid, ideal for both wet or dry hobbing, and available with Fanuc or Siemens CNC with easy, user-friendly dialogue programming.
- MTB's comprehensive new recontrol/retrofit package for larger-capacity profile grinding gear machines with outdated controls, adding highly desirable performance at a fraction of the cost for new machinery.

The package is built on state-of-the-art Fanuc or Siemens CNC platforms and includes MTB's user-friendly Human Machine Interface (HMI) with Profile and Worm Conversational Software designed to simplify the operator's programming, setup, and operational tasks, and help reduce costly nonproductive time, as well as the risk of operator error.

In addition, the MTB package includes provisions for advanced, fast, and flexible on-board wheel dressing, as well as optional on-board inspection featuring the latest Marposs or Renishaw 3D scanning probe technology (depending upon the machine, control choice, and application). The package includes all required mechanical and electrical components – standardized, up-to-date, and easily replaceable to help avoid early obsolescence.

"With the rate of today's controls obsolescence increasing and the longevity of the physical machine tools today, upgrading your controls platform becomes important to remain competitive," says MTB's Ken Flowers. "This new recontrol/retrofit

program is the best way for companies to extend the productive life of their older machines for years to come, take their performance to levels expected today, and at the same time save tremendously versus the cost of new equipment."

The MTB recontrols/retrofit program is available for all major gear grinding machine makes and models, in size ranges 400 mm and above, and can be performed at the customer's facility or at MTB, depending on the customer's location, requirements, and machine size.

machinetoolbuilders.com

Nidec Machine Tool America—Booth 2300

In the spotlight is Nidec's new CF26A Cut Chamfer System. This new chamfer machine was honored with the prestigious 53rd IDEA "Judges Committee Special Award" at the 53rd Machine Design Awards. Nidec's Tool Design Simulation software creates the perfect chamfer shape before machining even begins. The specially designed ChamferX tools create the exact specified chamfer through the entire tooth, including the root.

The CF26A's Unique Circuit Configuration saves time by aligning workpiece grooves and tool blades and the Dry-Cut Method is environmentally friendly with no need for coolants, reducing the ecological impact.

Sharing the machine spotlight is the GE15HS. This machine features a specially cooled high-speed hobbing spindle that can operate at up to 6,000min-1, with stability and accuracy. The GE15HS can cut wet or dry and takes full advantage of Nidec's Granmet SF hob substrate and Mighty Shield Σ coating for maximum productivity.

Complementing the fast cycle times of the GE15HS is the Load & Go system from Automation Within Reach. This automation system easily integrates with NIDEC gear machines and is easily changed over for a wide variety of parts. This combination provides the optimum solution for profitable production.

Federal Broach, part of the NIDEC family of companies, will exhibit a new broaching machine as well as Nidec cutting tools. Federal Broach will display their in-house tool sharpening and recoating services as well. In addition, visitors will see sample parts from NIDEC's Lamda DED additive manufacturing systems.

Underpinning NIDEC Machine Tool America's dedication to their customers' success is an extensive program to have machine tools in stock for quick delivery. Hobbers, shapers, and gear grinders are all available for quick delivery and visitors can take advantage of MPT Expo special pricing. Visitors to the Nidec booth, number 2300, will also be able to discuss the financing and leasing options available.

nidec.com

Norton | Saint Gobain—Booth 3813

Saint-Gobain Abrasives, one of the world's largest abrasives manufacturers, will be highlighting a range of high-performance, innovative production grinding wheels and technology

ASK THE EXPERT LIVE

Since 2015, *Gear Technology* has hosted live "Ask the Expert Live" presentations and the next edition will be held at the AGMA Media Expert Stage (Booth 3136) at AGMA's Motion + Power Technology Expo (October 17–19 in Detroit).

The Future of Gear Manufacturing

Tuesday, October 17, 10:30 a.m., featuring:

- Joel D. Neidig, Director of R&D, ITAMCO
- John Perrotti, Chairman and CEO, Gleason Corporation
- Prof. Dr.-Ing. Karsten Stahl, head of the Institute for Machine Elements and Director of the Gear Research Center (FZG) at the Technical University of Munich
- Carlos Wink, Chief Engineer, Eaton Mobility Group

Manufacturing of Gears for Electric Vehicles

Tuesday, October 17, 2:30 p.m., sponsored by Reishauer, featuring:

- Pascal Diggelmann, Head of Application Technology, Reishauer
- Dr. Hermann J. Stadtfeld, Vice President Bevel Gear Technology, Gleason
- Dr. Oliver Winkel, Head of Application Technology, Liebherr

Automation for Job Shops

Wednesday, October 18, 10:30 a.m, sponsored by Schafer Industries, featuring:

- Rob Cherba, Automation Sales Manager, Liebherr Automation
- Geoff Dawson, Director of Michigan Regional Sales, FANUC America
- Ryan Finfrock, Engineering Manager, Schafer Industries
- Gerd Walter, COO, Creative Automation

Solving the Skilled Workforce Challenge

Wednesday, October 18, 2:30 p.m., sponsored by Forest City Gear, featuring:

- Kika Young, President, Forest City Gear
- Mary Ellen Doran, Executive Director, AGMA Foundation
- Kris Ward, Sr. Director, Strategy & Business Development, SME
- Megan Schrauben, Executive Director, MiSTEM

at the MPT Expo. Norton Quantum Prime grinding wheels, which feature proprietary nanocrystalline ceramic grain offering high productivity gains across a wide range of applications, will be featured. The Quantum Prime grain delivers exceptionally high grinding efficiency and part quality, as well as significantly longer wheel life than traditional ceramic grains.

Also, attendees can see high-performance Norton IDeal-Prime internal diameter grinding wheels for precision applications featuring Quantum Prime nanocrystalline ceramic grain. The combination of the microfracture properties of the ceramic grain and the retention capability of the advanced bond, ensures long wheel life, excellent grinding efficiency, and consistent part quality with superior surface finishes which results in cost savings of 30 percent and more.

Additional key Norton grinding technologies at MPT Expo include:

- Xtrimium range of gear grinding solutions designed for high-performance gear grinding in extreme, tight tolerance environments will be featured. The portfolio of gear grinding products is specifically designed by category to provide higher profile accuracy, supreme form holding, and burn-free grinding in worm, profile, and bevel applications. Highlighting the range is an innovative dual-worm wheel design that enables two operations in one grinding wheel, substantially saving time and cost.
- For the high-performance external grinding of cam and crankshafts and internal grinding applications in automotive and bearing industries, Vitron7 cBN Grinding Wheels have a high-precision vitrified bond.
- Norton Finium abrasive microfinishing film rolls for precision applications are designed with a patented topside resin system alongside two backing types and an innovative grit size color coding. This combination is specifically engineered to deliver high material removal and exceptional surface finish uniformity.
- Norton Stellar inserted-nut grinding wheels for double- and single-disc grinding offer improved wheel life, increased parts per wheel, and lower cost per part.

nortonabrasives.com

Reishauer—Booth 2622

Reishauer continues to have a decisive influence on modern gear manufacturing. Since Reishauer developed the world's first generating gear grinding machine, it has been driven to consistent innovation.

Reishauer provides solutions to improve your grinding and dressing processes and machine maintenance with the help of the company's expertise and newly available data science. Process monitoring, optimizing with data analysis, identifying necessary maintenance work in advance, planning efficiently, and reducing downtime to a minimum.

Reishauer's MPT Expo customer experience will provide an immersive technical journey. Empower your organization with myReishauer, a customer application platform connecting your organization to the digital world of Reishauer. Come see how Argus will keep an eye on your grinding process and the ways it will benefit your organization. The RZ x60 4.0 series combines the proven machine basis of the RZ x60 series, including its highly efficient double-spindle technology with the latest control technology and modern interfaces, and is ready for future Industry 4.0 requirements. Immerse yourself in our virtual machine and experience Polish Grinding. Reishauer ensures customers can achieve the full performance potential of its generating grinding machines with the company's own Swiss-made tooling.

Reishauer invites you to be their guest. Refuel yourself, charge your device, and connect your organization with technology and unmatched customer service in an experience that will add value to your production.

reishauer.com

Star SU—Booth 3209

As the exclusive North American representative of Louis Bélet SA (Switzerland) Swiss cutting tools, Star SU will display its line of high-precision drills, end mills, thread, and gear-cutting tools including hobs and skiving tools in Booth 3209 at the MPT Expo. This includes solutions for micromachining applications within the medical, automotive, aerospace, watchmaking, and general machining sectors.

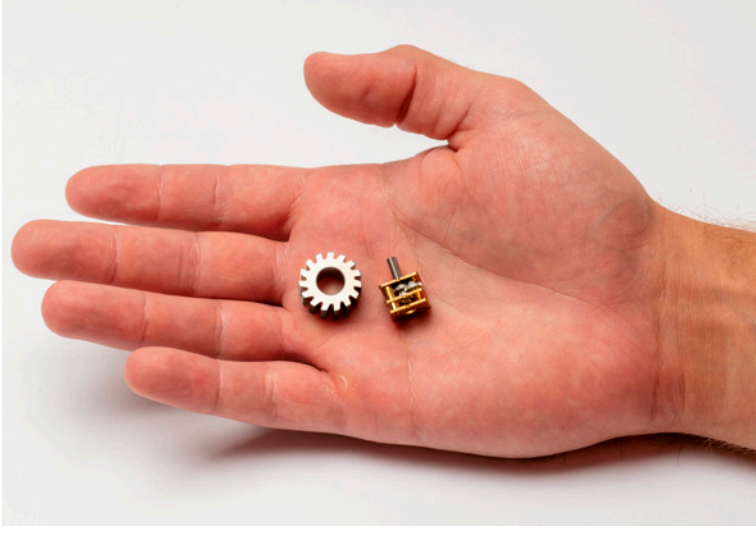
The Louis Bélet product line expands the dimensional range of the Star SU portfolio of round and gear tooling to include micro tools as small as 0.05 mm and specials down to 0.02 mm for Swiss-style machining, as well as extended offerings in fine pitch gear-cutting tools.

Star SU will also be showcasing its wide variety of gear-cutting tools including solutions for chamfer and deburring, hobbing, and milling, as well as scudding cutters manufactured to produce gear and spline teeth for reduced cycle times and tool costs.

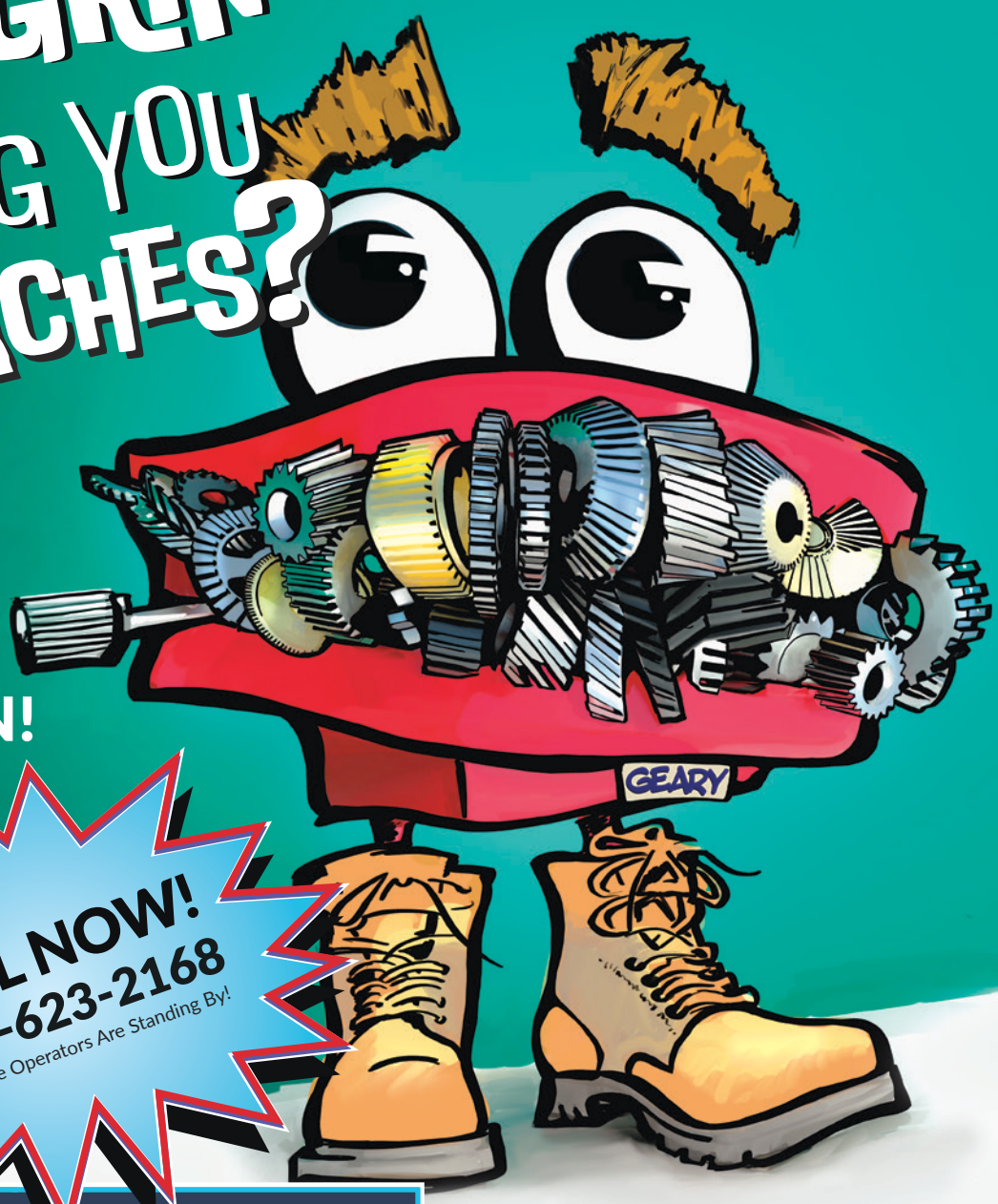
Additionally, the company will be showcasing its full offering of machine tools for producing gears and other fluid power components. This includes interactive demonstrations or displays on FFG Modul vertical gear hobbing; chamfer, deburr, and rolling of straight or helical gears or shafts; Profilator scudding machines; and Star Cutter NXT 5-axis grinder for cutting and sharpening gear tools.

Star SU, which is the marketing, sales, and service partner for Star Cutter Company, offers a comprehensive line of products and services that enables customization of each cutting and tool grinding operation from cutting speeds and feeds to automation and tool coatings.

star-su.com



TEETH GRINDING CAUSING YOU HEADACHES?



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forestcitygear.com

Transportation Alterations

NVH, energy efficiency, and lightweight vehicles drive Eaton's EV culture

Matthew Jaster, Senior Editor

The EV to-do list grows daily. Once the engineer has settled in on solving noise, vibration, and harshness (NVH) challenges, they pivot toward energy efficiency. They consider the vehicle's weight, the tooling needed to manufacture the gears, the skiving needed to make the surface finishes as smooth as possible.

"Without that ICE engine drowning out that noise, there are several factors to consider when working on EV drivetrains," said Mark Kramer, ePowertrain business unit director at Eaton.

Eaton boasts 100+ years of experience that began in 1911 when Joseph Eaton invented the first gear-driven truck axle. Fast forward to 2023 and the company has pushed all its chips across the table to leverage its gear manufacturing and transmission expertise into the electrification movement.

"We're updating everything from forging to the finishing of gears," said Justin Hopkins, product director at Eaton. "EVs require additional technology for finishing operations so we're developing new toolsets, getting more involved in skiving operations and making strategic investments that will better prepare the organization for this incredible shift taking place in passenger and commercial vehicles."

Engineering Diversity Required

Eaton recently announced a new name for its Vehicle Group and eMobility businesses. Eaton's Mobility Group represents the company's focus on providing solutions across the propulsion spectrum and meeting the evolving needs of its customers from internal combustion to electrified or a combination of both.

"Our new name, Mobility Group, leverages our 100-plus years of diverse experience in the vehicle space and Eaton's extensive electrical background at a time when the industry is quickly becoming a mixed market of internal combustion and electrified vehicles," said Pete Denk, president, Eaton's Mobility Group.

Eaton will continue to offer traditional powertrain solutions as manufacturers and the industry determine optimal propulsion systems based on market demands. To support increasing degrees of electrification, the Mobility Group offers a suite of technologies, including power distribution solutions, power electronics and transmissions that improve safety, efficiency, and performance.

Eaton supplies drivetrain, powertrain systems and critical components that reduce emissions and improve fuel economy, stability, performance, and safety.

According to Kramer there are many questions left unanswered about the future of EVs and e-mobility. "What is the gear capacity going to look like in the coming years, for example? How many OEMs are going to keep gear manufacturing in-house? How much of the global gear capacity are we able to transfer to ourselves from a business standpoint?"

"Commercial vehicle adoption appears to be on a much slower trajectory than passenger vehicles," Hopkins added. "It's a juggling act between handling our enormous commercial vehicle capacity and investing in the physical space and engineering talent needed to meet EV demands today."

Where Eaton finds a significant advantage is the strong global partnerships and contract manufacturing experience the company brings to the market.

"We've taken the approach to not only be a contract manufacturer but also a

design partner. We provide feedback and help our customers improve their designs and manufacturing processes. I think we're finding ourselves in a position to really help ramp up their production and provide input based on our rich history as a contract manufacturer," Hopkins said.

There's a particular path toward success in electrification. Kramer believes Eaton's ability to design gears, gearboxes and systems in the future will add value to the company's customer base as well as save costs internally.

A Digital Toolset

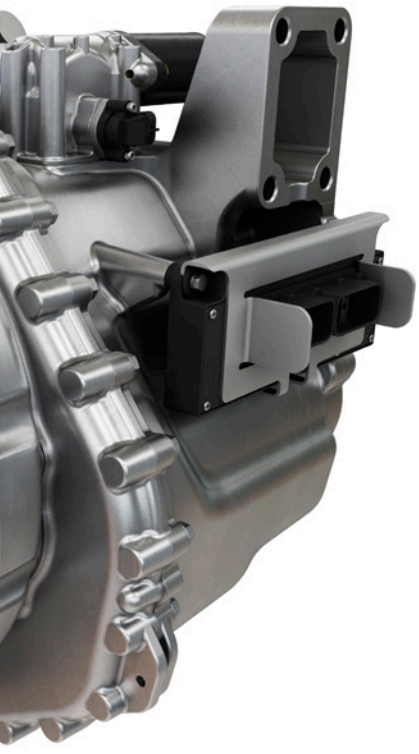
Eaton's Vehicle Group leveraged advanced Industry 4.0 technology to help its global operations safely navigate the COVID-19. The company envisions Industry 4.0 as both operational and informational technologies, enabling autonomous production systems that are connected, optimized, transparent, proactive, and agile. Supported by an integrated ecosystem, the technologies are composed of augmented reality, rapid application development, autonomous robots, digital simulation, and additive manufacturing.

A few examples of Industry 4.0 technology include:

- Microsoft's HoloLens 2 augmented reality goggles that offer the capability to display 3D images in physical spaces and connect remotely. This remote assistance technology ensures that ongoing work can be performed while keeping everyone safe.
- Augmented reality also assists with knowledge retention and ongoing training. For instance, the Vehicle Group identified an opportunity to use the technology to train operators and engineers on new equipment, which would have traditionally been conducted by instructors who travel to the various remote sites. Additionally, the technology has proven critical for recent customer reviews and approvals.
- Eaton's Vehicle Group is interconnecting plant systems and machines to collect, analyze and report real-time information, which optimizes plant floor management and provides visibility to real-time production issues in order to address them right away. These efforts are designed to reduce lead times; maintenance, repair and operations (MRO), inventory, indirect labor/direct-labor costs; as well as increase performance and improve quality.
- To optimize manufacturing flow and eliminate the need for forklifts and other human-operated transport

machinery, the Vehicle Group is using autonomous automated guided vehicles (AGVs) or autonomous mobile robots (AMRs). In addition to improving the flow of materials throughout a manufacturing facility, AMRs and autonomous AGVs increase safety and allow for social distancing while also lowering costs.

- COBOTs, which are robots intended to interact with humans in a shared space or to work safely in close proximity, are being used to safely handle complex and repetitive tasks. This results in improved consistency and accuracy during the manufacturing process.
- Another way the Vehicle Group is increasing productivity is by using digital simulation applications to define which solution and/or combination of factors will result in the highest output. These applications can run several scenarios by changing parameters, such as the number of operators, work in process material, cycle times, operator standardized work and many others.
- Additive manufacturing is leveraged to improve safety, quality and efficiency by designing and producing tools, poke-yokes and gauges internally on both polymer and metal materials. This allows fast reactions (shorter lead times), reduced purchase costs and highly customized solutions. For example, lead times can be reduced from weeks to days, while reducing costs from thousands to hundreds.



The Balance Between Mechatronics and Mechanical Engineering

Ideally, Eaton would like to see mechatronic backgrounds in up-and-coming engineers joining the organization. The balance between electrical and mechanical system knowledge would be extremely beneficial for the company's EV plans, according to Kramer.

"We're developing talent internally, but it would be nice to see a push toward mechatronics, for sure. As it stands now, we're hiring engineers that become gear experts after they've been with the organization for some time."

"This industry is not going away anytime soon," Hopkins added. "It's more about getting people interested through learning and mentorship rather than trying to recruit people. These new engineers are seeing this incredible opportunity available in electrification today."

Both our interview subjects for this article are now heavily involved

in electrification despite starting in mechanical engineering.

"I naturally progressed toward the mechanical side of things," Kramer said. "I started my engineering career with an aerospace company where everything was theoretical. I never saw inside the plane; I did most of my work from my office. When I started at Eaton's Proving Grounds—located in Marshall, MI—everything was hands-on. I was able to work on the vehicles and solve challenges in real-time. With EV technology, I'm learning something new everyday as an engineer."

Hopkins' engineering fascination began with farm equipment. "I made my father take me to farm shows to look at the latest equipment. I started getting into Corvettes and Ferraris when I was 12 and knew I wanted to work on engines and specialize in high-performance cars. I was interested in combustion and thermal dynamics. Now we're working on electric vehicles which I find is also a huge passion for me. What we're doing is supporting a very positive transition in society right now. Even though I still love those high-performance cars, I'm very motivated to be helping society to a cleaner energy future."

While internal development is a great asset, Kramer noted that in the future superchargers and manual transmissions will be gone. It will become more important to upgrade machine tools in Mexico, improve tool life in South America, leverage emerging technologies in the United States. "There will be a growing need for mechatronics expertise, for sure."

Investing in the Future

Eaton's investments in North American manufacturing are in addition to the company's recently announced $500 million to support electrification, energy transition and digitalization across all industrial platforms.

"Eaton solutions are at the heart of electrical systems everywhere and are vital to accelerate complex infrastructure projects for buildings, healthcare facilities, data centers, industrial facilities and utilities," said Mike Yelton, president, Americas Region, Electrical Sector at Eaton. "The latest investment in regional manufacturing reflects our commitment to respond rapidly to unprecedented customer demand and the tremendous abilities of our longtime employees and channel partners."

New regional expansion will enable Eaton to increase production of its circuit breakers, switchboards, panelboards, and other assemblies that enable power distribution for critical infrastructure across industries. In addition to El Paso investments, the company will expand capacity at its existing facilities in Beaver, Pennsylvania; Juarez, Mexico; Arecibo, Puerto Rico; and Haina, Dominican Republic.

By capitalizing on the global growth trends of electrification and digitalization, they're helping to solve the greatest manufacturing challenges facing our world today.

"For us, the most important aspect of our EV journey is producing quiet and efficient equipment," Kramer said. "Whether that means smaller batteries or more efficient geartrains, at this point everything is still on the table."

"We're looking at getting more range out of these EVs—lightweight factors come into play," Hopkins added. "All the OEMs don't want to know the gearbox is there. It also must be bulletproof. It must be 99 percent efficient, hyper quiet and needs to be cost-effective."

The list of demands seems to increase daily, but that's not stopping these engineers from rolling up their sleeves and working on the best possible solutions.

In addition, they will continue to monitor the changing trends taking place in the passenger as well as commercial vehicle markets. It's clearly a fascinating time for the automotive industry and the entire transportation market segment.

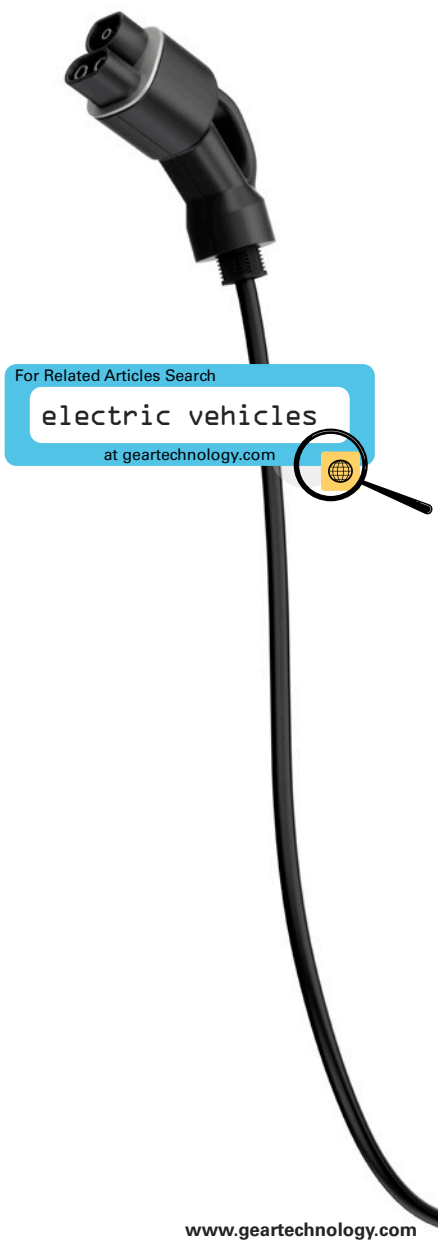
"Tesla uses a 1-speed automatic transmission that utilizes a single gear," Kramer said. "When and where does the market shift to multi-speed transmissions and what is that going to look like? Eaton offers 4-speed transmissions as well as fixed reduction gear sets, so we're trying to develop technology in both spaces."

"On the commercial side, OEMs are currently experimenting with a lot of different architectures," Hopkins said. "We're selling integrated EV technologies, but we need to be prepared for the move toward smaller packaging, lighter materials, etc., so we can be ready regardless of the architecture selection."

At the end of the day, all the work towards electrification will come down to the industry figuring out several key factors in the coming years.

"We're trying to get the EV market into the mainstream here in the United States, but a lot of what happens in the next five to 10 years will come down to solving various infrastructure challenges," Hopkins said.

eaton.com



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In the Spotlight: Heat Treat 2023

A conversation with Conference Chair Andrew Banka

Aaron Fagan, Senior Editor

Carburizing services image courtesy of Cincinnati Steel Treating, Booth 3213.

The roots of heat-treating run deep within ASM (American Society for Materials) International, as its society was founded in Detroit in 1913 as The Steel Treaters Club. The heat-treating constituency of ASM created the Heat Treating Society (HTS) to provide focused leadership, communications, and service development to its network of worldwide membership of captive and commercial heat treaters, equipment manufacturers, researchers, governments, and technicians. To discuss Heat Treat 2023, the 32nd annual HTS Conference and Exhibition, Gear Technology took a moment to catch up with conference chair Andrew Banka, vice president of Airflow Sciences Corporation. Heat Treat 2023 is colocated with IMAT and Motion + Power Technology Expo in Detroit, October 17–19.

What will make Heat Treat 2023 special?

While we went forward with Heat Treat 2021 amid the pandemic, we strongly believe that Heat Treat 2023 will mark a return to pre-covid normalcy. This year's event promises an exceptional experience with a robust attendance expected. Beyond the excitement of reconnecting in person, Heat Treat 2023 will have approximately 150 exhibiting companies, offering attendees a comprehensive view of cutting-edge technologies and solutions in the heat treatment sector. Moreover, in partnership with IMAT, attendees can access an impressive array of over 450 technical sessions, ensuring that this event serves as an indispensable knowledge-sharing platform for anyone involved in the industry.

Please tell us a few things that may be new or unusual about the conference this year.

We are very excited to feature an unprecedented lineup of distinguished keynote speakers, each bringing their unique insights to the forefront. Dr. Stefanie Tompkins, Director of DARPA, will delve into "Materials Science and Thermal Processing at DARPA—On the Road to Discovery." Dr. Bryan W. McEnerney, NASA Technical Fellow, will address "The Challenges of Insertion of Advanced Materials & Processes for Spaceflight." Dr. Iver Anderson, a Senior Metallurgist, will explore "Heat

Treatment Effects on Sintering of Highly Grain-refined Dy-free Nd-Fe-B Anisotropic Magnets." Finally, Dr. Marvin Barnes, Branch Chief at NASA, will shed light on the extraordinary applications of ordinary materials. These keynotes promise to be enlightening highlights of the event, offering valuable insights into the world of materials science and thermal processing.

This year, Heat Treat will go beyond professional growth by enhancing the well-being of attendees. They can join in exciting wellness challenges to stay active and win prizes. We hope attendees will stop by the new Wellness Lounge on the exhibit show floor, offering a peaceful retreat with comfy chairs, soothing music, infused water, and healthy snacks. Plus, we encourage participation in a new walking challenge to track steps and earn rewards while elevating professional interactions at Heat Treat & IMAT. It's a comprehensive approach to ensure everyone leaves the event refreshed and enriched.

Will there be any tours, classes, or other opportunities attendees will not want to miss out on?

The VIP Industry tour is always a crowd favorite, serving as a firsthand introduction to the industry's latest tools, products, and services. Think of it as a "speed-dating" event with exhibitors, offering a rapid overview of their offerings. Alongside the technical program, we will also feature exhibitor presentations in the Solutions Center right on the expo show floor. And, in response to popular demand, we're reintroducing mini-education courses at the expo, featuring topics like General Heat Treating and Metallurgy for the Non-Metallurgist, ensuring a well-rounded and informative experience for all.

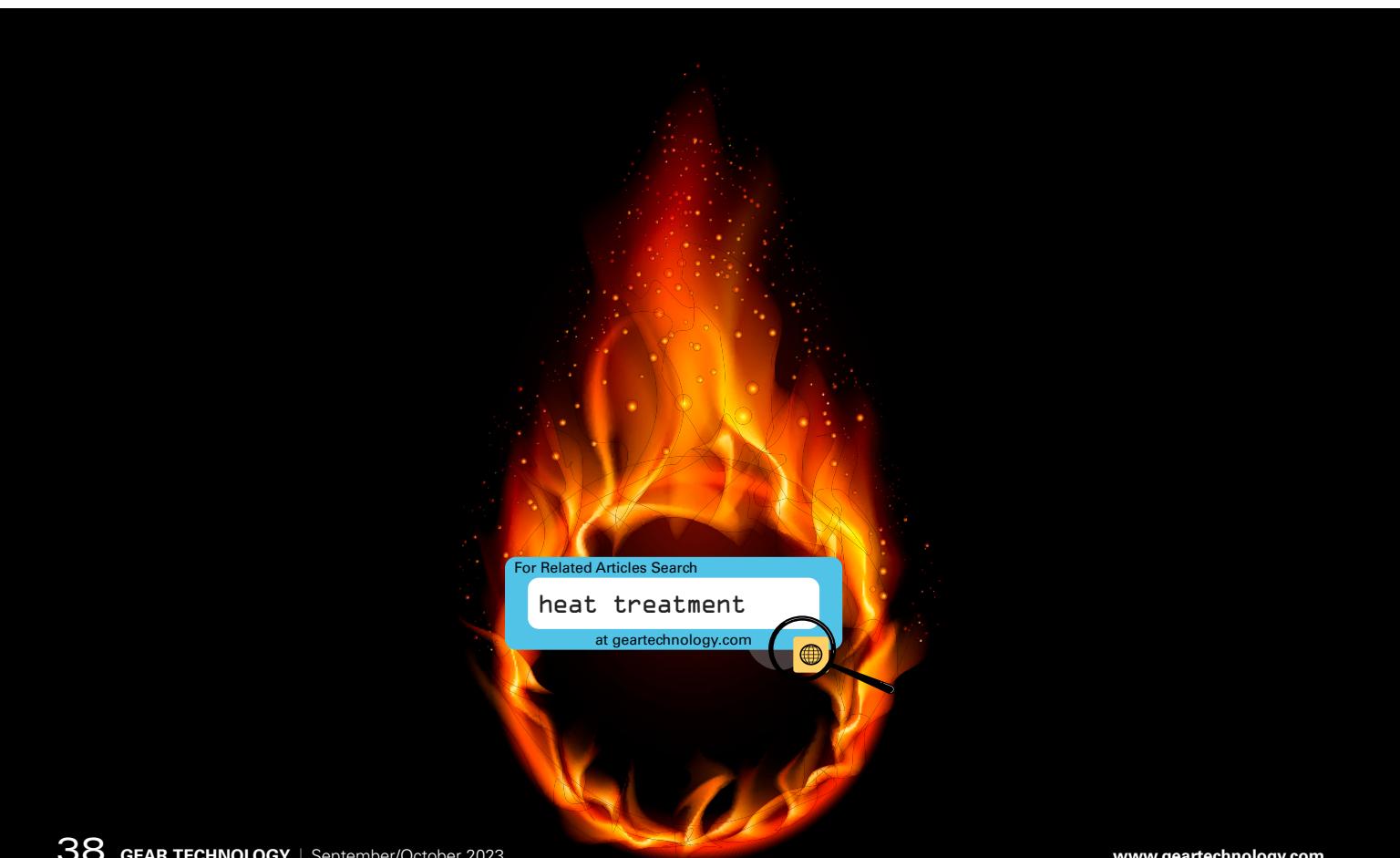
What is something attendees may not think to look for at an event like this?

Attendees are often pleasantly surprised to discover that Heat Treat 2023 is not just your typical industry expo. Beyond the exhibits, it offers extensive technical and educational opportunities. With the incorporation of wellness and sustainability initiatives this year, the conference now provides a truly "well-rounded" experience for attendees.

Are there any attendance statistics to share that will encourage people who are on the fence about attending?

We are expecting between 2,500–3,000 attendees, which includes the colocated ASM Annual Meeting, IMAT. Since the Heat Treat conference and MPT Expo are located in Detroit, we do expect a high number of Expo-only attendees.

asminternational.org/heat-treat



ARGUS eyes on the grinding process

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- Potential zero-defect production

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Project-Based Groups for Standards Development

Amir Aboutaleb, VP Technical Division, AGMA

AGMA's standards development process has been reorganized from a committee-based structure to a project-based format. This change means that AGMA will no longer have standing, topic-specific committees. Instead, project working groups will be formed to develop and deliver project-specific objectives. The group will be dissolved at the end of the project. The change will enable the AGMA's Technical Division Executive Committee (TDEC) to pivot its resources in a timely manner to meet and address the ever-changing needs and challenges of the gearing industry.

Since its inception more than 100 years ago, AGMA has been helping the gear industry by developing technical standards and information sheets covering a wide variety of topics from design to manufacturing, testing, and failure analysis. Today AGMA's catalog contains over 103 standards and information sheets. None of this would have been possible without the dedicated participation and valuable contributions of the industry experts, from AGMA membership, joining forces together in over 23 standing, subject-based technical committees formed over the years to address the industry needs as they surfaced. To continue that tradition and maintain its mission to help the industry with its ever-changing needs and challenges, the TDEC has approved the re-organization of the current technical committees.

The subject-specific committee-based system had a few disadvantages. For instance, due to the broad scope of their subject matter, committees usually had more than one document assigned to them. However, not everyone on the roster of that committee was interested in or had the needed knowledge to actively participate and make contributionsfor during the development, or subsequent review and revision, of every document assigned to the committee. And that almost always introduced issues in complying with ANSI numerical requirements during final review and approval. Furthermore, the other major disadvantage of the subject-based committee system manifested during the review and evaluation of new projects within the confines of the pre-determined scopes of the existing committees. This was analogous to trying to fit a square peg into a round hole.

So, after thorough reviews and careful discussions, the TDEC has approved switching from subject-based technical committees to a project-based working group format. In the new project-based system, AGMA will utilize a broader base of potential volunteer industry experts to form a working group dedicated to a single project, as opposed to the old process of only using the existing committee roster. AGMA will solicit involvement from all prior technical committee members, and all technical representatives from current member companies, through general announcements in the *Gear Technology* and *Power Transmission Engineering* and through ANSI's public announcements. The expanded pool of experts offers the potential for larger participation from industry experts.

Needless to note, the aforementioned change doesn't prevent the old committee roster from "signing up" for, or continuing in, future projects. In fact, from a member's perspective, there will be little to no noticeable change from the current system to the project-based format. Many of the experts around the table for a new project will be the same experts from the committee-based system. This fact—along with the complete archive that AGMA maintains from all past projects—will ensure the historical "know-how" is brought forth to the new project-based working group system.

Furthermore, it should be noted that in the new system, members who are interested in keeping up with the project's progress but do not wish to be a member of the project working group, will be able to do so through the AGMA document portal (Govenda). However, only those member companies who sign up to work on a new project will have voting privileges on the project.

We expect the new system will enable AGMA to meet and respond to the industry's ever-changing needs and challenges as efficiently as ever.

If interested, additional details may be found in the newly revised AGMA 999, Operating Instructions for AGMA Technical Division. If you have questions or would like to be added to the pool of experts, please contact us at *tech@agma.org*.

Thank you all for your continued support.

agma.org/documents/AGMA_999-C23.pdf

Experimental Evaluation of Wind Turbine Gearbox Structural Models Using Fiber Optic Strain Sensors

Unai Gutierrez Santiago, Xabier López Fuentes, Alfredo Fernández Sisón, Henk Polinder, and Jan Willem van Wingerden

Reducing the cost of energy (CoE) has become one of the main research drivers in Wind Energy (Ref. 1). As a result, wind turbines have experienced a significant increase in rotor diameter. This can be understood considering the equation for the generated power (P):

$$P = \frac{1}{2}\rho A \upsilon^3 C_p \tag{1}$$

where

ρ is the air density;
A is the area swept by the rotor;
υ is the wind speed;
C_p is the power coefficient;

Power is proportional to the swept area and grows with the square of the rotor diameter.

Geared drivetrains dominate land-based or onshore wind energy. It is estimated that 75 percent of turbines have a gearbox (Ref. 1). The leading OEMs, such as Vestas, Siemens Gamesa Renewable Energy (SGRE), General Electric (GE), and Acciona-Nordex all use geared drivetrains in their onshore turbines. The latest SGRE onshore platform 5.X has a power rating of 6.x MW and rotor diameters of 155 m and 170 m. In offshore sites, the share of direct drive turbines is more significant, but Vestas and Ming Yang also use geared drivetrains and target rotor diameters as large as 236 m with expected rated powers of 15 MW. The design requirements for wind turbine gearboxes are given by standards IEC 61400-4 (Ref. 2) and AGMA 6006 (Ref. 3). Torque is the main sizing factor in gearboxes. Assuming a limitation to maintain the tip speed of the blade's constant, the rotational speed decreases linearly with the rotor diameter. Therefore, input rotor torque (T) grows with the cubic exponential of rotor diameter.

$$T \propto \rho R^3 v^3 C_p \quad (2)$$

where

R is the rotor radius.

The significant increase in rotor diameters has pushed gearbox manufacturers to introduce multiple technological innovations to boost the torque density of current designs. Torque densities of 200 Nmkg−1 are now available thanks to, for example, new gearbox architectures with more planetary stages and planets per stage, new materials, improved manufacturing tolerances, and additional surface finishing techniques. To achieve compact and lightweight drivetrains, a trend has emerged toward increasing the mechanical integration of the main bearing, gearbox, and generator (Ref. 4). Overall, these light designs increase stress on gearbox components, and accurate structural models are needed to maintain or even increase gearbox reliability. Structural models based on the finite element method (FEM) with a high level of complexity to capture all interactions between gearbox components are widely used for this purpose. These models must be validated through experimental evaluation to achieve the desired degree of confidence. Once validated, FEM structural models provide a suitable platform to optimize gearbox components to increase torque density further.

The main objective of this study is to perform an experimental evaluation of the structural model of a five-planet first planetary stage from a modern 6MW wind turbine gearbox. The FEM structural model comprises the rotor side housing, also known as the torque arm housing, the first stage ring gear and the transition housing between the first and second ring gear. Strain measurements on the outer surface of the ring gear obtained in a full load back-to-back test bench have been used to validate the structural model. Optical fiber strain sensors have been used because they offer a higher signal-to-noise ratio, are immune to electromagnetic interference, and allow a more straightforward installation because multiple strain sensors can be accommodated in a single fiber.

This study has been conducted using a Siemens Gamesa Renewable Energy (SGRE) gearbox manufactured by Gamesa Energy Transmission (GET) shown in Figure 1. The gearbox is a 3-stage gearbox; the first and second are epicyclic planetary stages, and the third is a parallel stage. A drawing of the shafts and gears in this gearbox is shown in Figure 2. The structural housings of the gearbox have been omitted for clarity. The first planetary stage has five planets, and the second stage has three. The rated power of the gearbox is 6.x MW and weighs approximately 44,000 kg. The first stage of this gearbox has been chosen for this study because it is the most critical one due to the high torque that it supports.

Figure 1—Drivetrain assembly of SGRE 5X 170 prototype turbine in Høvsøre wind farm (Denmark).

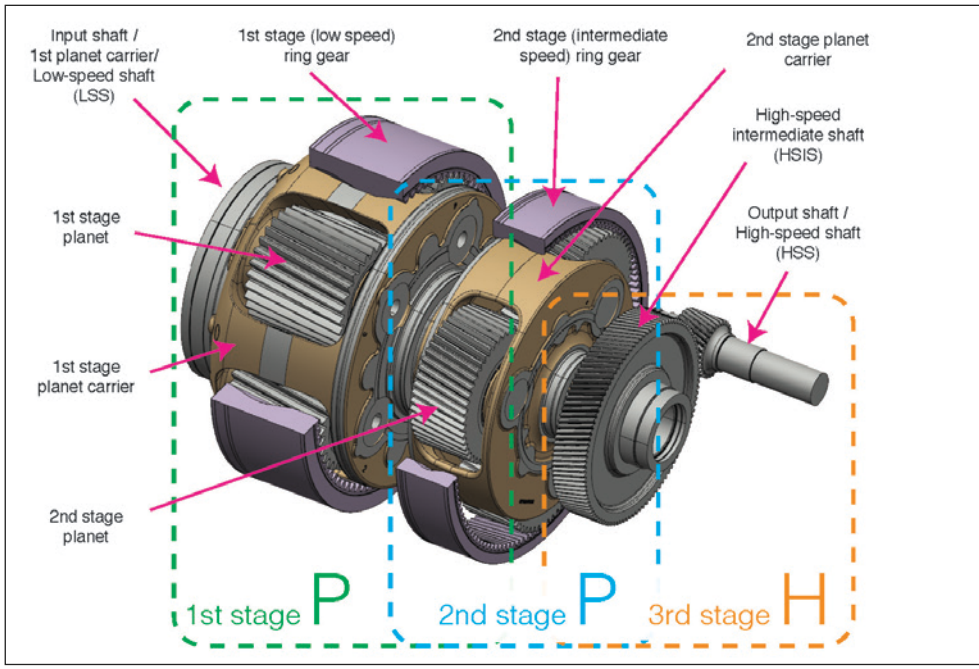

Figure 2—Assembly drawing of shafts and gears from the 3-stage Siemens Gamesa Renewable Energy gearbox (PPH configuration).

The remainder of this paper is organized as follows, The "Model Description" section describes the structural model, and the "Experimental Setup" section describes the experimental procedure used to evaluate the model. The "Results" section covers the correlation between the experimental results and the model simulations. Finally, the "Conclusions" draw the main conclusions of this work and suggest recommendations for future work.

Model Description

A planetary gear stage transforms the input speed according to the gear ratio, which is defined by the relation between the number of teeth of the ring gear and the sun gear, respectively. The same inverse relation applies to the load. This transmission is achieved using a complex rotative gearing system. The ring is held stationary in a typical wind turbine planetary gearbox, whereas the input torque is transmitted to the stage by the planet carrier. The planets contained by the planet carrier are the components that transfer the torque to the sun gear, which is the output of the stage.

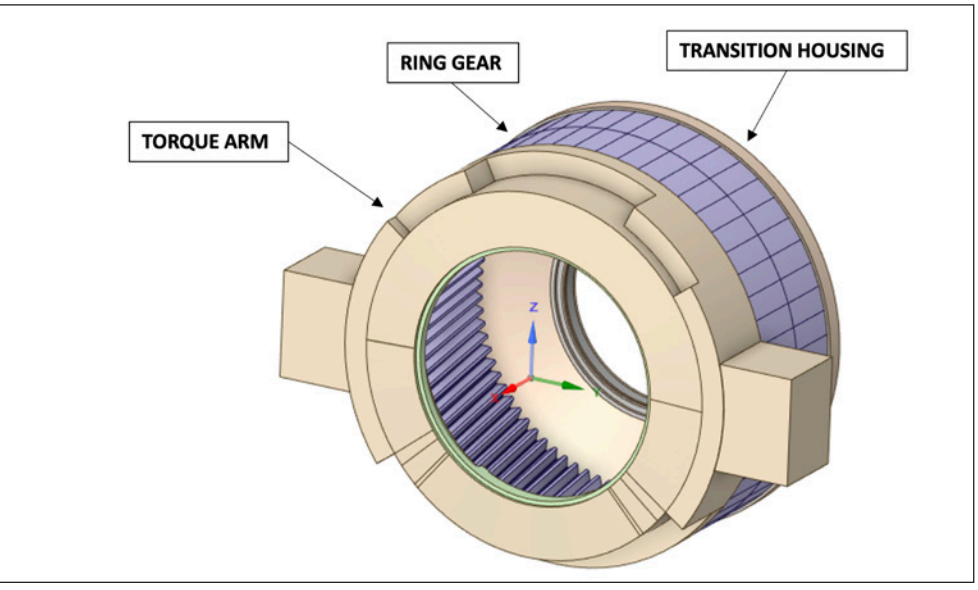

Figure 3—Simplified geometry used for the analysis.

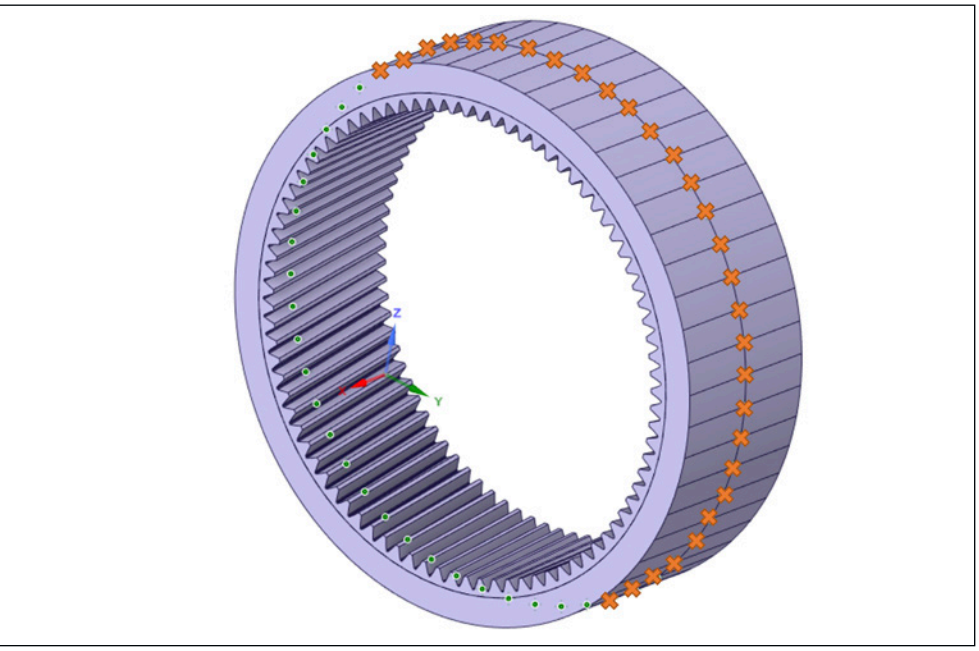

Figure 4—Strain gauges position in FEM model.

In an ideal design, the input torque is shared evenly between the planets in the carrier. The uneven torque distribution is considered by applying the mesh load factor K_γ defined in the standard AGMA 6123 (Ref. 5). The ring gear is stationary. When the flanks of the planet mesh with the ring gear, the planet rolls along the inside of the ring gear. At the same time, the planet's opposite flanks contact the sun gear, transferring the torque to this component. All these interactions between the parts produce the gear forces at the teeth.

It is well known that the complexity of a FEM model is directly linked to the resources required by the model. These resources can be measured in terms of computational cost and time needed to prepare the model and post-process the generated data. Therefore, it is very valuable for day-to-day work to find a model that accurately represents the results in the areas under study without being excessively costly in terms of personal and computational time.

In this study, two different FEM models have been studied. The first one is a detailed model of the first planetary stage of a gearbox with a rated power of 6.x MW. In contrast, the second one is a simplified model shown in Figure 3. These models will be referred to as "high complexity" and "low complexity" models. Both models consist of the torque arm, or rotor side housing, the ring gear, the transition housing between ring gears, and the corresponding bolts and pins that complete the assembly. As shown in Figure 3, the torque arm and transition housing are symmetrical about the z-axis (vertical axis). This applies to models of both complexity levels.

To simulate the initial conditions of the assembly, a preload has been applied to each bolt. The bolts have been represented by beam elements, which have been found suitable to model the effect of the preload and are computationally more efficient than modeling the bolts as solid bodies. The calculations have been performed in *Ansys 2021 R2* software.

The forces of the model react with the torque arms, which are fixed in the Z direction, to recreate the behavior of the gearbox under working

conditions. Also, the bearings' outer rings that support the planetary stage loads have been restricted to rotating in X. Moreover, the ring of the bearing that supports the axial force generated in the gears has been limited in the axial direction. Regarding the interaction between the planets and the ring rear, a force has been applied at each tooth that, in an instant of time, is in contact with a planet, as shown in Figure 5. To do so, it has been assumed that one tooth of the ring gear fully contacts with one tooth of the planet and that the torque is evenly distributed between the planets, i.e., the mesh load factor K_γ equals 1. In helical gears, the contact between the teeth develops progressively along the diagonal line of contact, and several teeth can be in contact simultaneously. Therefore, the whole length of a tooth is never wholly engaged with the mating gear. Due to the complexity of simulating the loads along the line of action of the helical gears, the forces have been simplified to be tangential to the flank of each tooth.

The gear cycle has been defined by using several steps so that the compression-tension effects produced by the planets passing at the tooth roots are simulated. As shown in Figure 6, in the first step of the analysis, the preload was applied to the bolts. Then, in subsequent steps, the mesh force load has been applied at the corresponding flank. For example, in Step 2, the forces that simulate the loads from the planets are applied in the model, as shown in Figure 6. Then, in the following steps, the forces are moved subsequently to the flank of the tooth on the right, hence recreating the gear cycle. This process has been performed for assessments at 50 percent and 100 percent torque. Eight different angular positions have been analyzed in different steps to study the effect of the carrier's angular positions.

It is worth mentioning that to compare the results against the data obtained with the fiber-optic strain sensors, in the FEM model, a node has been positioned in the same location as each strain sensor around the ring gear (Figure 4). Hence, the deformations have been simulated and measured in the same locations.

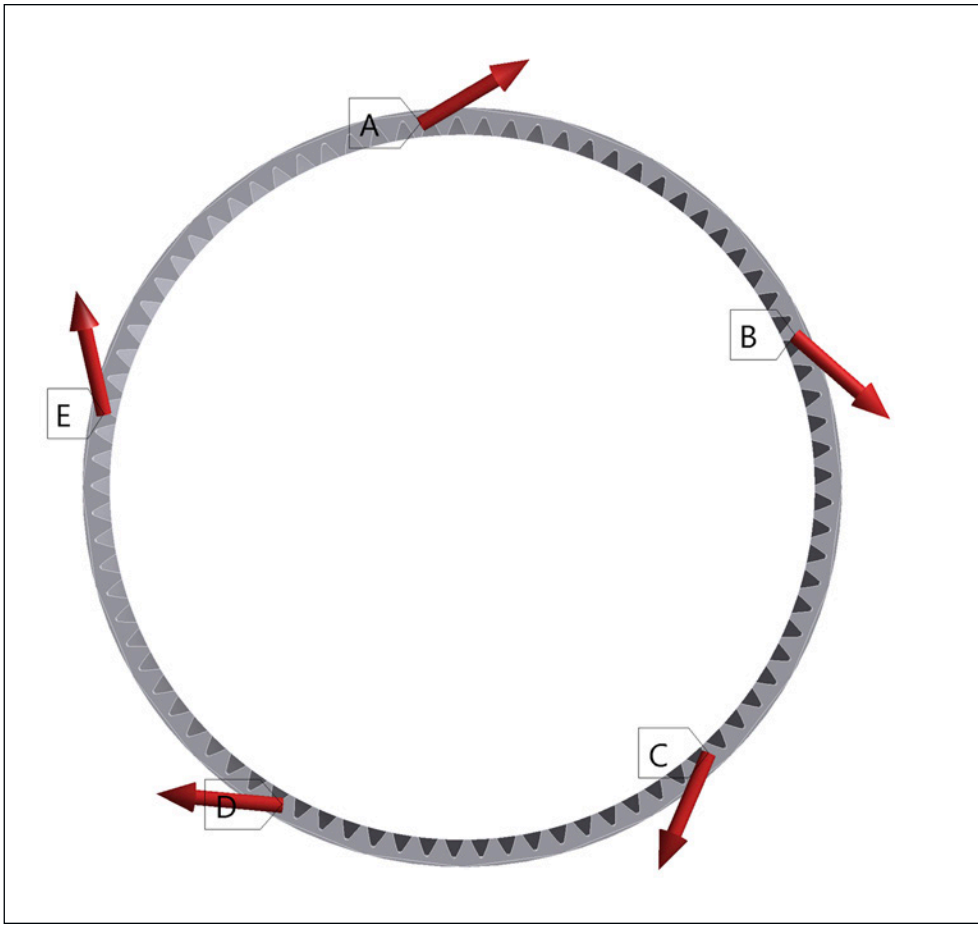

Figure 5—Applied forces in the ring gear.

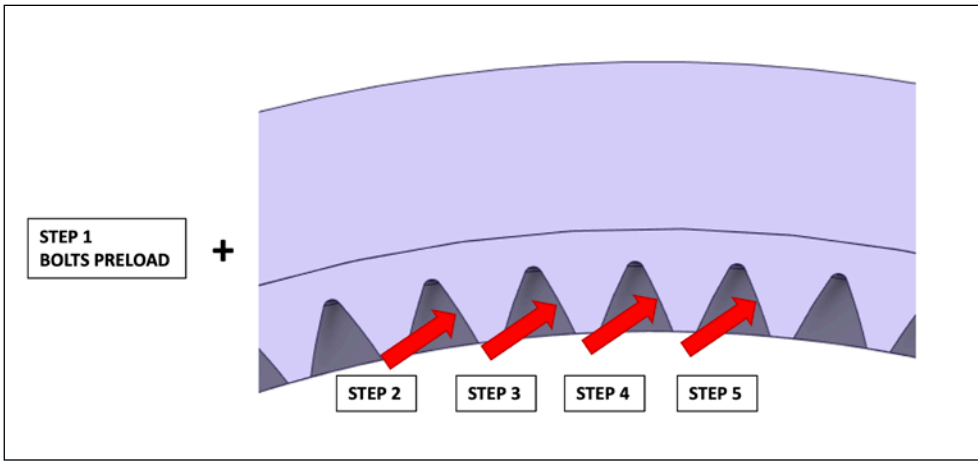

Figure 6—Applied force steps in the ring gear (local).

Experimental Setup

Test Bench

A full-scale prototype gearbox, instrumented with fiber-optic strain sensors on the outer surface of the ring gear, was tested in a back-to-back test bench for up to 100 percent of its nominal torque. All tests presented in this study were performed on the back-to-back test bench shown in Figure 7, property of the company DMT GmbH & Co. KG (Ref. 6) at Krefeld (Germany), with electric motors of rated power of 7.5 MW. The position of the fiber-optic sensors can be seen on the outer surface of the first stage ring gear of "Test Gearbox 1."

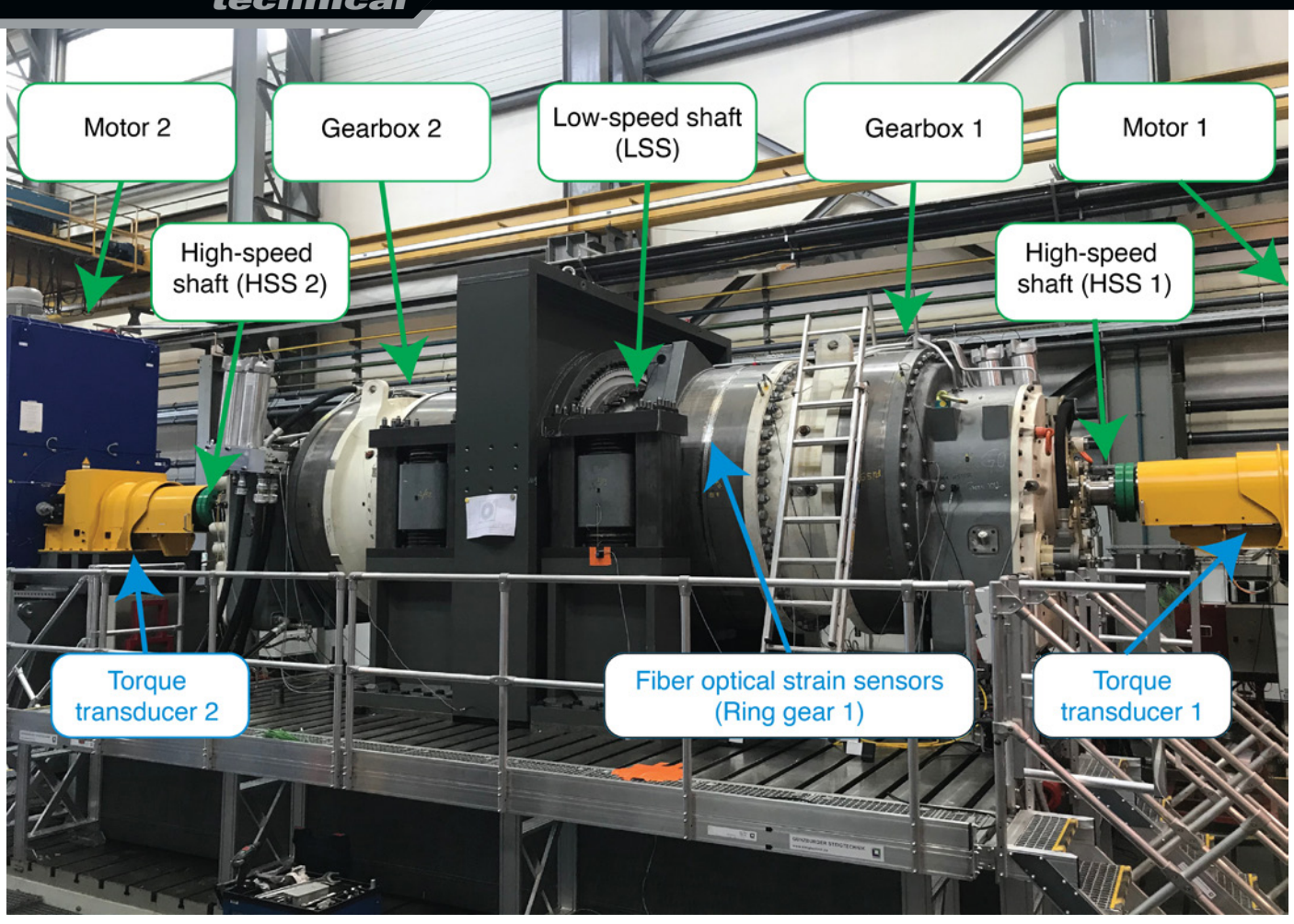

Figure 7—SGRE gearboxes on a back-to-back test bench (property of DMT GmbH & Co. KG).

Fiber-Optic Strain Sensing

A new method to measure the input torque of wind turbine gearboxes was introduced in Ref. 7. This method is based on strain measurements on the outer surface of the ring gear. The instrumentation requirements and the data logging process are simplified because the ring gear is static. Optical strain sensors based on fiber Bragg gratings (FBGs) were used because they offer a higher signal-to-noise ratio and are immune to electromagnetic interference. Since multiple strain sensors can be accommodated in a single fiber, they allow a more straightforward installation. A satisfactory correlation was found between the input torque of the carrier and the deformations on the outer surface in Ref. 7.

Four optic fibers were installed on the outer surface of the first stage ring gear, at the middle section along the width of the ring gear in the axial direction, as shown in Figure 7. The fibers were installed tangentially to the middle

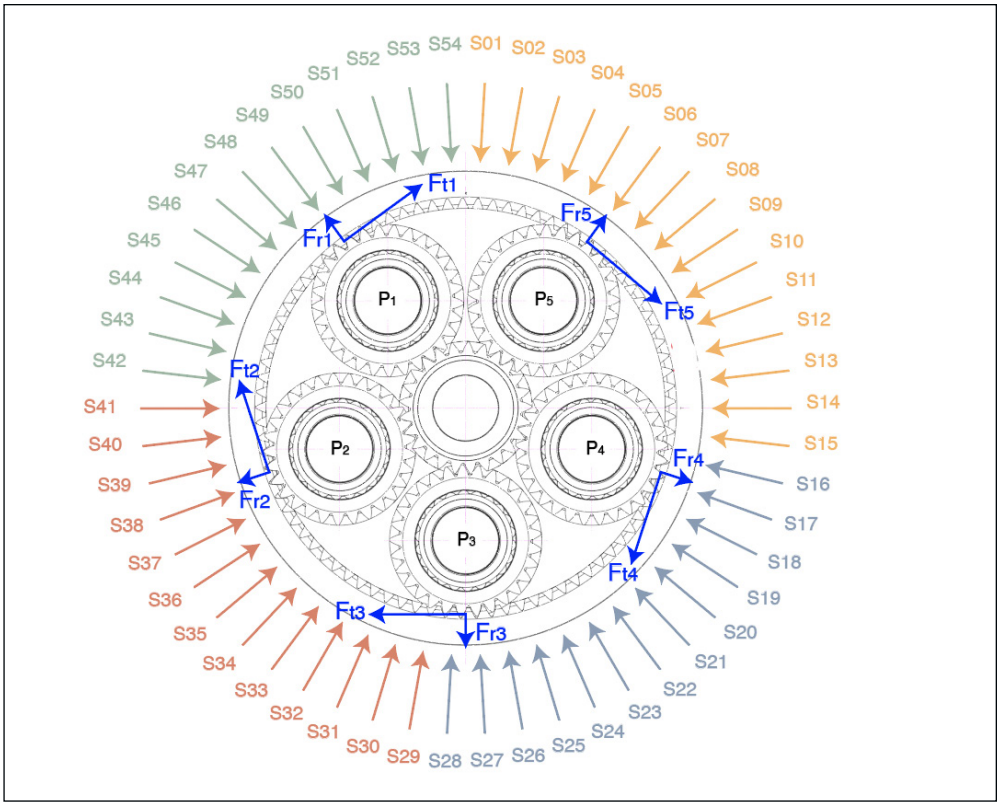

Figure 8—Location of the fiber-optic strain sensors (S01 to S54).

section, covering a complete revolution along the outer perimeter of the ring gear. Figure 8 shows the radial and angular location of all the strain sensors with the corresponding labels in a rotor side section view. The four colors of the sensor labels indicate how the FBGs belong to separate fibers (S01 to S15 in fiber number 1, S16 to S28 in fiber number 2, S29 to S41 in fiber number 3, and S42 to S54 in fiber number 4). The fiber optical sensors were supplied and installed by the company Sensing360 B.V. (Ref. 8). A more comprehensive description of the optical fiber instrumentation used can be found in Ref. 7.

Fiber Bragg gratings are sensitive to strain and temperature. The signals were detrended to remove the effect of temperature on the measured shifts in wavelengths of the FBGs. Once the long-term shift caused by temperature had been removed, the remaining signal was caused entirely by the strain imposed by the planet gear mesh events. An inductive sensor was used to provide a pulse for every full rotation of the input shaft so that the relative position of the planet carrier is known, and peak-to-peak values can be assigned to individual planets, as shown in Figure 9.

Nineteen short tests were performed under different stationary speed and torque conditions to characterize the relationship between strains and torque and the mesh load factor. The torque level was increased in five percent increments from 10 to 100 percent of the nominal torque. For each test, strain data was recorded for around 35 revolutions of the carrier. The gearbox rotational speed was kept constant and equal to the nominal value. A correlation between the average torque and the average peak-to-peak values of the strain sensors placed on the outer surface of the ring gear was found in Ref. 7 shown in Figure 10. Since peak-to-peak values can be assigned to individual planets, the procedure also can provide information about the load sharing between planets. Figure 11 shows the average K_γ values of the five planets against torque presented in Ref. 9. The values shown by the circular markers in Figure 11 represent the mean value of all 54 sensors, and the shaded patches represent the bounds limited by the minimum and maximum K_γ from all sensors.

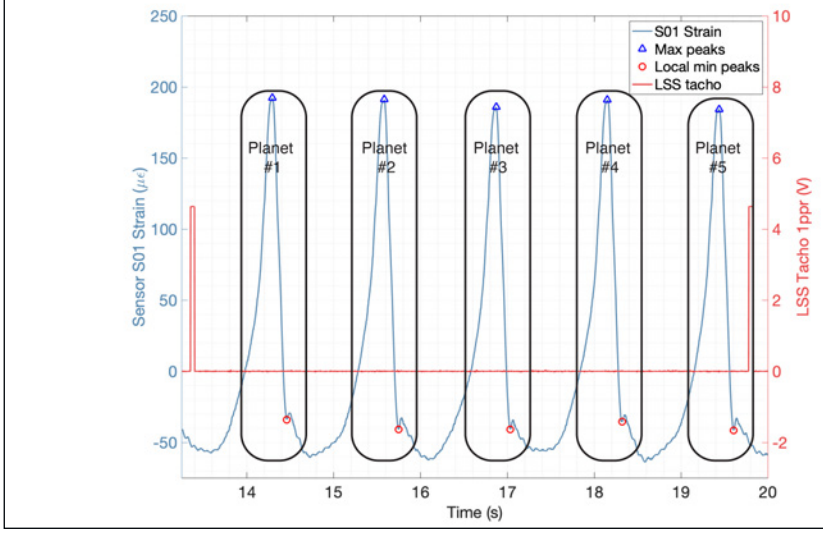

Figure 9—Sensor S01 strain signal (left axis) during a single revolution of the input shaft (right axis) with detected peaks assigned to the corresponding planet.

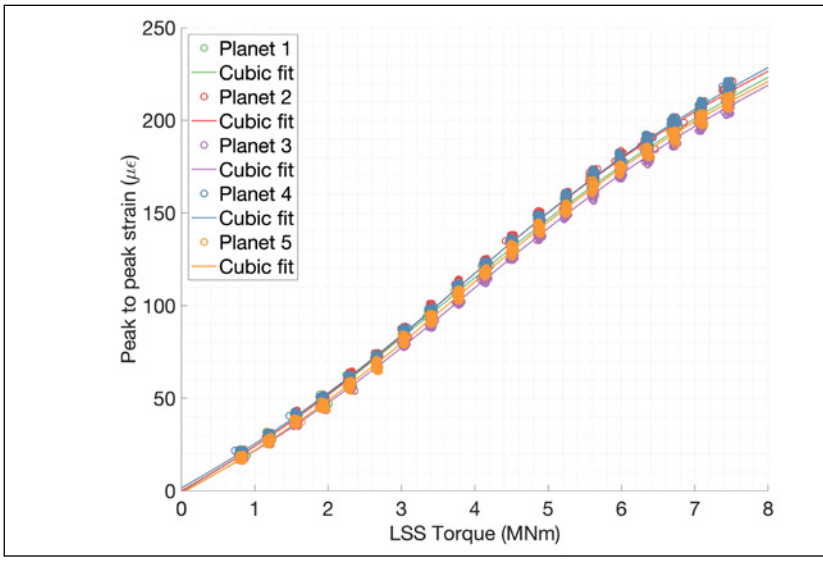

Figure 10—Peak-to-peak strain values of sensor S52 vs. torque in the low-speed shaft separated for each planet, and their corresponding cubic fit.

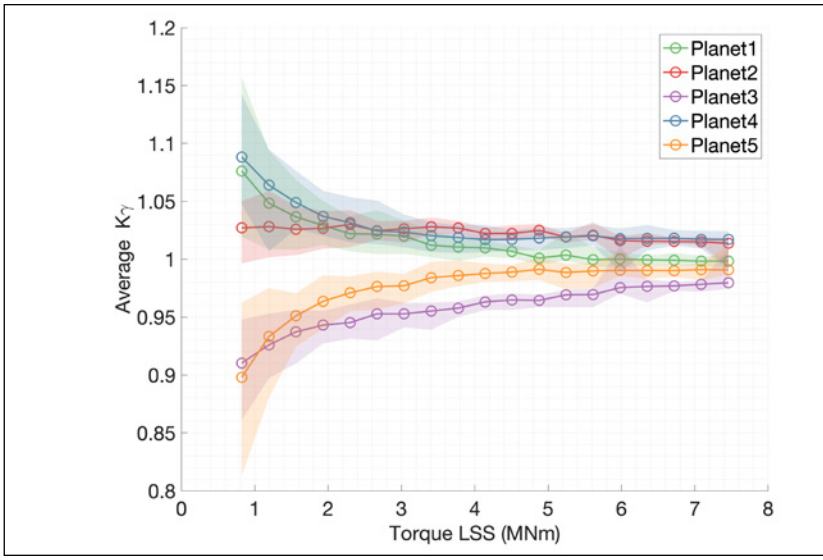

Figure 11—$K_{\gamma,\,avg}$ values from all fiber strain sensors. The mean value is represented by the circular marker and the shaded patch.

Results

As depicted in Figure 8, strain sensors have been positioned in the middle section of the ring gear along the external surface. A total of fifty-four sensors were installed using four fibers. The results provided by the FEM model have been compared to the experimental ones by extracting the elastic strain results at the nodes located at the same position as the strain gauges as shown in Figure 4.

The correlation of the results of the 100 percent torque load case is shown in Figure 12. Normalized strains are shown according to their angular position in the ring gear. This angular position, shown in Figure 8, is defined clockwise in the rotor side view with zero at the top vertical location. Simulation results for both high- and low-complexity models, presented in the "Model Description" section, are shown in Figure 12, denoted as "FEM High" and "FEM Low". As can be inferred, the FEM strain results agree well with the strains measured with fiber-optical sensors. As expected, the match between simulation and sensors is less accurate for the lower complexity model. A single planet, identified as number 4 in Figure 8, yields a lower agreement between simulation and sensor strain values. Nevertheless, the average differences between FEM models and sensors were considered very satisfactory based on previous experience correlating strain measurements.

Two alternative approaches have been used to quantify the accuracy of the results. First, the strains of all 54 sensors have been compared to the simulation results using the root mean square (RMS) value. This provides a picture of how well the strains are simulated for the complete revolution of the ring gear. Additionally, the accuracy of the maximum strain levels corresponding to each of the five planets has also been assessed. At 100 percent torque level, the deviation from measurements achieved by the high complexity model for step number 5 (see Figure 6) is 11.5 percent when considering the root mean square level of all 54 strains; and 12.4 percent when considering the strain maxima peaks. In comparison, for the same load step number 5 in the low complexity model, a deviation of 25.2 percent was observed using the root mean square approach and 21.4 percent when comparing the strain maxima.

The effect of the angular position of the planet carrier on the simulated strains has been studied using different steps. For each planet carrier position, four different teeth were loaded, as described in Section 2. The planet carrier was then rotated 90 degrees to study another four teeth, which accounted for eight angular positions of the planet carrier in total. This study of the angular position of the carrier was accomplished using the low-complexity model. The average accuracy obtained by all eight steps has been found to be 23.9 percent using the RMS approach and 22.9 percent for the strain maxima. Depending on the angular positions the variability observed was ±2.13 percent and ±3.85 percent respectively.

We found the correlation of the compressive stresses before and after the highest tensile strain positions is less accurate than the correlation obtained in the rest of the positions showing compressive stresses. This effect appears for both torque levels, 50 percent and 100 percent, and higher and lower complexity models. The discrepancy in the results of the positions corresponding to planet four might be because of neglecting the loads of the gearbox that come from the rest of the stages. Moreover, as has been described in Section 2, the input torque is assumed to be evenly distributed between the planets. This assumption might also be a source of discrepancy in the correlation of the results since the torque distribution between the planets is not even. The uneven distribution of torque is considered in the mesh load factor Kγ. Further investigations should be carried out considering K_γ in the FEM model to obtain a more accurate correlation.

Regarding the transitions from minimum to maximum strain values, a good correlation is observed in all the positions. Hence, similar compressive-tensile behavior is described by both the FEM model and the strain gauges around the ring gear. Overall, a satisfactory agreement has been obtained between the FEM model and the results obtained by the optical strain sensors. Thus, the FEM model has been deemed reliable for obtaining accurate results and performing further investigations regarding technical aspects of the gearbox. As expected, the higher complexity model yields more accurate results. The complexity of the model must be considered thoroughly to achieve the optimum balance between accuracy and cost for the application under study.

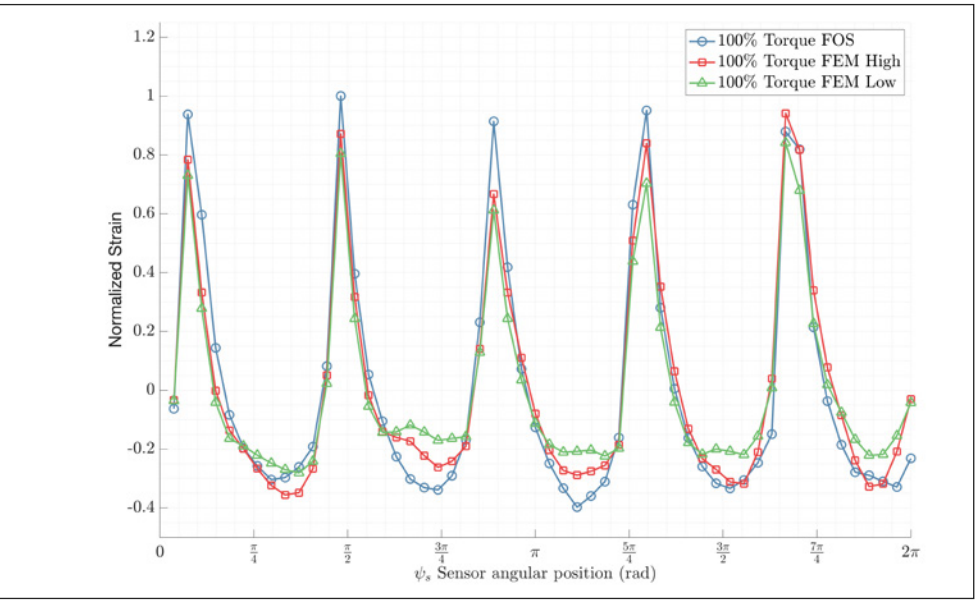

Figure 12—Fiber-optic strain sensor (FOS) measurements vs. simulation results (FEM) at 100 percent torque, "High" and "Low" represent the complexity of the model used.

Conclusions

We have performed an experimental evaluation of the structural finite element model of a 6MW wind turbine gearbox using fiber-optic strain sensors. Two different FEM models have

been studied with different degrees of complexity. Fifty-four fiber-optic Bragg gratins were used to measure strain on the outer surface of the first stage ring gear. Tests were performed in a full-scale back-to-back gearbox test bench under different torque conditions.

A good correlation has been found between the experimental strain measurements and the results of the FEM models. The difference between simulation and strain sensors obtained using the high complexity model has been 11.5 percent when considering the root mean square level of all 54 strains and 12.4 percent when considering the strain maxima corresponding to the mesh action of each planet. These results are considered very satisfactory based on previous experience with strain measurements. The differences for the low complexity model rise to 23.9 percent and 22.9 percent respectively. As expected, the match between simulation and sensors is less accurate for the lower complexity model. Therefore, a suitable trade-off between complexity and desired accuracy is needed considering the application of structural models.

Further investigations related to mesh load factor Kγ, the loads of the gearbox that come from downstream gear stages, and different angular positions of the planet carrier(s) are suggested for future work. This is expected to yield a better correlation of the results since the uneven distribution of the transmitted was not considered in the FEM models presented in this study.

Once correlated, these structural models can be used for further investigations, such as evaluating the effect of modifying critical design parameters. For example, the effect of ring gear rim thickness of the first stage can be studied with this model. The first stage ring gear is arguably the most expensive component of a wind turbine drivetrain. Gearbox manufacturers strive to make the rim of the ring gear as thin as possible while complying with the minimum thickness requirements set by their design rules and gear rating standards. These structural models can be used to research the effect of rim thickness on the tooth root stresses, which is contemplated by the KB factor defined in the standard ISO 6336 (Ref. 10).

Increasing the confidence in structural models through experimental data allows a more optimized gearbox design, which significantly improves torque density and the overall cost of the gearbox.

Acknowledgments

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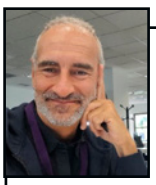

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Process and Tool Design Optimization for Hypoid Gears with the Help of the Manufacturing Simulation *BevelCut*

Melina Kamratowski, Julia Mazak, Jens Brimmers, and Thomas Bergs

Introduction and Motivation

Bevel gears are a machine element used for transmitting torque and speed at a shaft angle (Ref. 1). When operating under an axial offset, they are also referred to as hypoid gears. Both are manufactured using a multipart tool consisting of a cutter head as a solid body and exchangeable stick blades (Ref. 2). For dry cutting, stick blades made of carbide are inserted into the slots of a cutter head. The most common setup includes an inside and an outside blade in one blade group, which distributes the cut onto two cutting edges. Depending on their position in the cutter head, the blades of a blade group are referred to as the inside blade (IB) and outside blade (OB) (Ref. 1). The blades are subject to wear. When they cannot hold the geometric tolerance of the part, they need to be taken out of the cutter head, reground, and properly repositioned (Ref. 3).

Bevel and hypoid gears are usually manufactured on CNC machines with six independent axes. The machine motions follow the principle of the basic machine resulting in a complex kinematic relationship between tool and workpiece (Ref. 1).

Nomenclature

A_{cu}	machined area
i	gear ratio
h_{cu}	chip thickness
l_{cu}	chip length
m_{nm}	mean normal module
N_{cu}	number of cuts
R_w	nominal cutter radius
z_0	number of blade groups
$z_{1/2}$	number of teeth (pinion/ring gear)

This paper was first presented at the 17th CIRP Conference on Intelligent Computation in Manufacturing Engineering, 12–14 July, Gulf of Naples, Italy. It is reprinted here with permission.

For the manufacturing of bevel and hypoid gears, the available methods are characterized according to their way of indexing. For discontinuous face milling, one slot is cut after another from the stationary workpiece, the tool is retracted, the workpiece is indexed, and the next slot is cut. For continuous face hobbing, the indexing motion results from the relative position of the rotating workpiece and rotating tool. For both cutting methods, two ways of profile generation exist. When rolling, the workpiece's curvature is generated in the profile direction. As the generating path increases with the outside diameter, ring gears with a ratio larger than $i \geq 2.5$ are manufactured using a more economical approach. When plunging, the tool is fed directly into the workpiece resulting in straight gear flanks. The lack of curvature is compensated by additional curvature on the rolled pinion, so a smooth transmission is ensured for the gearset. This paper focuses on the combination of face hobbing plunging and face hobbing generating (Refs. 1, 4).

Due to the complex interaction between part design, resulting tool geometry, and the process design, manufacturing of bevel and hypoid gears poses several challenges (Refs. 3, 5–8). Figure 1 gives an overview of common obstacles during machining.

Changing chip geometry along the cutting edge and during the process oftentimes results in nonuniform tool wear. Areas of increased tool wear determine the part quality and thus lead to tool changes, regrinding of the blade, and process interruption (Refs. 3, 6, 8).

Through the inside and outside blades, the cut is divided onto the cutting edges of the respective blade resulting in enough space between the clearance side of the blade and the opposing flank. Thus, a favorable chip flow as well as even wear is ensured. However, poor tool design or adverse kinematic parameters can result in the engagement of the clearance side in the cutting processes. This results in disadvantageous cutting conditions and thus, increased or even catastrophic wear of the clearance side (Refs. 1, 3).

Interference between the tool and opposing flank occurs often at the toe and root of the workpiece for face hobbing. The crossing paths between inside and outside blades as well as complex tool modifications result in an unintended change of the tooth shape, which is detrimental to the gearset's performance (Refs. 1, 3).

The blade height can affect both efficiency of the tool's regrinding as well as the tool wear. If the blade height is chosen too large, more material is ground off the worn blades. Removing unnecessary material makes the process uneconomical. If the blade height, however, is too small, the blade's shoulder or the cutter head touches the workpiece's surface. The results can range from damaging the part to breakage of the tool or even a catastrophic failure of the machine axles (Refs. 1, 2).

Poor tool design or unfavorable kinematic parameters can lead to an incomplete machining of the workpiece's root. The remaining material sticks out in the form of a fin at the root. Due to its small dimensions, the fin is likely through-hardened during the subsequent heat treatment process. The brittle, hard particles can lead to failure of the gear during the finishing operation or during application (Refs. 1, 4).

The described challenges of bevel and hypoid gear manufacturing can be addressed with the help of process design, tool design, and gear design. Since there is a unique interdependence between tool, gear, and process parameters for bevel and hypoid gears, it is oftentimes difficult to determine which parameter has the highest impact without changing the design. Furthermore, current available design software can only give a qualitative output on the effect of design changes (Refs. 1, 3, 4, 8–11).

Objective and Approach

As the challenges in bevel and hypoid gear manufacturing need to be addressed, the objective of this paper is to show the tool and process design can be optimized based on the results of the manufacturing simulation *BevelCut*. As in the past, research

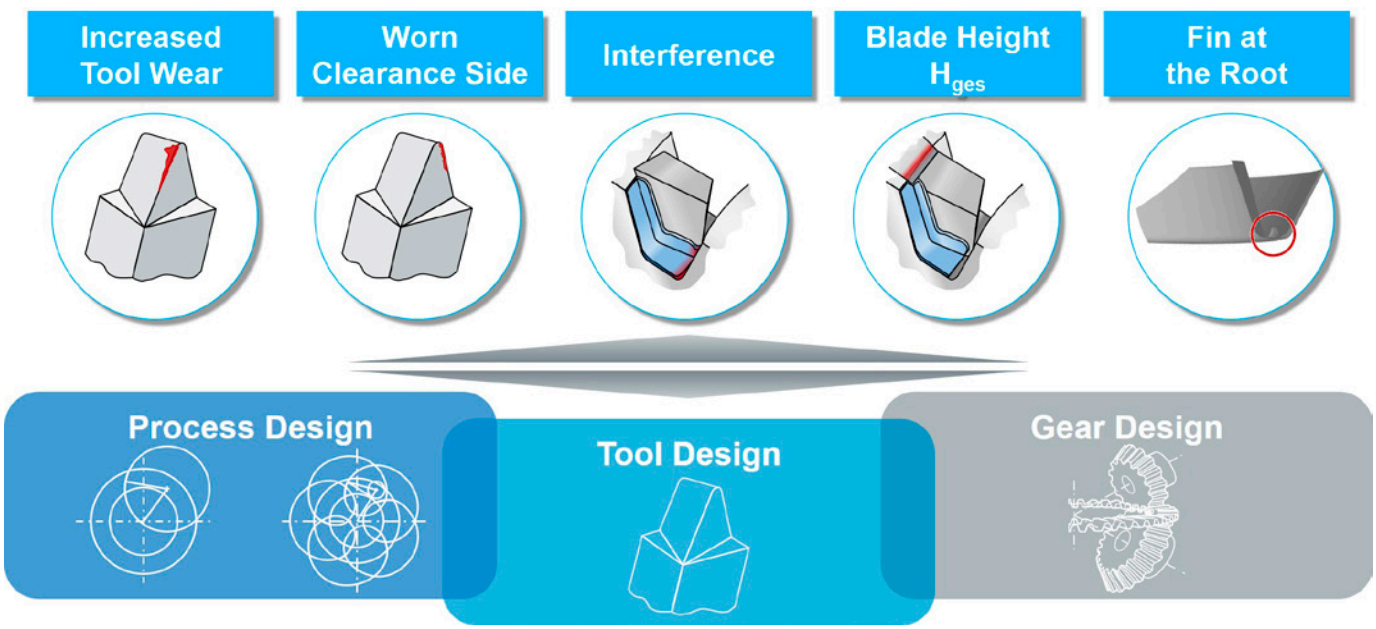

Figure 1—Challenges in bevel gear manufacturing.

has focused on face milling processes, for the first time both face hobbing rolling, and face hobbing plunging are analyzed in this paper.

First, the manufacturing simulation *BevelCut* is introduced. The underlying mode of operation for the planar penetration calculation is illustrated. An overview of the current scope and features as well as simulation results demonstrates the capability of the software.

As a next step, examples of experimental hypoid designs are analyzed by simulating the manufacturing of both ring gear and pinion by means of *BevelCut*. The resulting characteristics will indicate the cutting conditions for both parts.

As the different characteristics represent different aspects of the cutting conditions, the relationship between individual simulation results and cutting phenomena is investigated. Based on the underlying principle, corrective measures are deduced.

Finally, the tool and process data are adapted for the sample gearset according to the findings. The optimized design is simulated again by means of *BevelCut*. The simulation results verify and quantify the effect of the changes.

Manufacturing Simulation *BevelCut*

The manufacturing simulation *BevelCut* has been developed at the Laboratory for Machine Tools and Production Engineering (WZL) of RWTH Aachen University and has been applied mainly to analyze face milling rolling and plunging processes in the past (Refs 3, 12). Due to recent innovations, the program's scope has extended to face hobbing rolling and plunging processes as well (Ref. 8). The planar penetration calculation as the underlying principle, however, remains the same for all process methods and is illustrated in Figure 2.

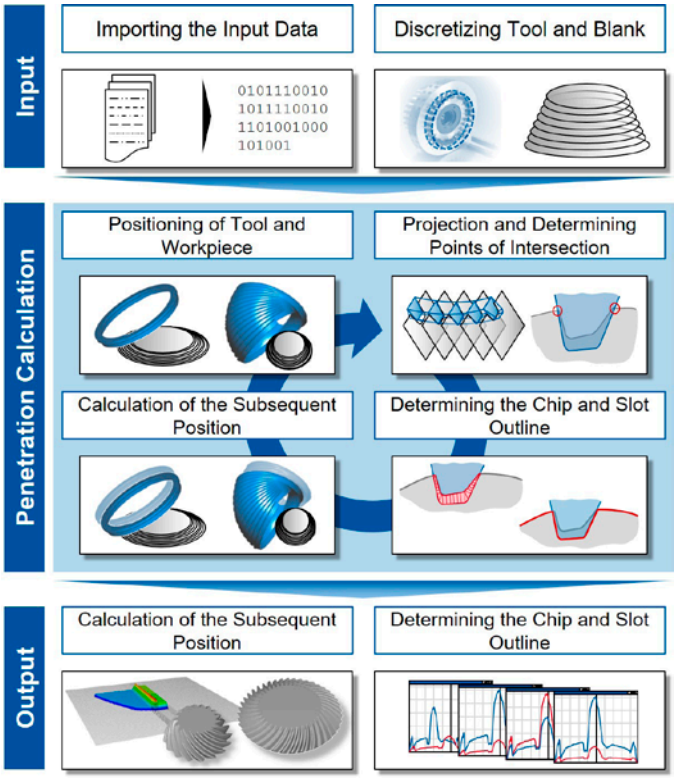

Figure 2—Mode of operation of the manufacturing simulation BevelCut.

After importing all necessary data from the design software, the workpiece blank represented by a bevel frustum is discretized along its rotational axis. As a result, the blank is represented by circular planes of differing diameters. The tool is discretized along its cutting path. The resulting enveloping body includes the tool geometry as well as the machine and process kinematics (Ref. 3, 12).

The core of the penetration calculation consists of four steps. First, the tool and workpiece need to be positioned correctly according to the regarded moment in time. Subsequently, the tool profile is projected onto the individual planes, and the intersections between the workpiece and the projected tool outline are determined. With the help of these intersecting points, the chip outline can be determined and thus, the new slot outline. This information is stored and as a next step, the tool and workpiece are repositioned again. These four steps are repeated until the end of the process has been reached (Refs. 3, 12).

The resulting workpiece geometry as well as all information on the undeformed, 3D chip geometry are evaluated as part of post-processing. For every cut that occurred throughout the process, the chip thickness h_{cu} can be evaluated along the unrolled profile edge as a maximum $h_{cu,max}$ or mean h_{cu},mean value. The chip thickness h_{cu} represents the load of material a point on the profile edge has to the machine. Similarly, every point of the unrolled profile edge can also be attributed to a chip length l_{cu}. The chip length l_{cu} indicates how long the tool and workpiece are in contact and thus, is an indicator of friction and heat within the process. The machined area A_{cu} combines the chip thickness with the length of the chip. These values are available for every chip cut at every point in time by every blade. To condense the information further, the maximum and mean chip thickness can also be evaluated for the entire process. Based on this information, the number of cuts N_{cu} each point on the profile edge contributes to throughout the process can be determined. By analyzing the number of cuts N_{cu}, the influence of the pulsating load on the blade's fatigue life can be determined (Refs. 3, 12).

Currently, the manufacturing simulation *BevelCut* can simulate both face hobbing and face milling processes. Straight plunging and single-generating methods are implemented as well. Therefore, every combination common in the industry is represented. The standard blade profile as well as all blade modifications such as profile crowning, tip relief, and root relief as well as their combinations allows for reproducing every possible gear design.

Simulation Results

The simulation was performed for a gearset of an automotive application. For this example, neither gear design nor process was optimized. The input data is shown in Table 1.

Parameter		Pinion	Ring gear
Number of teeth z_1 / z_2	[-]	11	39
Normal mean module m_{nm}	[mm]	3.59	3.59
Number of blade groups z_0	[-]	17	17
Nominal cutter radius R_w	[mm]	88	88
Generating process	[-]	Rolling	Plunging

Table 1—Simulation data.

The distribution of the chip thickness h_{cu} is shown in Figure 3. For every cut, different characteristics were calculated. The color gradient represents each cut from the beginning of the process (blue) to the end of the process (red). The superimposed black line represents the maximum value of the characteristics while the gray line shows the mean value.

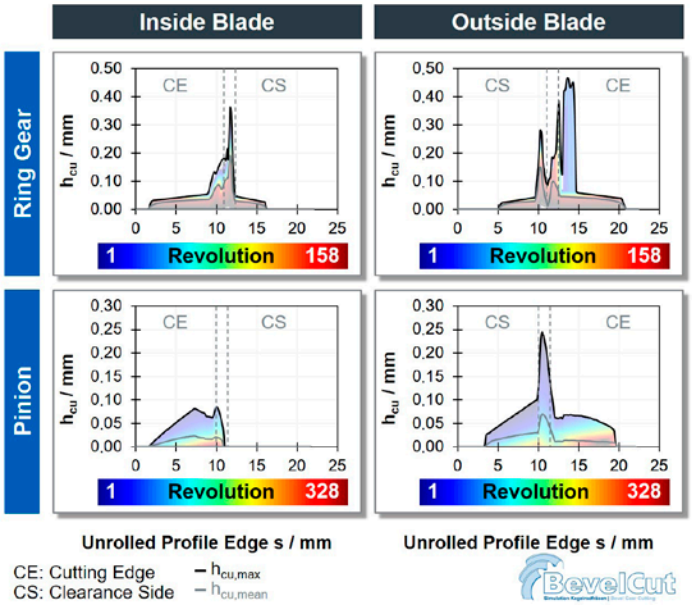

Figure 3—Chip thickness distribution h_{cu}, $h_{cu,max}$, *and* $h_{cu,mean}$.

The ring gear was manufactured by plunging. The outside blade shows a significantly higher chip thickness h_{cu} than the inside blade. Both blades have a significant portion of the clearance side contributing to machining. The outside blade furthermore shows a larger number of high values for the chip thickness h_{cu} occurring on the radius of the clearance side.

For the pinion, which was manufactured by rolling, the outside blade also displays significantly higher values for the chip thickness h_{cu} than the inside blade. However, the highest maximum chip thickness $h_{cu,max}$ occurs at the tip of the blade. The clearance side of the outside blade contributes to machining to a great extent.

Overall, the values for the chip thickness h_{cu} vary significantly during the cutting process for both pinion and ring gear. The maximum values occur mainly during the initial tool rotations. The course of the chip thickness h_{cu}, however, differs between the ring gear and pinion. The chip thickness h_{cu} at the clearance side indicates the existence of interference. The cuts are differently distributed between ring gear and pinion. For both processes, the outside blade shows the most critical values.

Figure 4 focuses on the number of cuts N_{cu} on the left and the maximum chip length $l_{cu,max}$ on the right side for the outside blade as it is the most critical one. The maximum number of cuts N_{cu} is reached at the tip of the ring gear and at the flank of the cutting edge for the pinion. While there is a uniform distribution for the ring gear, the pinion shows a more irregular course with two maxima.

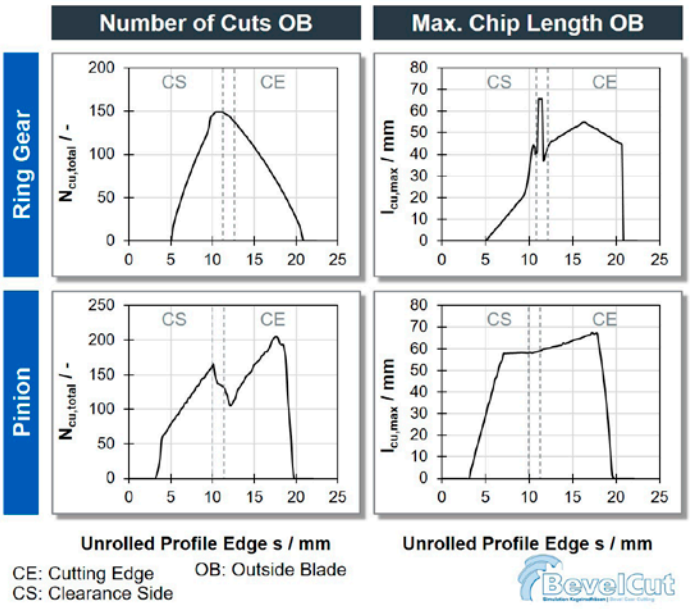

Figure 4—Analysis of the number of cuts N_{cu} *and max. chip length* $l_{cu,max}$.

The peak of the maximum chip length $l_{cu,max}$ occurs at the clearance side radius for the ring gear. The pinion, however, machines the longest chips at the flank of the cutting edge. The clearance side contributes to short chips for the ring gear, but longer chips for the pinion.

As the number of cuts N_{cu} conveys information on the dynamic load, the highest pulsating load occurs at the tip of the ring gear blade and at the cutting edge of the pinion blade. The chip length l_{cu} allows conclusions on the contact length between the workpiece and tool during the process. The longest contact occurs at the radius of the clearance side for the ring gear and at the flank of the cutting edge when machining the pinion.

The 3D model in Figure 5 shows the total view or the individual flanks of the workpiece including deviations due to manufacturing. Details of the slot outline are visible in the individual intersecting planes. Thus, the noticeable fin occurring in the root of the ring gear can be detected easily and its dimensions can be quantified. The pinion outline shows no fins.

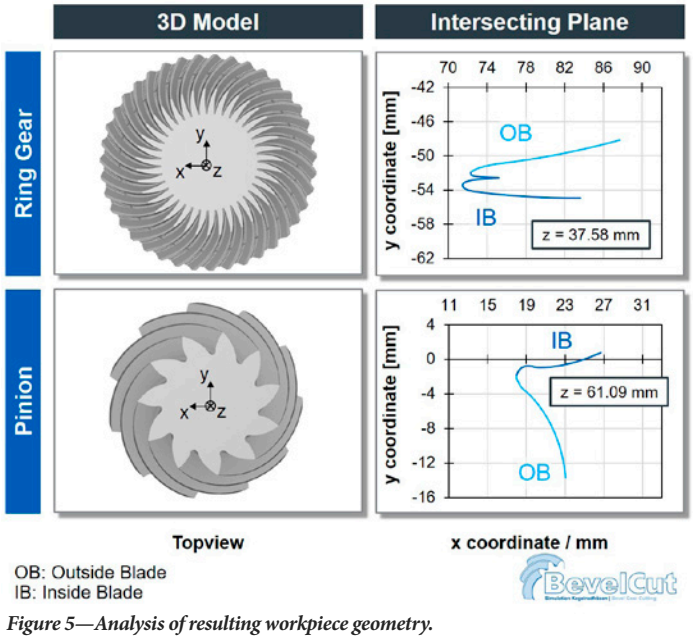

Figure 5—Analysis of resulting workpiece geometry.

Application Suggestions

As the characteristics represent the cutting process, the correlation between the individual variables and cutting phenomena is necessary to optimize the tool and process parameters. Figure 6 gives an overview of the cutting phenomena and the underlying characteristics, whose relevant area is marked with a red circle.

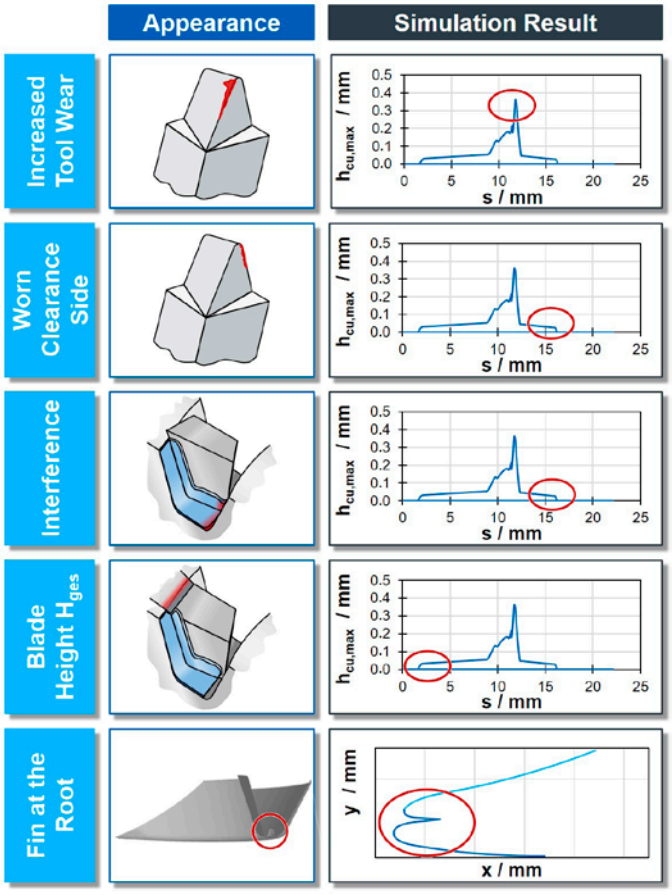

Figure 6—Correlation of characteristics and cutting phenomena.

Tool wear can be influenced by many parameters such as cutting speed, tool angles, tool radii, and feed. The feed directly influences the chip thickness h_{cu}. Areas of increased chip thickness h_{cu} as well as steep gradients or peaks indicate a higher risk for increased or disproportional tool wear. Corrective measures include the identification of where on the profile edge and where during the process these irregularities occur. By adapting the feed ramp accordingly, the chip thickness h_{cu} can be affected. The general blade position as well as changing the feed strategy such as vector feed or modified plunging can affect how the chip load is spread between the inside and outside blade.

Similarly, wear on the clearance side can be detected with the help of the chip thickness h_{cu} as well. Corrective measures for this case focus on avoiding a contribution to cutting. This can be achieved by changing the blade position and spreading the chip load evenly between the inside and outside blades. Adapting the tool geometry to obtain slimmer blades is another measure. If no chip thickness occurs on the clearance side, but wear still occurs, a further analysis of the chip flow will be necessary.

Interference can be detected by the existence of chip thickness h_{cu} on the clearance side. They are usually high but only occur for a short amount of time. Corrective measures include the adaptation of the blade position as well as the inactive tool geometry.

Whether the blade height needs to be adapted can be determined through the position of the chip thickness h_{cu} on the unrolled profile edge. If the entire profile edge contributes to machining, increasing the blade height is advisable to avoid a collision with the shoulder. If the simulation results show a large inactive portion of the profile edge, a reduction of the blade height is advisable. When adapting the blade height, however, the building tolerances during cutter head setup should be taken into consideration.

A fin at the root can be detected when analyzing the resulting workpiece geometry. So far, available design programs give a qualitative, visual output of the root geometry. Currently, there is no detailed possibility for quantitative validation. Corrective measures to avoid fins are the adaptation of the blade position as well as adapting the tool geometry.

Optimized Process Design

For optimization, the same gear design as defined in Table 1 was used. To keep the functionality of the gearset, the flank geometry must remain identical, and the tool and process optimization may not change or interfere. As most problems occurred at the ring gear, the focus is on the simulation results of the ring gear.

Figure 7 shows the effect of the changes on the distribution of the chip thickness h_{cu}. The increase in the blade height resulted in more clearance between the shoulder and the workpiece surface. By decreasing the blade width as well as the clearance radius, the slimmer blades do not interfere with the clearance side anymore. Through an adaption of the position of the inside and outside blades, the chip thickness h_{cu} is more evenly distributed between the blades. As a consequence, the maximum chip thickness $h_{cu,max}$ is reduced significantly and interference was eliminated.

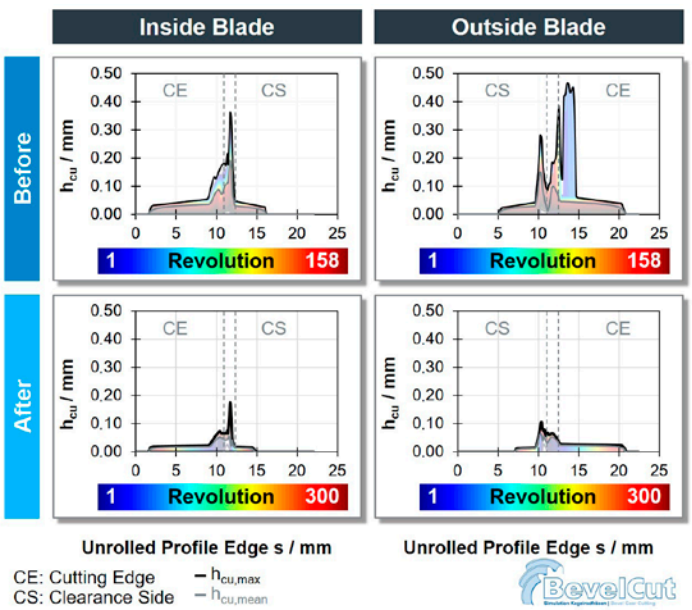

Figure 7—Ring gear chip thickness distribution h_{cu}, $h_{cu,max}$, *and* $h_{cu,mean}$.

To eliminate the fin at the root of the ring gear, further modifications were added to the optimization. The ring gear's slot geometry with and without the optimization is depicted in Figure 8.

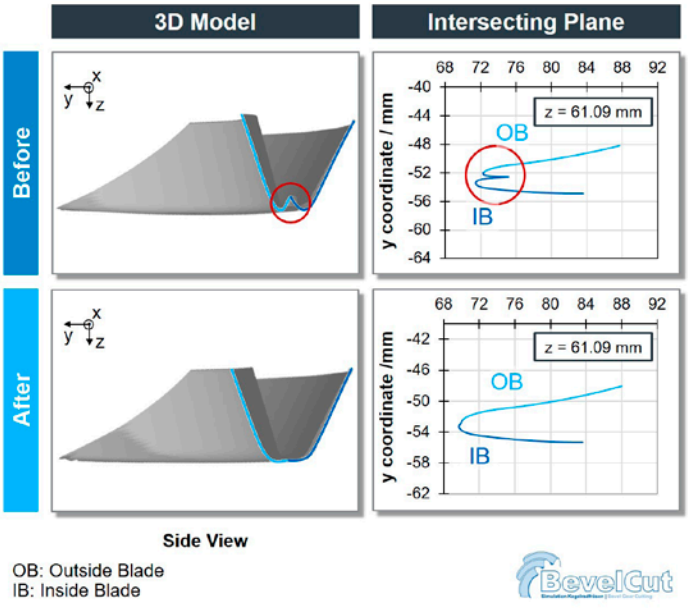

Figure 8—Ring gear slot geometry.

The limitations, however, consisted of not creating interference at the toe again and backlash as well as tooth thickness having to remain the same. As the blade width cannot be increased to cover more of the slot width, the point radius and thus the position of the inside and outside blade were adapted once more. This results in a decreased risk of interference, and a more even distribution of the cut between inside and outside blades is the result. As a consequence, the reductions of the maximum chip thickness $h_{cu,max}$ is reduced and the fin is eliminated. However, this example also illustrates that the challenges in manufacturing and connected phenomena limit the scope of possible changes to tool and process design. Therefore, it is important to determine the quantitative effect of the changes on the cutting characteristics and the resulting workpiece geometry.

Summary and Outlook

In this paper, the mode of operation as well as the current scope of the manufacturing simulation *BevelCut* was presented. The cutting characteristics for an exemplary design were evaluated for both pinion and ring gear manufactured using face hobbing rolling and plunging. A relationship between the simulation results and cutting phenomena was established. Based on this relationship, corrective measures were deduced. The simulation results show a successful optimization of the tool and process parameters for the gear design. Thus, for the first time, a simulation-based tool and process optimization were conducted for face-hobbing processes.

In the future, the manufacturing simulation will be extended by process modifications such as modified plunging and double roll. Quantifying the height of the fin for the individual intersecting planes will aid in the optimization of the tool design. Implementing algorithms for predicting chip formation will contribute greatly to the analysis of the mentioned challenges and cutting phenomena. For this, a validated cutting force model for bevel gear cutting is necessary.

Acknowledgments

The authors gratefully acknowledge financial support from the WZL Gear Research Circle for the achievement of the project results and the contribution of Dana to this research.

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Liebherr

INTRODUCES WOMEN'S RESOURCE GROUP TO SHARE IDEAS AND CULTIVATE RELATIONSHIPS

Liebherr recently interviewed Monica Collins, founder of the Women's Resource Group at Liebherr in the U.S., to learn why the group was formed and what impacts they are making on the women working for Liebherr in the United States. Collins has been with Liebherr for four years and serves as a human resources generalist assisting the manufacturing, production, and warehouse departments for all their HR support needs.

Collins started the group back in December 2021 and the membership was kept small with only 25 members, to foster a more personal group environment. Since its founding, the group has now opened their membership for any women working for Liebherr in the USA and has more than doubled their size with 55 members currently.

1. What was your main motivation behind founding this group?

I wanted to create a group for women within our company that would allow them to feel heard. A place to share ideas, cultivate relationships and learn from one another. Most importantly, take what we learn from our meetings and guest speakers back to our departments at work and into our day-to-day lives. I believe that we are on our way to achieving that goal.

My main motivation behind the Women's Resource Group was built directly into our Mission Statement: "We are committed to supporting an engaging culture in which women can connect and support each other through learning, life experiences and creativity. We are committed to fostering a diverse and safe environment in which all voices are heard."

2. How often does the Resource Group meet?

We meet once a quarter, with different activities or speakers planned for each meeting. Our meetings are held in-person for our members in the Newport News branch, and we also have members attend meetings virtually. If a location has several members, they will often gather to listen to the speaker together, allowing them to participate in their own discussions in-person while attending the meeting virtually.

3. What does the meeting agenda normally consist of?

For every meeting we have a keynote speaker come to talk to our members about relevant topics for women in the workplace. In the past our speakers have touched on topics such as how to be an effective communicator, navigating a male-dominated industry and how company culture effects office relationships.

Leaving the meeting members feel that they have learned something, whether it is a new way to approach their goals, how to define what should be their top priority, and how to find a mentor to help guide them in their career.

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4. How do members benefit from attending these meetings?

It's important to me for our members to have key takeaways after our meetings that they can use both professionally and personally. Our current members have found the group to be extremely rewarding, allowing them to advocate for themselves and others. They also benefit from the opportunity to meet women from other Liebherr locations across the country.

5. Have the Women's Resource Group strengthened the company culture since this group started?

I believe it is important for women in the workplace to feel that they are cared for by their employer and through this group, members feel supported by Liebherr to make a difference. Many members are happy that Liebherr provides resources for their female employees and feel more involved in their workplace by participating in the discussions we have during our meetings.

6. What overall impact has this group made on the women working for Liebherr in the USA?

Members often share with me how they have felt personally impacted by the Women's Resource Group. Because of the open discussions and the women, they have met in the group, they feel more at home at Liebherr and empowered in the workplace.

Every person who attends our meetings leaves with something different, some find it to be a great way to network with women at other Liebherr locations, some look forward to it because it adds more life and fun into the workday. We have even had a member pursue an MBA program because of the support and advice she has received in the group.

liebherr.com

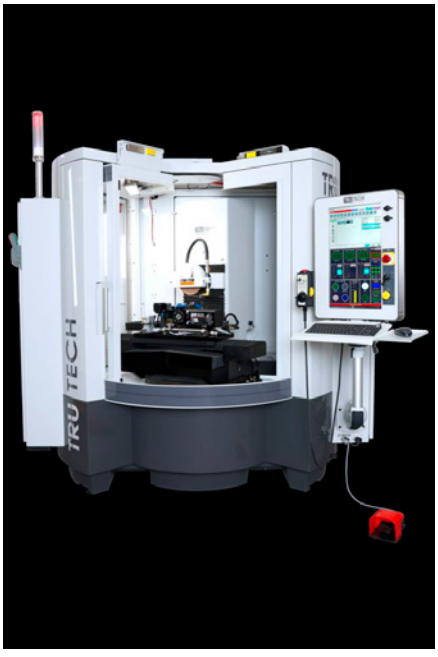
Star Cutter

ACQUIRES TRU TECH SYSTEMS

Star Cutter Company has acquired Tru Tech CNC grinding systems from Resonetics (Nashua, NH), assuming all design and manufacturing of the Tru Tech high precision CNC grinding machines currently performed at the Michigan facilities in Mt. Clemens and Lewiston. Additionally, Star Cutter secures the service, training, and spare parts support for Tru Techs' vast installation base across North America and Europe.

"Tru Tech is a strategic purchase that perfectly complements our existing business," said Brad Lawton, Star Cutter Company chairman and CEO. "It expands our technology offering to address earlier operations in the tool grinding process. New capability in blank preparation and cylindrical grinding, as well as Tru Tech's large install base, will create synergies with Star Cutter Company's existing business units. This is a true win-win that benefits both our company and, most importantly, our customers."

A key differentiator of the Tru Tech systems is their ease of use and ultra-fast set-up while delivering great accuracy and repetitive results. Tru Tech's Perimetric grinding technology and CNC Pick-N-Place software enable these machines to achieve extremely high accuracy suited for high precision and micro components in medical, aerospace, electronics, and other industries. These systems are also capable of handling diverse needs from one-piece, small lot runs through lights-out production.



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Höganäs

APPOINTS HENRIK AGER PRESIDENT AND CEO

The board of directors has appointed Henrik Ager as the new president and CEO of Höganäs AB, as of October 2, 2023. Ager was CEO of Copperstone Resources AB.

"We are very pleased to welcome Henrik Ager as the new CEO of Höganäs. Henrik has strong experience leading successful businesses based on involving leadership and a clear strategic agenda. Under the leadership of Henrik, the board looks forward to further executing on our existing strategy to be the preferred supplier of sustainable metal powder, thus continuing to strengthen Höganäs position as the market leader of metal powders for demanding uses in automotive and many other industries," says Magnus Hall, chairman of Höganäs AB.

"I am both proud and excited to lead Höganäs going forward. Höganäs is a global leader in powder metallurgy and surface coating, with an exceptional team and a world-leading portfolio of products and innovations. We now need to continue to leverage these strengths to both lead and support the sustainable transition for customers and society at large, utilizing the capabilities of metal powder technology," says Ager, new CEO of Höganäs AB.

Prior to being the CEO of Copperstone Resources AB, Ager spent eight years with Sandvik as the business area president of Sandvik Mining and Rock Solutions, division president of Sandvik Rock Tools and vice president strategy of Sandvik Mining. Before Sandvik, Ager was a partner at McKinsey where he spent 16 years. Ager is a Swedish national and has an MSc in accounting and finance from the Stockholm School of Economics.

hoganas.com

October 17–19—Motion + Power Technology Expo 2023

Produced by AGMA, Motion + Power Technology Expo (Detroit) is a three-day show that connects professionals looking for motion power solutions with manufacturers, suppliers, and buyers. Attendees will find new power transmission parts, materials, and manufacturing processes. Buy, sell, and get business done with organizations in aerospace, automotive, agricultural, energy, construction and more. Hundreds of exhibitors and attendees means MPT Expo is a unique opportunity to find partners that can help fulfill your specific production needs. The show is co-located with Heat Treat 2023 and IMAT 2023.

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October 24–26—Southtec 2023

Southtec 2023 (Greenville, SC) draws manufacturing suppliers, distributors, and equipment builders from across North America and around the world. With hundreds of exhibiting companies, attendees can find all the latest technologies and services—plus the experts who build them—ready to demonstrate solutions that can help them grow their business. Visitors can make side-by-side comparisons, discover integrated equipment, hear about industry trends and forecasts, and leverage their purchasing power.

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November 1–2—Advanced Engineering 2023

Advanced Engineering (Birmingham), has rebranded to celebrate the evolution and new developments in 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 the sectors they work in, removing any limitations created by the specific show zones. In 2023, Advanced Engineering will welcome back a full speaker program with representatives from some of the leading companies in UK manufacturing. Last year, attendees were treated to talks by leading industry figures from companies like Siemens, Ford, Jaguar Land Rover, Make UK, Rolls-Royce and Airbus.

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November 9–10—Aachen Forum on Gear Production

In this seminar, attendees will learn about gearing, electromobility and their interrelationships. How gearing can increase the efficiency and performance of electromobility, and which components are needed for this. Also, a detailed look at the design and manufacture of gears for electric vehicles. Attendees will explore the challenges of gearing for electromobility, such as adapting to hard-to-reach places, increasing durability, and reducing energy consumption, and discuss how grinding technology and tool design must meet requirements to improve the properties and improve the quality of gears for electric vehicles. The Aachen Forum on Gear Production (AFGP) is held annually in alternation with the Aachen Conference on Gear Production (ACGP). While the Forum at the RWTH Aachen Campus is dedicated to a technical focus (2023 the interlocking in the E-Mobility sector) the conference, on the other hand, is dedicated to various facets of gear technology.

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November 12–15—2023 STLE TFC and E-Mobility Conferences

The 2023 STLE Tribology Frontiers Conference (TFC) will be held November 12–14. The event will allow attendees to engage with world-renowned industry, academic and government researchers to learn more about the technical, environmental, and social issues impacting tribology research in the 21st Century. The 2023 STLE Tribology & Lubrication for E-Mobility Conference will be held in conjunction with the TFC from November 14-15. The event will feature educational sessions and networking discussions with leading industry experts covering technical content, analysis, and best practices for addressing the challenges and opportunities associated with electric vehicle technologies and how they will impact the tribology and lubrication field.

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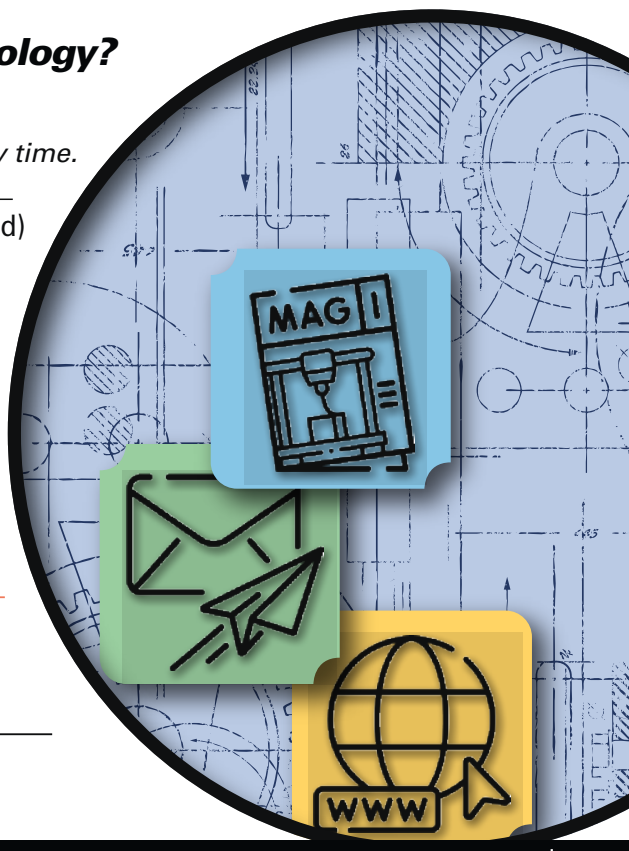
☐ I **DESIGN** gears
☐ I am a **SUPPLIER** to the gear industry
☐ Other (please describe) _____

What is your company's principal product or service? _____



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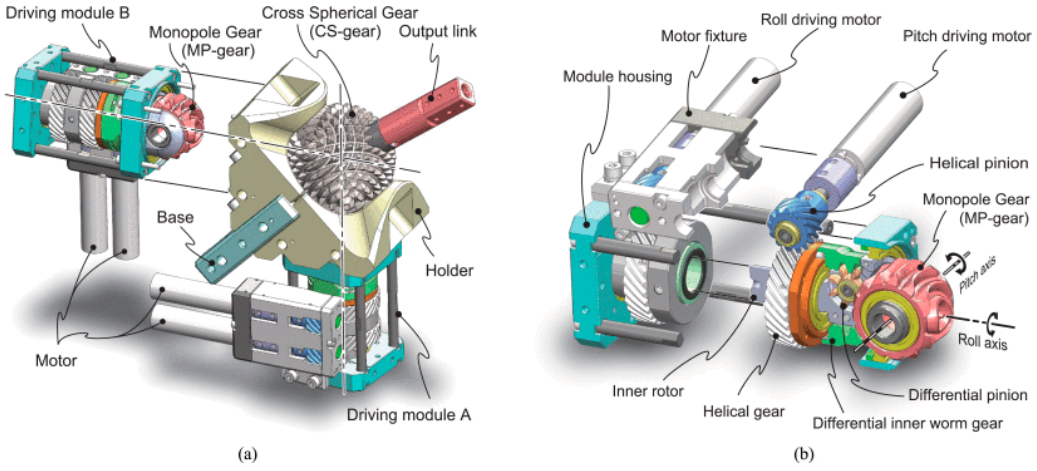
Three Degrees of Freedom

Notes on an active ball-joint mechanism based on spherical gear meshing

Aaron Fagan, Senior Editor



See the ABENICS active ball-joint mechanism in action here: **youtu.be/AHUv9Zda_48**

At first glance, they have a similar appearance to one of those spiked dryer balls you use in the laundry, but upon closer inspection, they have a breathtaking geometry that allows for practical applications: they are so-called "ABENICS," an active ball-joint mechanism with three rotational degrees of freedom (3 RDoF) without slippage based on spherical gear meshings. First presented by Kazuki Abe et al. in IEEE Transactions in Robotics in 2021, the paper says, "The capabilities were inspired by the unique interactions between two different innovative gears [the cross spherical gear (CS-gear) and monopole gear (MP-gear)] and the superimposition of those interactions by the CS-gear's quadrature spherical tooth structure. One MP-gear constrains two of the three RDoF of the CS-gear. The driving module which drives the MP-gear converts this "constraint" into a "drive" and drives the CS-gear with two RDoF. The CS-gear orthogonally superimposes the interactions caused by two MP-gears to achieve three RDoF driving forces. The principle was revealed by analyzing an equivalent linkage modeled on the mechanism of ABENICS. The linkage also led to the kinematics and torque equations. The theory and physical characteristics of ABENICS were verified in comprehensive and continuous positioning experiments on manufactured prototypes. The flexibility of the actuator placement was also verified in different configurations of the driving modules. The active ball joint, ABENICS can transmit high torque and reliable positioning in three RDoF without an orientation sensor, which applies to robot joints and orientation control mechanisms."

When imagining the arm of a robot, it conjures an image of a mechanism containing several axes of motion that are each driven by a single motor and gearbox. This works fine for most applications, but in circumstances with spatial constraints, additional volume limits the range of motion. Also, including another degree of freedom requires extending the arm even further and adding more motors. Now imagine a mechanism that works more like a shoulder joint than an elbow, where the output link can rotate in several axes in a much smaller space. Although the strength of this style of joint can be less than a traditional single-axis one, the freedom afforded by this novel design more than makes up for it. Robots can use ABENICS in situations requiring complex and precise movements in small areas, such as food service or manufacturing.

The magic rests within the specially designed spherical gear. While it looks complicated, the gear can be best described as a pair of 2D gears that revolve around the x and y axes, thus giving the appearance of a dryer ball. This allows the central gear to be pitched, rolled, and slid along both drive gear axes. The output link is attached to a single pole on the end of the gear. The drive gears are shaped like the central gear, except they revolve around a single and can rotate in two axes: pitch and roll. To accomplish this, the project's team placed a bearing through the gear and added a differential pinion to pitch the end up and down. Behind that is a linkage that rotates the entire end when the rear helical gear is spun. A pair of motors are mounted just above the two helical gears in a perpendicular fashion to save space.

A 2022 paper by Frederico Thomas, first presented at the International Symposium on Advances in Robot Kinematics, states, "Kazuki Abe and his collaborators have recently presented an actuated gear-based spherical mechanism called ABENICS. It has received a lot of attention, not only because of its eye-catching motions during operation but also, and mostly, because it can successfully be used when large motion ranges and high stiffness are required. Nevertheless, the main disadvantage of Abe et al.'s design is that it is an over-actuated mechanism: it requires four instead of only three actuators." Thomas proposes a variation on this mechanism which requires three actuators, thus simplifying its control and potential cost.

Further Reading:

Kazuki Abe et al.
https://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=9415699

Frederico Thomas
https://www.iri.upc.edu/files/scidoc/2601-Kinematics-of-a-Gear-Based-Spherical-Mechanism.pdf

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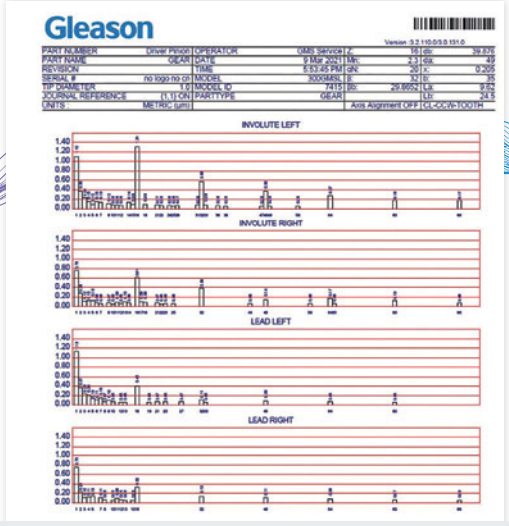

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