gear TECHNOLOGY ™

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State of the Gear Industry
Cutting Tools
Lubrication Expo

TECHNICAL

Very High Cycle Fatigue Testing of AMS 6308 Steel

Cutting Tool Selection Criteria for Cylindrical Gear Manufacturing

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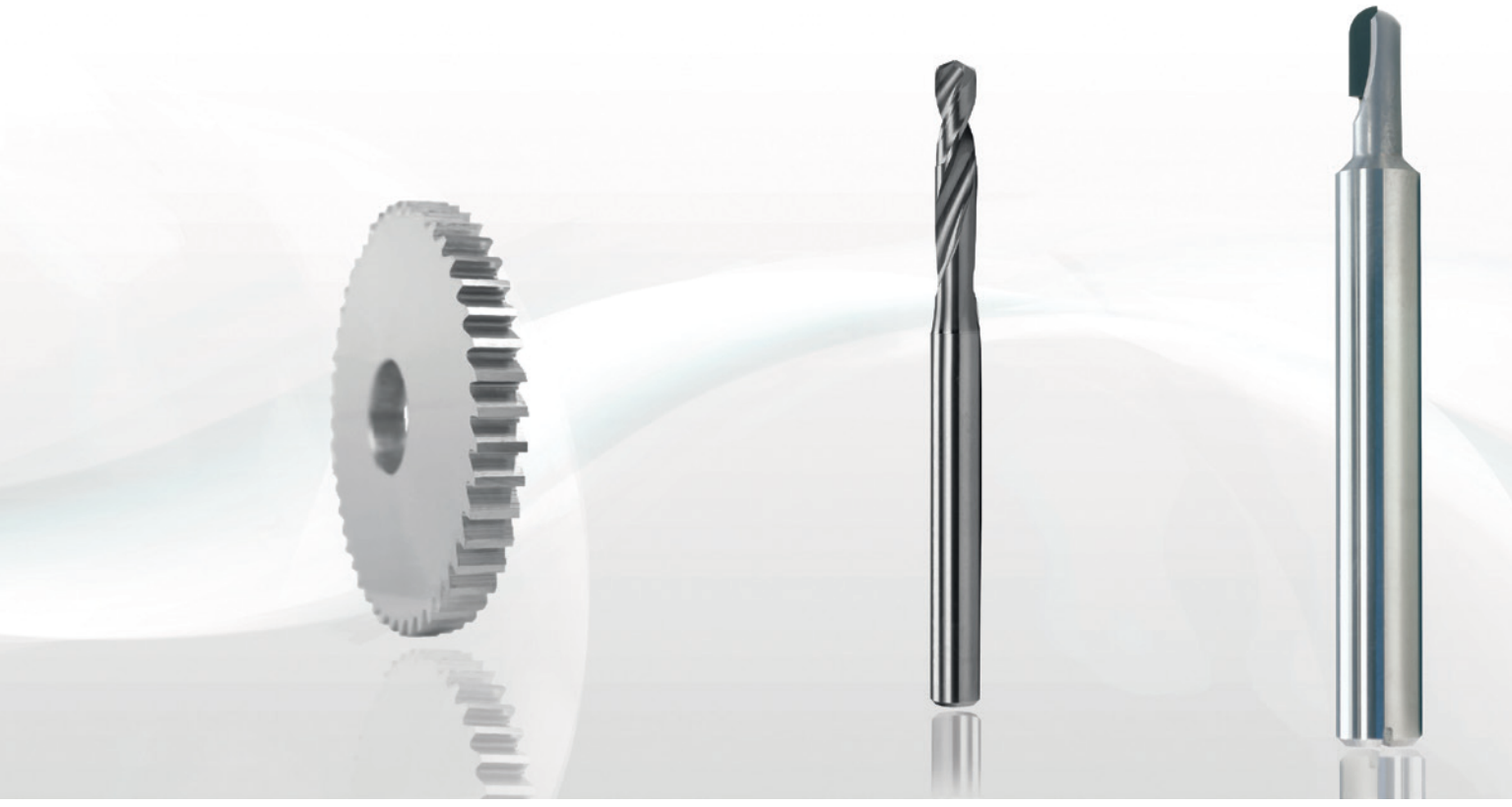

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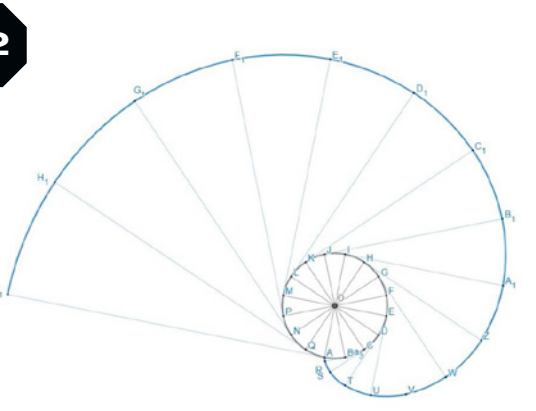

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Vol. 42. No. 1

Skiving of rings and shafts

Skiving³: machine, tool and process

Gear skiving machines LK 180/280 and LK 300/500

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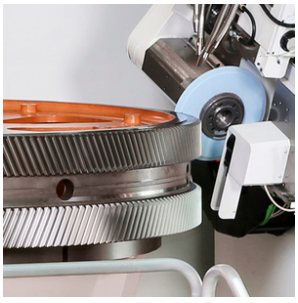
GT VIDEOS

Automated Tool Change with the EMAG VST 50

Efficiency and process reliability are critical in modern manufacturing—and this is exactly where the EMAG VST 50 excels. A standout feature: the fully automated tool change. Thanks to an integrated robot, the tool change takes less than 90 seconds—all while production continues uninterrupted! The tool magazine ensures a smooth process: it swivels outward, the robot swiftly and precisely replacing the tool.

geartechnology.com/media/videos/play/286

Kapp Niles ZP Series



Gear Profile Grinding Machine ZP 10 with automatic tool changer from Kapp Niles. The machine concept stands for maximum workpiece quality, flexibility and a long service life. The basic machines are equipped with a dresser, integrated measuring device, balancing unit and comprehensive software. The machines feature generously dimensioned rotary tables with electrical direct drive and large rotary table bores.

geartechnology.com/media/videos/play/285

GT REVOLUTIONS

Connected Quality: Getting the Basics in Place

Connected quality goes beyond point solutions. It integrates systems and processes to deliver continuous improvement across the organization. To some, it might sound straightforward. To others, it could seem like a daunting prospect. A connected, holistic approach to quality is perhaps the biggest opportunity to win an advantage over your competitors. We need to make sure we have the right data, in the correct context, shared with the right people in a timely fashion.

geartechnology.com/blogs/4-revolutions/post/30867-connected-quality-getting-the-basics-in-place

AGMA Media
1001 N. Fairfax Street 5th Floor
Alexandria, VA 22314
Phone: 847-437-6604 | Fax: 847-437-6618

EDITORIAL
Publisher & Editor-in-Chief
Randy Stott. Vice President Media
stott@agma.org

Senior Editor
Matthew Jaster
jaster@agma.org

Senior Editor
Aaron Fagan
fagan@agma.org

Technical Editors
Robert Errichello. John Lange. Joseph Mihelick. Charles D. Schultz. P.E.. Mike Tennutti. Frank Uherek

GRAPHIC DESIGN
Design Manager
Jess Oglesby
oglesby@agma.org

ADVERTISING
Associate Publisher & Advertising Sales Manager
Dave Friedman
friedman@agma.org

Manager, Member Engagement and Sales
Katie Mulqueen
mulqueen@agma.org

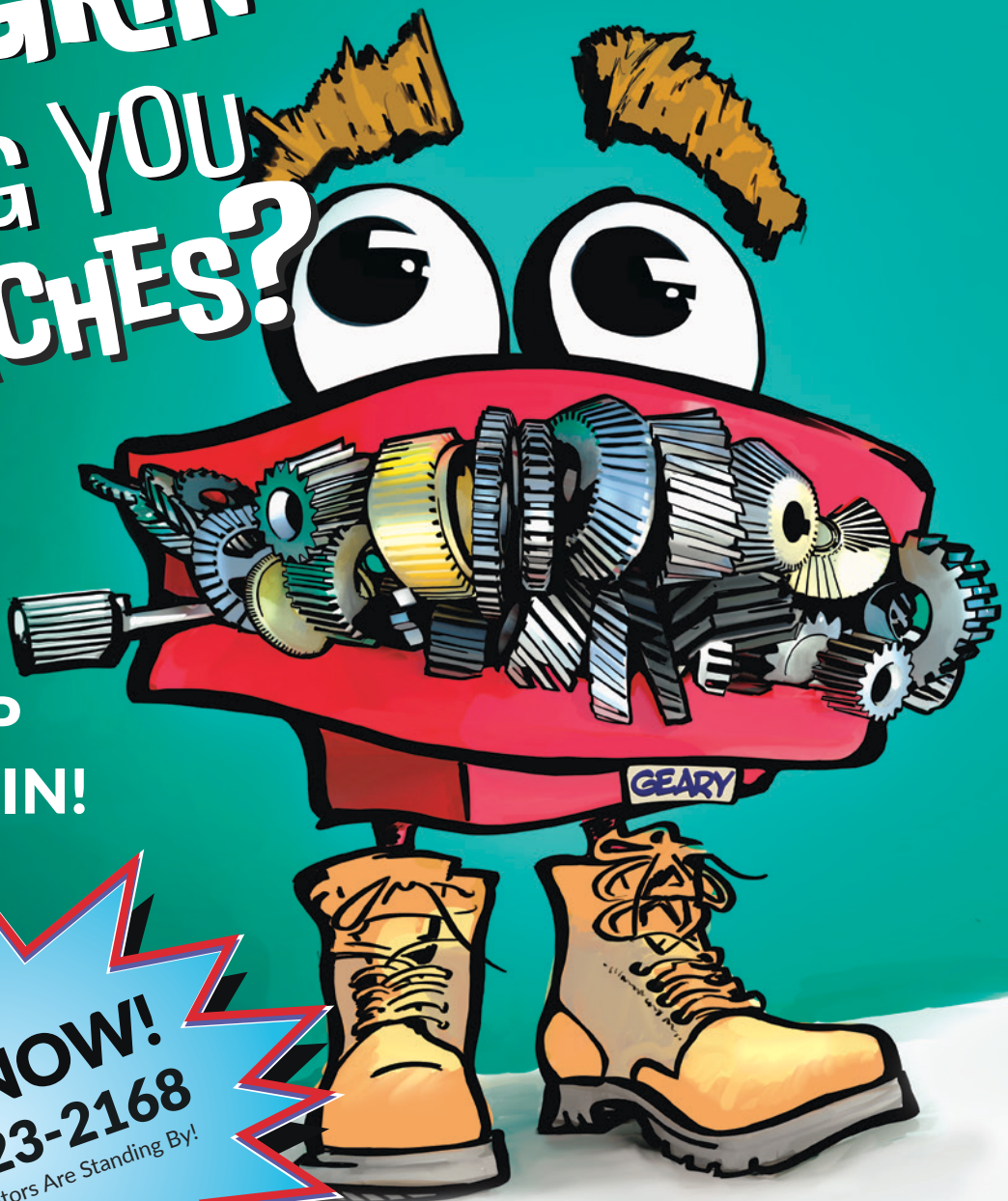
Materials Coordinator
Dorothy Fiandaca
fiandaca@agma.org

CIRCULATION
Circulation Manager
Carol Tratar
tratar@agma.org

MANAGEMENT
President
Matthew E. Croson
croson@agma.org

FOUNDER
Michael Goldstein founded *Gear Technology* in 1984 and served as Publisher and Editor-in-Chief from 1984 through 2019. Thanks to his efforts, *the Michael Goldstein Gear Technology Library,* the largest collection of gear knowledge available anywhere, will remain a free and open resource for the gear industry. More than 40 years' worth of technical articles can be found online at *geartechnology.com.* Michael continues working with the magazine in a consulting role and can be reached via e-mail at *mwg42@hotmail.com.*

TEETH GRINDING CAUSING YOU HEADACHES?



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Take This with a Grain of Chaos

"Take this with a grain of salt" is that old saying you use when you offer up some advice that may or may not apply, that comes from a dubious source, or which bears skepticism. This year's annual State-of-the-Gear-Industry survey is like that, but not because we did a poor job of it, and not because we doubt the sincerity or business acumen of our respondents, but rather, because the survey happened to come at a very turbulent time.

Most of our survey responses came in between January 15 and January 25. Smack in the middle of that was the inauguration of President Donald J. Trump. Normally after a presidential election, there's a sense of closure—a clear sense of direction and a feeling that we know what to expect over the next four years. Business returns to a sense of normalcy.

Not so this year. Already we've seen massive tariffs threatened, rescinded and enacted against trading partners large and small. We've seen entire government agencies shuttered over a weekend. It's hard to know what might be coming next.

I'd like to be clear that this is not a political criticism or commentary. I'm not offering up judgment about whether any of this is right or wrong, necessary or even legal. My real point is that, for good or bad, Donald Trump makes planning more difficult and prognostication near impossible.

And he's not the only disruptive factor. There's still conflict in Ukraine, the Middle East and central Africa. Even without trade wars, there's a lot going on to challenge supply chains.

Add to that the potential disruption of new technologies. Artificial intelligence is clearly on a lot of people's minds, as is robotics. And while the big push for electric vehicles is still very real, the rollout, consumer acceptance and political support have all diminished.

In our annual surveys, the gear industry has always skewed towards the optimistic. Despite everything that's going on in the world and all the potential disruptions out there, this trend remains true this year, with 78 percent of respondents expressing some level of optimism about their future (compared with 74 percent last year).

The chaos is definitely represented in the rest of our statistical results. The trendlines go every which way.

To me, the true value in the survey is in the insights offered in the comments sections. You can get a real feel for what's on the industry's mind by reading the open-ended comments. Our editors rely on your comments to help guide our coverage over the coming year. You can use those same comments to get a feel for what the rest of the industry is thinking.

We're pleased to present our annual State-of-the-Gear-Industry survey. It begins on page 28. Just remember to take it with a grain of chaos, and let me know what you think at *stott@agma.org*.

Randy Stott

Publisher & Editor-in-Chief
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Star Cutter

OFFERS ADVANCED FLX MACHINE WITH NUM CNC CONTROL SYSTEM

Star Cutter Company launched the FLX machine in 2024, powered by NUM's advanced FlexiumPro CNC control system with *NUMROTO* software to easily program all kinds of different tools. This significant advancement underscores Star Cutter's commitment to delivering cutting-edge solutions for high-volume tool manufacturers, providing an enhanced platform for automated, high-precision manufacturing.

The decision to transition to NUM's FlexiumPro CNC control system was driven by Star Cutter's dedication to innovation and operational efficiency. The FLX machine represents a complete redesign from previous models, making this the ideal moment to adopt NUM's latest FlexiumPro CNC system along with NUM DrivePro servo amplifiers.

One of the standout features of the new FlexiumPro system is its seamless integration with existing technologies. Star Cutter re-used much of the logic and custom programming developed for earlier generations of NUM systems, significantly reducing engineering effort during the transition.

Among the FlexiumPro's innovations is a modernized EtherCAT communication interface that reduces power consumption and shrinks the electrical panel footprint. The system's cutting-edge single-cable motors allow for easier maintenance, while its system-on-chip (SoC) technology has increased CNC computing power by tenfold. The FLX machine's B and C axes are driven by NUM's TMX series hollow shaft torque motors, ideal for tool grinding applications, which demand very smooth and accurate rotation, especially at low speeds.

The FLX machine is designed with automation and wheel change enhancements, making it ideal for high-volume toolmaking customers. One of the most notable improvements is a 30 percent reduction in wheel change time, thanks to a redesigned wheel magazine area and increased system processing power.

Star Cutter has also integrated robotics to handle both wheel and tool changes, offering up to 15-wheel pack locations and 1,200 tools, which significantly extends automated production runs. This makes the FLX a game-changer for catalog-standard carbide tooling manufacturers.

In terms of efficiency, the FlexiumPro system's built-in IIoT (Industrial Internet of Things) connections facilitate seamless transmission of production statistics to plant analytics systems. The inclusion of super-capacitors in the system's Real Time Kernel ensures safe shutdowns during power failures, further enhancing the reliability needed for lights-out manufacturing.

Star Cutter remains focused on advancing its FLX, NXT, and PTG platforms to serve a broader range of industries. Future enhancements will continue to align with customer needs, particularly in the high-production and medical sectors. As part of its commitment to customer service, Star Cutter will ensure a smooth transition for clients adopting the new CNC system, providing comprehensive support and training to ensure optimal performance.

num.com

starcutter.com

Seco Tools

RELEASES LATEST HELICAL MILLING CUTTER

The new Seco LN4-11 Helical Milling Cutter provides up to three times longer tool life per edge and boosts productivity to achieve the lowest cost per part. The cutter ensures high material removal rates in applications requiring a helical milling cutter 32–63 mm in diameter.

The LN4-11 provides shops with several avenues to cut costs and improve profitability. Its adaptability to a variety of applications enables shops to reduce tooling inventories and costs. Operators simply change out the cutter's inserts to go from one application to the next. The tool's front and helical insert pockets also eliminate the risk of incorrect insert placement to improve efficiency and reduce waste.

"The new Seco LN4-11 Helical Milling Cutter is the answer to the challenges shops face today," said Seco Product Manager Magnus Engdahl. "It's impossible to load the inserts of the cutter incorrectly, and every cutter body and insert feature an individual Seco Data Matrix code that provides access to cutting data and spare part tracking. It's an excellent opportunity for shops to improve productivity and efficiency while overcoming the challenges created by lesser skilled operators."

The milling cutter has two different inserts. There are two cutting edges on the front inserts and four edges on the helix inserts. The design allows robust machining operations and aggressive material removal rates.

Cost performance is enhanced, and tool life is improved. Inserts are available in a broad range of grades and geometries for a variety of operations and materials. The LN4-11 meets the demands of general engineering and automotive applications as well as those in the aerospace sector.

Each cutter's individual Data Matrix code ensures easy access to all relevant tooling information including

individual data metrics, cutting data, compatible products and spare parts.

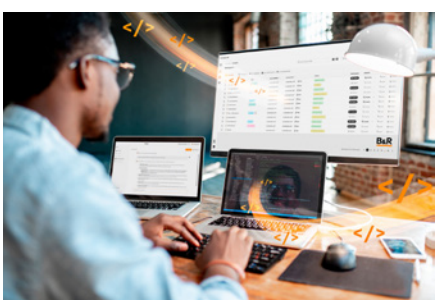
secotools.com

B&R Automation

INTRODUCES NEW SAFETY FUNCTIONS

B&R—a division of ABB—introduces Safety+, an innovative open approach to programming safety functions. Developers can now also use the latest software engineering tools and methods for safety applications. An innovative data structure with a digital fingerprint makes the source code freely accessible while also meeting the special requirements of functional safety. In this way, B&R has overcome an obstacle that was previously a barrier to innovation in safety programming.

"With Safety+, we're providing customers with an open programming system for the first time, allowing them to use familiar advanced tools and methods from standard programming," explains Franz Kaufleitner, product manager for safety at B&R, ABB's machine automation division. "Safety applications can be developed much more efficiently and flexibly."



Three main features make this productivity boost in programming safety-oriented applications possible: An innovative data architecture, flexible choice of language and data type, as well as the use of tools and processes from standard programming.

A key new feature of Safety+ is the innovative data architecture. Data is stored in a freely accessible format and every change documented. The source

files are stored in an open text-based code repository in formats such as XML or JSON. To ensure the integrity of the program code despite being open, each file is given a digital fingerprint that indicates when something changes. Supplemented with detailed metadata, what was changed, when and by whom is completely transparent.

What´s new in safety programming systems is that this metadata doesn't only reference the complete safety application. Engineers can now track every change down to the function block and parameter set level, which allows them to optimize the code in a more targeted way. This results in more agile engineering of safety functions that can then be more easily adapted to changing user requirements.

In addition to the new data architecture, the new openness of Safety+ allows engineers to create and manage safety applications using third-party tools and platforms. "By integrating safety programming into common tools such as GitHub and Jenkins, developers can work with a high degree of flexibility," says Kaufleitner. "This simplifies the development process and also promotes collaboration and exchange within the developer community."

A command line interface (CLI) is available for automatic build generation and continuous integration, allowing developers to interact directly with the software in headless mode and process program code efficiently.

As the third major innovation, Safety+ also provides new freedom choosing a programming language and application-specific fine-tuning when programming with data types. Developers were previously limited in their choice of programming languages and data types for functional safety applications, which had a negative impact on development time and flexibility.

Safety+ provides engineers with a wider range of programming options, including function blocks, ladder diagrams and structured texts. Safety+ removes previous restrictions on data types and supports elements such as arrays, structs and real data types that are standard in non-safe programming. "With Safety+, we give developers the freedom they need to create innovative and efficient safety solutions", emphasizes Kaufleitner. "I don't think it's an exaggeration when we talk about a small revolution in safety function programming."

Previously, encrypted proprietary file systems were used in systems for engineering functional safety applications. While these protected applications from unauthorized changes, they also prevented the use of common productivity-enhancing software tools and methods.

br-automation.com

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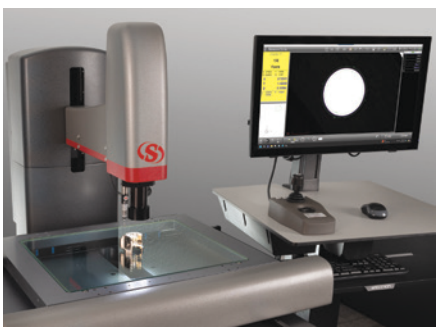
The pneumatic grippers featuring 2PXS, 2PXM, and 2PXL models are Proofline sealed and IP 64 rated. With exceptional gripping force facilitated by an oval piston, 2-finger low weight design, PX grippers provide spring force mechanisms

for both external and internal gripping. The grippers also incorporate innovative sensor technology, including magnetic switches, inductive sensors, or analog position measuring systems. Additionally, they feature an air purge connection and are drop-in compatible with standard universal grippers on the market.

smwautoblok.com

L.S. Starrett
INTRODUCES VISION METROLOGY SYSTEM



The L.S. Starrett Co. has expanded its AVR Vision Metrology Line with the introduction of the AVR400 CNC Vision System, the largest benchtop platform to date from Starrett with stage travel that is twice the speed of previous Starrett AVR models. The stage travel is 15.8"x 11.8"x 7.9" (400 mm x 300 mm x 200 mm) in the X-Y-Z axes with a speed of up to 120 mm/sec.

"We are very pleased to offer customers a new, faster vision system capable of measuring a broader range of larger part sizes, as well as providing the ability to put more parts on the stage at one time," said Mark Arenal, general manager, The L.S. Starrett Company—Metrology Division. "Users will reduce inspection and measurement time, while maintaining accuracy."

The Starrett AVR400 offers full CNC capabilities including X-Y-Z positioning and comprehensive zoom and telecentric lens options. Users can also choose to use motorized manual positioning via a pendant with a joystick and track ball. Equipped with the M3 software package from MetLogix, a traditional mouse as well as a touchscreen monitor make user interaction easy and intuitive.

Auto part recognition enables creating a part measurement program that comprises the desired features of a part for inspection, which can automatically be saved in the system or to a network. Programmable light output options can be built into the program as defined steps, including being called up as the part recognition program initiates. Once the program is created, placing that part within the camera's field-of-view allows for the saved program to initiate and run the inspection. A Renishaw Touch Probe may also be

utilized for quick acquisition of discreet points along a part's profile as well as Z-axis measurements.

For high stability, the AVR400 features a granite base. An extensive line of accessories is available including a modular system workstation on rolling caster wheels, providing convenient repositioning on the shop floor and in QC labs. The AVR400 Vision Metrology System is Made in the United States.

starrett.com

Kennametal

MEETS SMALL PARTS MACHINING DEMANDS

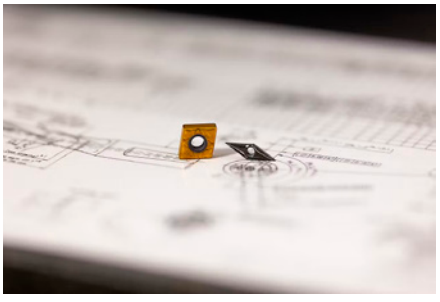
Machining small parts calls for high precision, tight tolerances and excellent surface finishes. Kennametal's TopSwiss platform is designed to meet these demands across industries like medical, aerospace and defense, automotive and general engineering.

But first, what is Swiss-type turning?

Performed on a CNC Swiss lathe, this method involves a sliding headstock and guide bushing, which rotates the workpiece on a spindle as it is fed across a stationary cutting tool. Parts range from bone screws and hip and shoulder implants to bushings and fuel injectors and can be made from various materials.

Practical Swiss-Type Tips

Precision and tolerance: For greater accuracy in the geometries when machining, being able to minimize deflection (bending of the workpiece) is very important. By reducing the amount of material sticking out from the guide bushing, you can minimize bending and increase the precision needed for the component. Additionally, by using sharp cutting edges, you can reduce cutting forces, which can result in more precise cuts and a smooth surface finish.



Avoid workpiece damage: Choosing the right material can significantly affect how the workpiece comes out. Harder materials may require a slower machining speed, while softer materials may require a more forceful speed to achieve optimum results. Coolant usage can also be a factor to help prevent damage to the parts.

Achieve better chip evacuation: The challenge of working on small parts is the combination of tight spaces and chip size. Along with adjusting cutting speeds, feed rates and the material being machined, you will have to manage the depth of cut to prevent chip build-up. Effective chip evacuation also involves ensuring proper coolant flow to clear the tool's path and selecting the appropriate solid-cutting tools, inserts, grades and coatings.

Maximize your tool path: As we know, machining small parts has limited space

in which to work. But if you select the right cutting tools and parameters, use CNC software that can meet your complex requirements and properly apply the workholding necessary to reduce vibrations, you can successfully maximize the efficiency of the part.

As part of the small parts line, Kennametal's TopSwiss tooling features sharp cutting edges, low cutting forces and superior chip evacuation that result in longer tool life and excellent surface finishes.

kennametal.com

Eaton

ADDS ENDURANT AMT PARTS TO ITS AFTERMARKET PORTFOLIO

Eaton's Mobility Group is now offering aftermarket Endurant automated manual transmission (AMT) parts and remanufactured units. This new offering expands the existing AMT portfolio of products for Daimler DT12 and Volvo I-Shift transmissions and provides a one-stop shop for all makes of manual and AMT transmissions operating in North America.

This expanded offering includes genuine remanufactured units, gears, shafts, kits, electronics and components needed to remanufacture or repair the Endurant HD transmission. Through this launch Eaton will distribute these parts only to independent aftermarket customers. The Eaton Cummins Joint Venture (ECJV) will maintain support for all other distribution channels.

As with its other transmission components, Eaton continues to partner with master distributors Crane Carrier Company and HME Parts to streamline availability for independent rebuilders.

"The share of vehicles with AMTs in North America continues to grow and is poised to become the largest segment of transmission replacements in the industry," said Leandro Girardi, director, Aftermarket, Eaton's Mobility Group. "With our expanding product portfolio, independent rebuilders can rely on Eaton for all their AMT service needs, backed by our standard aftermarket warranty."

In addition to Endurant parts, Eaton's Mobility Group offers a comprehensive aftermarket portfolio for other popular AMTs, including the Detroit DT12, Volvo I-Shift, and Mack mDrive transmissions. Eaton now supplies more than 450 unique components—gears, seals and bearings—designed to support the growing AMT market.

eaton.com

Unlocking the Potential of Power Skiving

Improving gear production flexibility and efficiency

The high-precision gear skiving tools are part of the Skiving³ technology package.

Power skiving has evolved from a complex and difficult-to-control cutting method into a viable alternative to traditional shaping or broaching. Liebherr-Verzahntechnik GmbH's Skiving³ technology package combines machines, tools, and processes to make gear skiving more efficient and flexible. This advancement enables manufacturers to machine a broad range of workpieces, from small to large batch sizes, making it suitable for both series production and contract gear manufacturing.

The Evolution of Power Skiving

Gear skiving is a rotary gear-cutting process where the workpiece and tool are positioned at a cross-axis angle. This setup allows for high flexibility in machining while also offering productivity and cost benefits. Skiving is versatile and can be applied to various workpieces, including large and small gears, external and internal gears, and even workpieces with interference contours. However, the complex kinematics of the process historically limited its use.

Haider Arroum, Head of Sales for gear cutting tools at Liebherr-Verzahntechnik GmbH, recalls how gear skiving used to be a repetitive process prone to errors. Once the machine was set up, it was often best to avoid making changes to prevent inaccuracies. But advancements in machine technology, such as direct drives, along with new tool materials and intelligent simulations, have revived interest in skiving in recent years, improving its reliability and productivity.

Streamlining the Power Skiving Process

Liebherr is a leader in gear skiving, offering the Skiving³ technology package, which provides a holistic solution by integrating machines, tools, and processes. This synergy results in faster manufacturing rates, improved quality, higher output, and reduced costs. Marcel Sobczyk, a gear cutting tool applications expert at Liebherr, notes that the switch to skiving has led to improved product quality and delivery times in their own contract manufacturing operations, such as spline and mating gear production.

Flexibility in Production

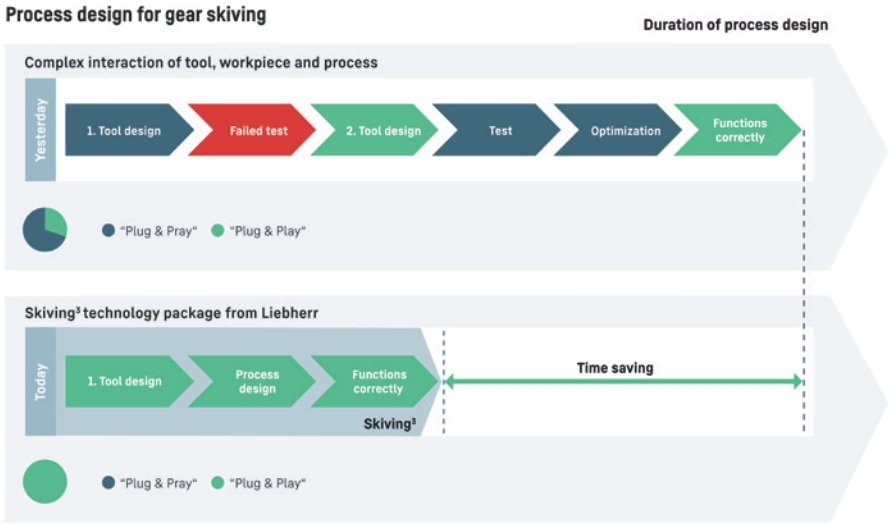
Historically, gear skiving was primarily used in high-volume series production. However, the Skiving³ technology has extended its applicability to small batch sizes, offering manufacturers more flexibility. By using advanced simulations and automatic corrections during the tool design phase, the right parameters are set early on, ensuring the first part is made correctly and the process runs smoothly from the outset.

This flexibility is particularly valuable in industries like e-mobility, where speed, precision, and productivity are crucial. Skiving³ has also proven beneficial in small-batch production, as demonstrated in Liebherr's contract gear manufacturing. Sobczyk explains that only a few parts need to be run in before achieving high-quality production, which is ideal for job shops or manufacturers with medium to small batch sizes of 20 to 30 parts.

Support and Service

Liebherr emphasizes customer support as a key part of the Skiving³ package. Sobczyk explains that Liebherr's approach goes beyond being a supplier; the company provides expertise and assistance to ensure successful gear manufacturing. For job shops, this level of support is crucial in optimizing their operations. Arroum adds that the transition from the earlier "Plug & Pray" approach to the more reliable "Plug & Play" method with Skiving³ has significantly simplified gear skiving, even for smaller batch sizes.

Liebherr's Skiving³ technology represents a major advancement in gear skiving, providing a more efficient, flexible, and cost-effective method for producing a wide range of gears. By integrating machine, tool, and process innovation, Liebherr has made skiving a viable option not only for series production but also for small-batch manufacturing. This technology is particularly beneficial in high-precision, high-speed applications like e-mobility and for manufacturers needing to produce smaller quantities with high quality and efficiency.



"Plug & Pray" approach to the more reliable "Plug & Play" method with Skiving³ simplifies the gear skiving process.

Conclusion

As Sobczyk highlights, "Skiving³ has simplified gear skiving, making it accessible for a wide range of applications." These developments mark a significant step forward, signaling a new era of excellence in gear cutting.

liebherr.com

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Precision and Innovation in Gear Cutting

Advanced cutting tools to meet changing market demands

NIDEC makes cutting tools in Japan, India and the United States with careful attention to base materials, coatings, heat treatment and design—all factors that affect accuracy and tool life.

Gear cutting has witnessed remarkable advancements over the years, with modern technologies transforming traditional methods into streamlined, highly efficient processes. NIDEC's tools and methodologies increase productivity and quality in manufacturing. This article delves into the technological innovations, market relevance, and advantages of their gear-cutting solutions.

Precision and Innovation in Gear Cutting

NIDEC has developed a wide range of cutting tools designed for precise gear manufacturing, including hobs, skiving tools, shaper cutters, shaving cutters, round broaches, keyway broaches, rotary cutters, chamfering tools, and fir tree broaches. These tools are utilized globally in gear production processes, particularly in sectors like automotive, aerospace, and robotics. NIDEC's emphasis is on advanced materials, coatings, and design to improve the performance and lifespan of cutting tools in gear manufacturing.

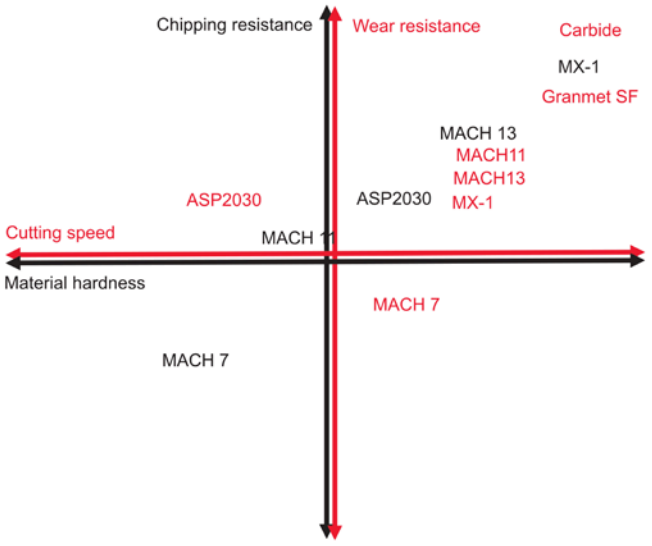
Cutting Tools Materials and Coatings for Gear Manufacturing

The performance of cutting tools in gear production heavily depends on the materials and coatings used. NIDEC has developed specialized materials and coatings to improve cutting efficiency, enhance durability, and reduce friction. For example, coatings like the Super Dry Coating are designed to improve the thermal resistance of tools used in high-speed cutting operations. These coatings prevent excessive wear by maintaining the tool's sharpness at elevated temperatures, extending tool life and enhancing productivity.

In addition, NIDEC has created coatings specifically for dry cutting, where no coolant is used. Tools with Super Dry coatings can operate effectively at cutting speeds up to 250 m/min, which contributes to reduced cycle times and lower operational costs. This technology is particularly useful in applications where traditional coolants would be difficult or undesirable to use, and it also supports environmental sustainability in manufacturing.

NIDEC's tools are also designed to be versatile, allowing them to be tailored to specific gear manufacturing requirements. The ability to customize these tools based on factors like the hardness of the material being processed and the type of gear being produced makes NIDEC's offerings highly adaptable to different production environments.

Helical broach by NIDEC.



Nidec's cutting tool material chart.

	Material	Wear Resistance	HI-Temp Hardness	Chipping Resistance	Appropriate Tool Use	Feature
Dissolution High Speed Steel	MACH3				Shaving	Improve Tool Life
	MACH5				Hob	Standard for wet cutting
	MACH7					Standard for dry cutting
	MACH11					For wet and dry use and tool life improvement
	MACH13					For wet and dry use and chipping resistance improvement
Powder Metal	MAC A				Shaping	For chipping resistance improvement
	MAC B				Shaping	Standard material
					Hob/Broach	Standard - chip. resistance
	MAC C				Hob	For hard to cut / high hardness materials
	MAC D				Broach	For hard to cut / high hardness material and tool life improvement
	MAC L				Shaping	For hard to cut / high hardness materials
	MX-1				Shaping/Hob	For hard to cut / high hardness material and tool life improvement
GRANMET SF					Hob	For high speed cutting
GRANMET BR					Broach	For broach corner wear, tool life improvement
GRANMET SK					Skiving Tool	For hard to cut / high hardness materials

Material	Type	Wear Resistance	Appropriate Use	Feature
Carbide	Series H	5 X or greater than high speed steel	Hob	High hardness material / high speed
	Series S	3 X or greater than high speed steel	Skiving and shaping	High hardness material

Material	Wear Resistance	Heat Resistance	Process	Type/Advantage	Hob	Shaping	Shaving	Broach
TiN			Wet	General purpose coating for wet cutting	○	○		○
Nano Dynamic			Wet	Coating for broaches, hard to cut material/anti-wear				○
Nano Dynamic II			Wet	Coating for broaches, improve surface, anti-wear				○
MightyShield ε			Wet	Coating for shaving tools, anti-wear, edge preservation			○	
SuperDry			Dry	General purpose coating for dry cutting	○	○		
SuperDry II			Dry	Coating for dry cutting, anti-wear	○	○		
SuperDry III			Dry	Coating for dry cutting, anti-wear	○	○		
MightyShield ∑			Wet & Dry	Anti-wear coating, suitable for all machining areas from wet to high-speed dry.	○	○		
MightyShield μ			Wet & Dry	Coating for fine pitch, anti-wear (thin film, even coating)	○	○		
MightyShield ∑II			Wet & Dry	Anti-wear coating, suitable for all machining areas from wet to high-speed dry.	○	○		
MightyShield α			Wet & Dry	Coating for carbide tools	○	○		

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Nidec's material and coatings chart.

Applications of Advanced Cutting Tools in Gear Production

Gear production involves a variety of processes, each with its own set of challenges. Hobbing, for instance, is commonly used for generating gear teeth, but it leaves behind tool marks that can affect the gear's performance. To address this, gear shaving is employed to refine the tooth profile, improving both precision and surface finish. The use of advanced materials in shaving cutters enhances their surface hardness, leading to longer tool life and more efficient operation.

After heat treatment, some gears require additional finishing processes, such as gear grinding or honing. Tools like carbide hob cutters have gained acceptance for finishing small-diameter gears post-heat treatment, as these gears may be too small to be processed on a gear grinding machine. Carbide hob cutters offer a combination of ultra-fine carbide particles, a specialized coating, and material that withstands the challenges of finishing after heat treatment.

Dry Cutting in Gear Manufacturing

The move toward dry cutting has become more prominent as manufacturers look to improve productivity while reducing costs associated with coolant usage. Dry cutting eliminates the need for coolants by using tools designed to withstand high temperatures generated during cutting. NIDEC's Super Dry Coating, which is used in gear hobbing, has been developed to improve the heat resistance of cutting tools, allowing them to perform at higher speeds without excessive wear. This enables gear manufacturers to achieve higher cutting speeds—up to 250 m/min—while increasing tool life and productivity.

In addition to improving tool performance, dry cutting also offers environmental benefits by reducing the reliance on coolant oils, which can be costly and difficult to manage. By utilizing coatings that improve the thermal properties of cutting tools, dry cutting systems can operate effectively without the need for lubrication or cooling fluids, leading to cleaner and more sustainable manufacturing processes.

Advanced Gear Cutting Techniques

In response to growing demands for high-precision gears, particularly in industries like automotive and aerospace, NIDEC has developed tools that support the latest gear manufacturing techniques. These techniques, such as gear grinding and honing, are used more frequently after heat treatment to achieve the desired accuracy and reduce gear noise and vibration. While grinding and honing typically involve additional post-heat treatment processes, these techniques ensure that the gears meet strict precision standards.

NIDEC's carbide hob cutters, designed for finishing post-heat treatment, are particularly effective in producing small-diameter gears. In contrast to gear grinding, which may not be suitable for these smaller gears, carbide hob cutters are capable of handling the complexity of post-heat treatment finishing. Their use has become increasingly common, especially in steering pinions and other components that require high precision.

Cutting Tool Design for Enhanced Precision

The precision of gear cutting tools is critical for ensuring that gears meet the necessary specifications for performance. Tool wear and vibration can lead to inaccuracies in gear profiles, which in turn affect the operation of transmission systems. To mitigate these issues, NIDEC designs its tools to minimize wear and enhance stability during machining.

For example, NIDEC's surface-treated shaving cutters are designed with increased surface hardness, which reduces wear and extends tool life. These cutters are also engineered with high rigidity, taking into account the elastic deformation of gear teeth during the cutting process. This combination of materials and design enhances tool performance and improves the consistency of the gear-finishing process.

The development of advanced cutting tools by NIDEC has significantly contributed to improvements in gear production, particularly in terms of precision, efficiency, and tool life. By focusing on specialized materials, coatings, and the integration of advanced manufacturing techniques, NIDEC has created cutting tools that meet the evolving demands of industries that require high-performance gears. These innovations help manufacturers achieve more precise, cost-effective, and environmentally sustainable gear production processes.

Conclusion

Cutting tools engineered for the gear industry continue to evolve rapidly, with innovations from companies like NIDEC driving efficiency and precision. By adopting advanced cutting tools, manufacturers can meet changing market demands and enhance competitiveness.

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The Tools Essential to Power Skiving

Cutting tools and strategies hold the key to maximizing machine performance across the application spectrum

Gottfried Klein, Director of Product Management, Soft Machining Solutions, Gleason Corporation

Automatic tool change on the Gleason 600/800PS Power Skiving Machine speeds up tool changes between roughing and finishing cuts.

The rise of power skiving to a preeminent cylindrical gear cutting process has been one of the gear industry's most compelling success stories in recent decades. What began many years ago as a promising, but specialized, cutting process alternative for cylindrical gears with challenging interference contours is now exceeding performance and application expectations across the board. A multitude of machine solutions have sprung up seemingly overnight, from dedicated machines to universal 5-axis machining and turning centers, for soft cutting and hard finishing of internal and external gears ranging from fine pitch modules of just 0.2 or smaller, to module 9 mm or greater, as well as for machining shafts, worms and special profiles such as splines or cycloidal gears. The process, depending on application parameters, has proven to be many times faster than shaping, much more flexible than broaching and, in some cases of external gears with small overrun space, can even outperform hobbing. Power skiving can now be applied to greatly improve the productivity of cutting everything from small, complex, high-precision gears for electromobility or robotics, to larger gears, where cycle time savings can add up quickly and quality parameters have never been higher.

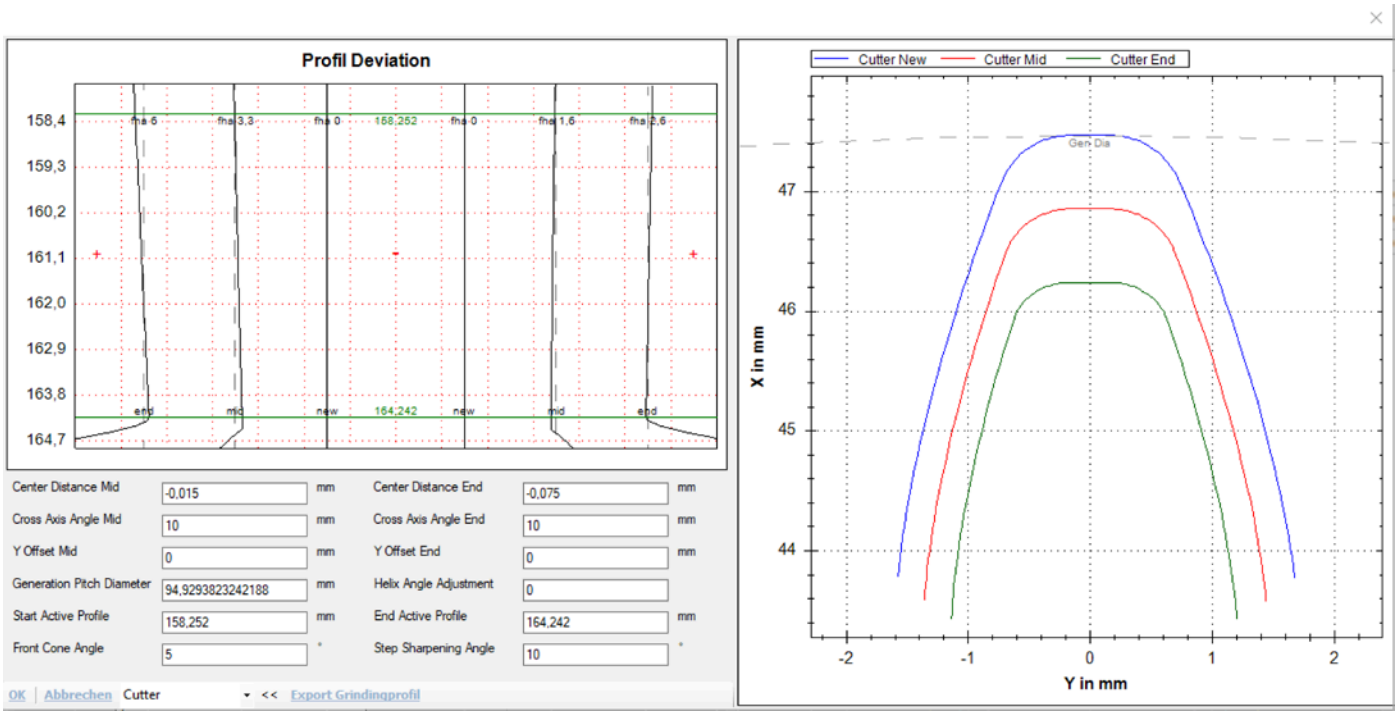
Now, if only it were that simple! There's a reason this process, more than 100 years old, languished on the gear production sidelines for so many years. The best possible result can only be achieved with a particularly rigid machine and drive line that, as a whole, delivers the necessary stiffness. Furthermore, the process works best in a complete system all working in concert: process simulation, production machine, metrology support, workholding, and—of course—the cutting tools.

Tooling Up for Optimum Results, Small or Large

Identifying the optimum cutting tools for power-skiving applications is of critical importance. Simulation software, whether proprietary or "off the shelf," enables the end user to simulate the entire skiving process in advance—an indispensable first step to determining the most effective process strategy and tool design. The simulation software analyzes the impact of various tool geometries and process parameters on chip formation, gear cutting quality and the collision situation, as well as effects on cycle time. Gleason has, through long experience and considerable application expertise in the field, been a pioneer in the development of conical and cylindrical cutting tools ideally suited to meet the challenging requirements of power skiving. When coupled with a suitable machine, the performance results are very impressive. Here are two recent, real-world application examples of power skiving tools at work, and how customers have benefited.

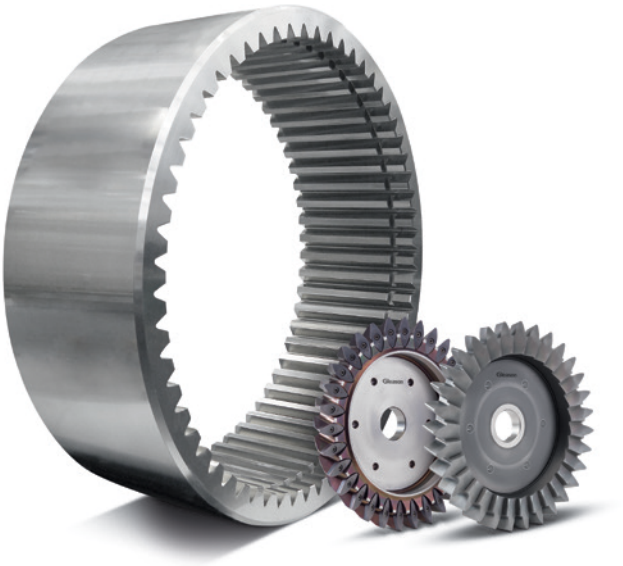
Example 1: Internal Gear, Fine Pitch (0.25 mm Module)

The workpiece in this case is a "strain wave" cylindrical internal gear, with 320 teeth, cut on a Gleason 100PS Power Skiving Machine. Strain wave gears are commonly used in industrial robots where backlash-free, very high precision performance is of the utmost importance. This particular workpiece consists of an internal gear, which meshes with a flexible cylinder with an external gear. The internal gear is an excellent candidate for power skiving. While the external meshing gear can be hobbed, a shaping operation would typically be used to produce the internal gear teeth. However, in the case of this small-module internal gear with a high number of teeth, power skiving proved to be the perfect alternative to achieve significant improvements in productivity and quality. For this application, Gleason provided a conical, solid-carbide tool with AlCroNite Pro coating. The tool featured quality AA, 163 teeth, designed for a 10-degree cross-axis angle. The power skiving application



Simulating the power skiving process is a vital first step that helps determine the most effective process strategy and tool design.

Example 1—Conical, a solid-carbide tool with AlCroNite Pro coating for power skiving of strain wave gears in robotic drives. Cutting time is just 0.6 min—much faster than conventional shaping.



Example 2—A two-step process using a carbide-inserted roughing tool (left) and a solid PM-HSS finishing tool (right) delivers much faster cycle times with very low tool cost vs. profile milling or shaping operations typically used to produce an internal gear of this size (9.5 module).

resulted in a total cutting time of just 0.6 min, performed in four cuts. Gear quality was exceptional as well: an IT5 acc ISO 1328 was achieved, with most criteria even better. Note that, with the solid-carbide tool, resharpening and recoating can be used, extending tool life to the point where the profile no longer meets the requirements.

Example 2: Large Internal Gear (9.5 mm Module)

Power skiving of internal gears with modules 2–4 mm is reasonably common today. For larger modules, however, profile milling or shaping is still considered the norm. However, this recent example—an internal gear, 60 teeth, 600 mm in diameter, module 9.5 mm—demonstrates how the power skiving process is inherently faster than traditional processes for soft cutting of workpieces this large, or larger. In this case, the power skiving time was just 45 minutes, as compared with profile milling (approx. 65 minutes) and shaping (approx. 290 minutes).

For this application, Gleason chose to optimize the process in two steps: 15 roughing cuts with a carbide-inserted tool in quality B and then finishing with a solid PM-HSS quality AA cutter. Both cutters featured AlCroNite Pro coating. Additionally, the Gleason 600/800PS Power Skiving Machine was equipped for automatic tool change between roughing and finishing cuts.

Why a two-tool process? It delivers the lowest tool cost and improves cycle time. Tool wear during roughing is high, so instead of using an HSS tool which needs frequent reconditioning, a carbide-inserted tool is used so that carbide inserts can be quickly exchanged in-house. This carbide-insert roughing cutter also delivers high roughing speeds of 120 meters per minute. Conversely, tool life of the HSS tool is much higher when finishing only, thus requiring reconditioning less often. With the HSS, AlCroNite Pro coated finishing tool, three finishing cuts are made: the first in double-flank cutting mode to remove most of the material from both flanks simultaneously, and then the last two single flank cuts, removing minimal material for the best possible quality and implementing potential flank and profile corrections.

It is also interesting to note that deburring could be done completely on the machine. For deburring of the lower face, the back side of the teeth on the finishing cutter could be used. The burr is removed with a cutting motion away from the tooth gap in the direction of the tooth so that no burr remains bent back into the tooth gap.

This two-tool power skiving strategy results in lower tool cost per gear and a competitive cutting time. Despite a total cycle time of just 46 min (including automatic change of cutter between roughing and finishing and automatic workpiece change) very good quality is achieved; with IT5 acc. to DIN 3962 for profile and lead and single pitch error. Run out and accumulated pitch error is largely dependent on pre-machining quality.

Summary

Consider the benefits of sourcing your power skiving tools from an expert company. Gleason power skiving tools are designed, manufactured, and supported by facilities in the US, Europe, and Asia. They are compatible not only with Gleason's complete PS series of Power Skiving Machines but also with non-Gleason dedicated and universal machines. These two tool examples exemplify the opportunities available to gear manufacturers today to enhance productivity, reduce tool costs, and achieve high-quality gears by employing the right tools and leveraging this remarkable process.

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Reshaping Manufacturing

Lubricant Expo North America highlights future fuels, digital transformation and sustainability

Matthew Jaster, Senior Editor

Lubricant Expo is North America's leading exhibition and conference event dedicated to the lubricant industry. Connecting lubricant solution providers with end-user buyers and the entire chemical and equipment supply chain, the show attracts thousands of engineers and executives each year. As the sister show to Europe's largest industry event, Lubricant Expo Europe, these two shows provide the largest dedicated exhibitions for lubrication solutions on a global scale, with a free to attend expo and conference that serves the interests of thousands of visitors representing more than 75 countries. Exhibitors cover the end-to-end chain of the industry, from finished lubricants and technologies for lubricant users, to the chemical ingredients and development devices for formulators and lab professionals.

This platform unites a diverse array of stakeholders, including lubricant manufacturers, supply chain partners, OEMs, end users, and lubrication experts. The expo offers attendees opportunities to network, discover innovative solutions, and explore strategies for optimizing product and equipment performance.

The 2025 edition boasts almost twice as many exhibitors compared to 2024, reflecting its increasing prominence and appeal across the lubrication industry. Additionally, this year's conference features senior representatives from companies such as Ford, GM, Klüber Lubrication, Lubrizol, Chevron Oronite, BASF, and ExxonMobil. Their active participation highlights the event's critical role in shaping the future of the lubrication sector and the industries it serves.

This year's Lubricant Expo will spotlight several emerging and transformative topics shaping the lubrication industry:

- **Future Fuels and Lubricants:** With the rise of hydrogen, biofuels, synthetic e-fuels, and ammonia, sessions will explore how these alternative energy sources are influencing the development of advanced lubricants that address high thermal stability, oxidation resistance, and material compatibility challenges.
- **Advancements in Electric and Hybrid Vehicle Lubrication:** Focus will be on fluid development for hybrid vehicle architectures and innovations for electrified drivetrains, emphasizing dielectric properties, reduced friction, and superior cooling capabilities.
- **Digital Transformation:** The role of AI, machine learning, and IoT in revolutionizing product development, from predictive modeling to streamlining the formulation process, will be thoroughly examined.
- **Contamination Control and Maintenance:** Key strategies in oil analysis, filtration, and contamination mitigation will be discussed to improve equipment reliability and extend operational lifespans.
- **Supply Chain Challenges and Innovation:** Sessions will address securing rerefined base oils, supply chain compliance, and adapting to geopolitical and regulatory pressures.
- **Sustainability and Green Technologies:** Biobased lubricants, renewable feedstocks, and reducing the carbon footprint of lubricants will take center stage, with a focus on eco-friendly innovation.

According to Tom Harris, event director, the key challenges taking place today in the lubrication market include:

- **Meeting Future Fuel Requirements:** Transitioning to alternative fuels requires lubricants with unique properties, such as enhanced thermal stability, wear protection, and corrosion resistance, to match the demands of hydrogen, biofuels, and e-fuels.
- **Sustainability Pressures:** Reducing carbon footprints, developing biobased alternatives, and conducting life cycle assessments are increasingly critical amid growing environmental regulations.
- **Supply Chain Constraints:** Limited availability of high-quality used oil feedstocks for re-refined base oils and navigating geopolitical tensions and regulatory compliance continue to challenge the industry.
- **Electrification and Hybridization:** The rise of hybrid and electric vehicles introduces engineering complexities for fluids, such as balancing lubrication for internal combustion engines and electric motor cooling.
- **Cost Competitiveness:** While advanced synthetic esters and biobased lubricants deliver superior

performance and sustainability, their higher costs and scalability remain barriers to widespread adoption.

Sustainability is a core theme of this year's Lubricant Expo, with significant emphasis on:

- **Biobased Lubricants and Renewable Feedstocks:** Highlighting advancements in natural, eco-friendly materials like plant oils and esters, while addressing challenges in feedstock availability and scalability.
- **Carbon Footprint Reduction:** Strategies to reduce emissions through accurate data collection, lifecycle assessments (LCAs), and the development of low-carbon formulations will be explored.
- **Re-refined Base Oils:** Industry leaders will address strategies to overcome supply chain hurdles for re-refined oils, promoting circular economy principles.
- **Eco-Friendly Lubrication Practices:** Sessions will showcase technologies and best practices that align with environmental regulations, emphasizing reduced toxicity, biodegradability, and energy-efficient formulations.

These discussions aim to align the lubrication industry with global decarbonization goals and establish pathways for achieving long-term sustainability.

Additionally, the Lubricant Expo is co-located with The Bearing Show 2025, connecting the evolving needs of bearings end-users with the latest technologies serving OEM development, maintenance professionals and R&D engineers. The Bearing Show features exhibitors from the entire ecosystem, including finished bearings, condition monitoring, tools and equipment, components, materials, testing, and machinery used in the processes of bearing production and application.

"Looking ahead, Lubricant Expo is set to continue its impressive expansion. Future editions will likely include an even broader array of exhibitors, groundbreaking presentations, and enhanced networking opportunities," Harris added. "Attendees can anticipate an ever-growing emphasis on sustainability, advanced technologies, and emerging trends, solidifying the event's status as a must-attend destination for professionals throughout the lubrication ecosystem. Its ongoing evolution ensures it will remain a central hub for fostering innovation, collaboration, and excellence in the years to come."

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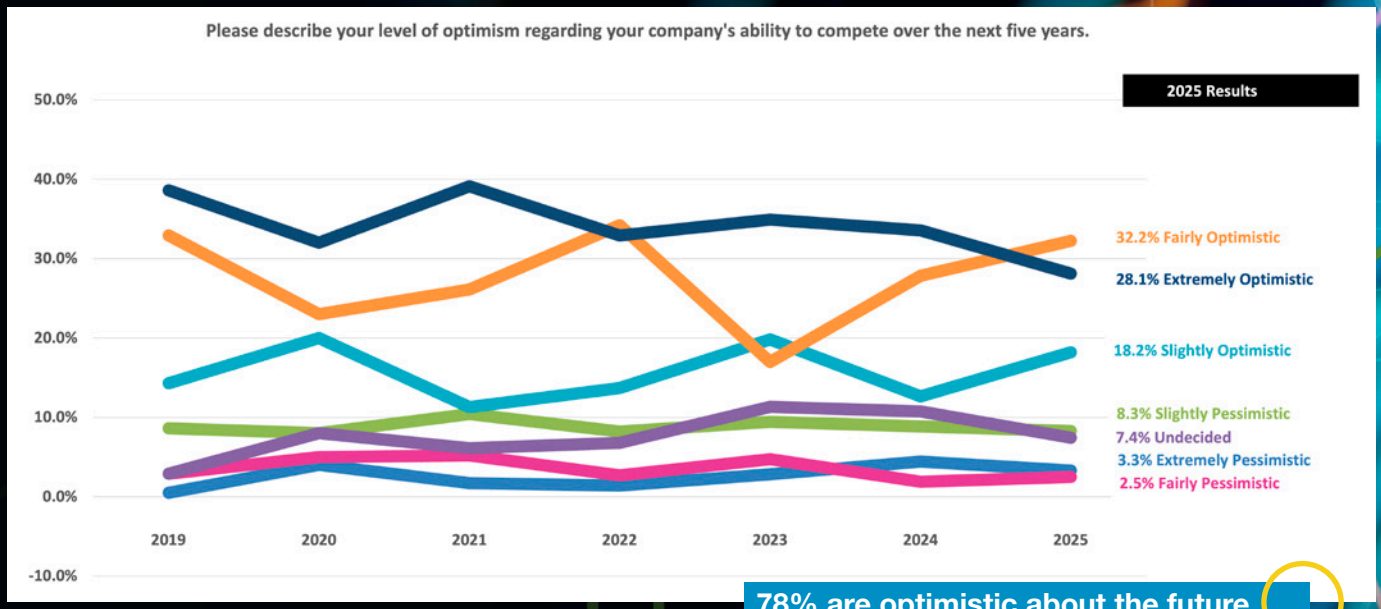
2025 State of the Gear Industry

Insights from the front lines of the gear community

Every year, *Gear Technology*'s State-of-the-Gear-Industry survey takes the pulse of the gear manufacturing world, revealing the latest trends, challenges, and outlooks shaping the industry. Conducted anonymously, the survey gathers insights from subscribers, AGMA members, gear manufacturers, suppliers, and industry experts—primarily from North America but with voices from around the globe. This year, nearly 200 professionals shared their perspectives, offering a real-time snapshot of the industry's health and direction.

Alongside the survey results, *Gear Technology* senior editors Aaron Fagan and Matt Jaster provide deeper analysis through exclusive conversations with leading manufacturers and machine tool companies, delivering firsthand insights into the forces driving today's market.



78% are optimistic about the future

Describe the most important trends affecting your business and the gear industry in 2025.

"President Trump is not a fan of wind power."

"New technology is emerging and the cost of acquiring the equipment has grown higher. Being a small- to mid-sized manufacturer, we are always facing this CAPEX expenditure and also lack of skilled manpower."

"Onshoring is good for American businesses."

"The impact of world trade and tariffs on exporting of gearing to the world."

"Downsides for our company: available product/portfolio, lead times, labor issues. Upsides: Service and repairs, excellent customer and technical support, proximity to customers, supply chain, new technology, excellent quality."

"The electrification trend."

"EV. AI."

"Plastic gears."

"Automotive performance and energy sector."

"Lack of knowledgeable gear machine operators."

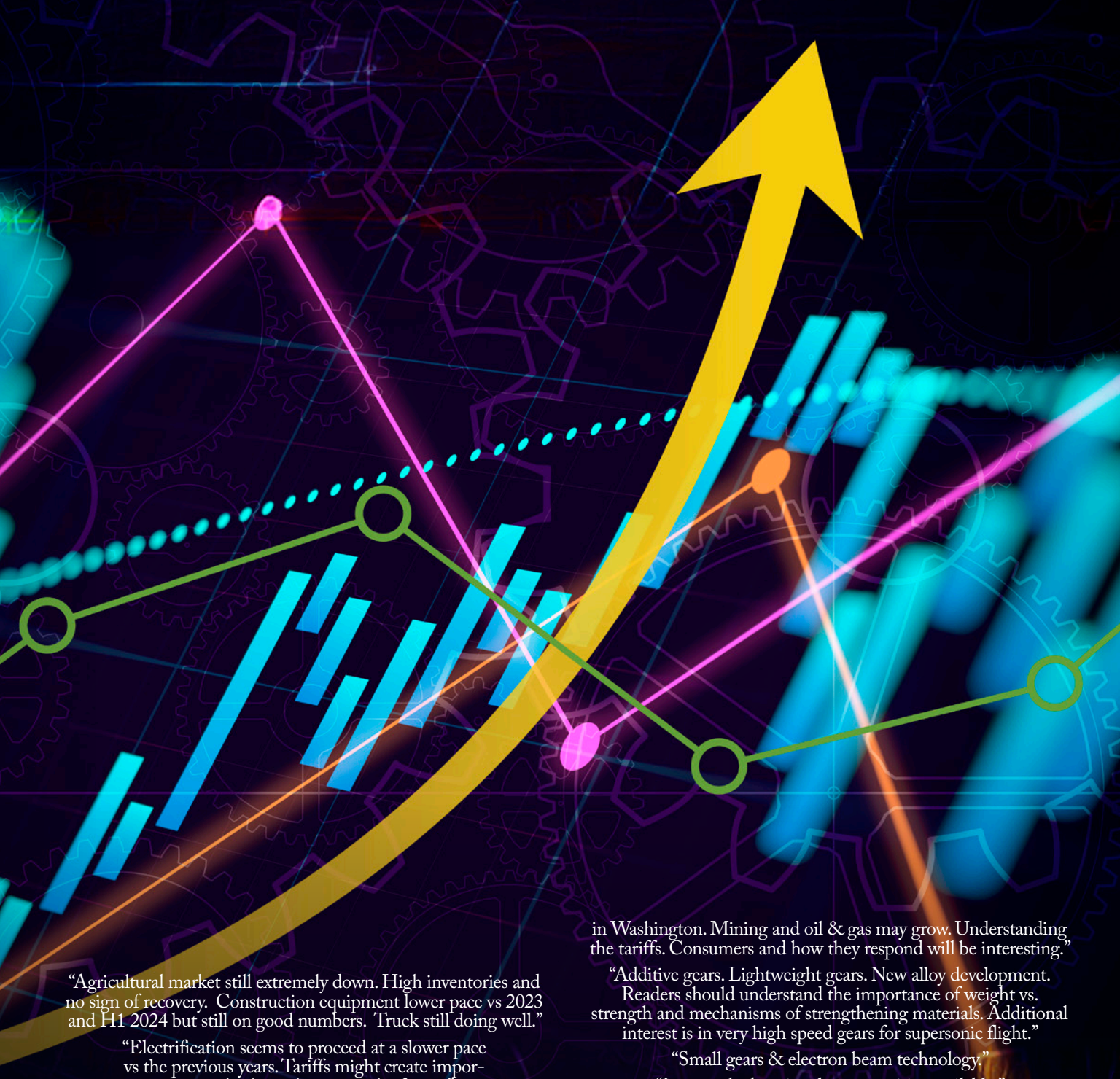
"Domestic capacity. It is hard to work through problems when the solution is multiple days away."

"Increasing influence of AI, CO_2 reduction over the entire life cycle (gearbox efficiency and gearbox production)."

"We in the Brazilian Industry mainly face the lack of a serious Government with well-defined Industrial policies. Especially in the field of gears, a total absurdity for the Brazilian Government is to tax the gear equipment that we need to import from high-tech countries. This makes us totally uncompetitive with other low-cost countries."

"The future is for high-quality gears, where the geometrical testing becomes mandatory!"

"High demand in rail and wind power. Expanding with high capex over next 5 years."



"Agricultural market still extremely down. High inventories and no sign of recovery. Construction equipment lower pace vs 2023 and H1 2024 but still on good numbers. Truck still doing well."

"Electrification seems to proceed at a slower pace vs the previous years. Tariffs might create important supply chain changes in the future."

"Global competition."

"In the second half of 2024, automotive was in decline, gear reducers were stable, other fields (automation, mechanical applications...) showed small growth. No big changes expected for automotive but we see some good signals from other fields."

"Target and trend in the automotive industry are not clear."

"Major changes in the automotive industry."

"High energy prices, high steel prices."

"AM on the one hand and the ever increasing volumes and advanced technology of EV drive lines is a definite threat to ALL conventional Gear Manufacturing Systems."

"Ukraine and Russia war."

"I believe we will see a change in the focus around the EV market. It hasn't gone well so far, but the push will stop happening in Washington. Mining and oil & gas may grow. Understanding the tariffs. Consumers and how they respond will be interesting."

"Additive gears. Lightweight gears. New alloy development. Readers should understand the importance of weight vs. strength and mechanisms of strengthening materials. Additional interest is in very high speed gears for supersonic flight."

"Small gears & electron beam technology."

"Increased educational opportunities available."

"Finding trainable individuals that can work 40 hours per week is difficult."

Car manufacturing has a trend to be supplied more from China, and others are already facing difficulties regarding pricing. Terrible market change if the trend continues for the gear machine makers."

"On the negative side, competition from India, uncompetitive U.S. steel prices, lack of investment in U.S. steel manufacturing, sustainability of U.S. economic growth against the threat of increasing tariffs. Positive trends include increased use of automation and robotics due to labor cost increases and advancements in AI."

"Global economies are in the pits."

"Development of fossil fuel production with the most efficient technical capability of the 21st Century."

"Inflation and uncertainty of the economy."

"Too many programs going to India."

"Gear technology, new gear designs, failure analysis in gear."

"We see a very important decrease in all industrial sectors."

"Technology has been stifled with Biden."

"Labor costs/competition with China."

"Lack of skilled labor, rising costs, diversification."

"I believe customer orders will increase due to economic optimism for the future and continuing advances in engineering technology."

"Workforce development, automation, inflation."

"Increasing offshore competition."

"NEV (neighborhood electric vehicle) transmission with planetary drive."

"Decarbonization of the passenger car industry."

"Electrification of propulsion systems."

"Repair of older equipment will be a larger portion of the market because of inflation."

"Breaking into new hybrid technology markets with government funding. Investments are being made to participate in this emerging market."

"Business is positive. Finding talent is not."

"Scrap."

"Automation and the increasing effectiveness of gear manufacture with 5 axis machines."

"The growing trend towards automation in industries is leading to an increased demand for precision-engineered bevel gears, as well as improving the durability and performance of gears."

"Deep discounting by competitors."

"Impacts of emerging technology on how we conduct business and how we manufacture."

"Electric vehicle growth, general economic conditions."

"Reduction or even elimination of the production of conventional transmissions with manual gearboxes."

"Firstly, the Chinese competition, with machines and labor cheaper than what we have access to. Then, I would say the demand for gears in new mechanical transmissions, or even the replacement of mechanical transmissions."

"Electrification and decarbonization of manufacturing. Staffing and training—how to find and develop highly capable team members."

"Gears are the heart of our equipment. The cost of manufacturing medium-accuracy gears is increasing, which is a major concern."

"Transmission performance increase, efficient gear cutting processes, energy-efficient gear cutting machines, digitalization, process monitoring, new closed-loop manufacturing strategies ."

"Increase in electric vehicles and stagnation of ICE vehicles."

"New high-quality requirement in EV gears."

"Robots."

"New materials, treatments along with need to reduce wear and friction."

"In my opinion, too much attention is being given to advanced technologies and not enough on learning the basic technologies; everyone wants to run when they can't even walk."

"My specialty is large gears for mining. Little work. Other specialty is high precision For defense. Also very little work."

"Gear noise, plastic materials for gears."

"Tighter tolerances in gear accuracy. Also, automation even in low volume applications."

"Hiring qualified personnel to train as machinist."

"The USA is not competitive with China, Europe, especially eastern Europe, South America."

"Mergers and acquisitions."

"Chinese tariffs."

"Effects in the EV market and a need to expand the ID/OD grinding capacity for gear manufactures."

"Consolidation."

"Lack of consistent policy and direction in the EV market. This could be a great opportunity to scale up consistently, but political flip-flopping on policy creates an unpredictable environment that is highly risky to make scale-up investment into."

"As a machine builder, the trend towards manufacturing gears on lathes and other standard pieces of equipment has affected our business and will likely continue to affect our business in a greater capacity as the ability make better quality gears on lathes is further developed."

"Tariffs."

"EV markets."

"EV and alternate fuel vehicles."

"Electrification is rolling out at uneven speeds across different industries."

"EV Market. Scope of the impact for an ICE to EV transition."

"Economy strength."

"Decrease in production due to election year."

"International gear standards.."

"The continued long deliveries of gear processing machines."

"Gearing in robotics applications."

"Tariffs. Strong dollar. Available and skilled workforce."

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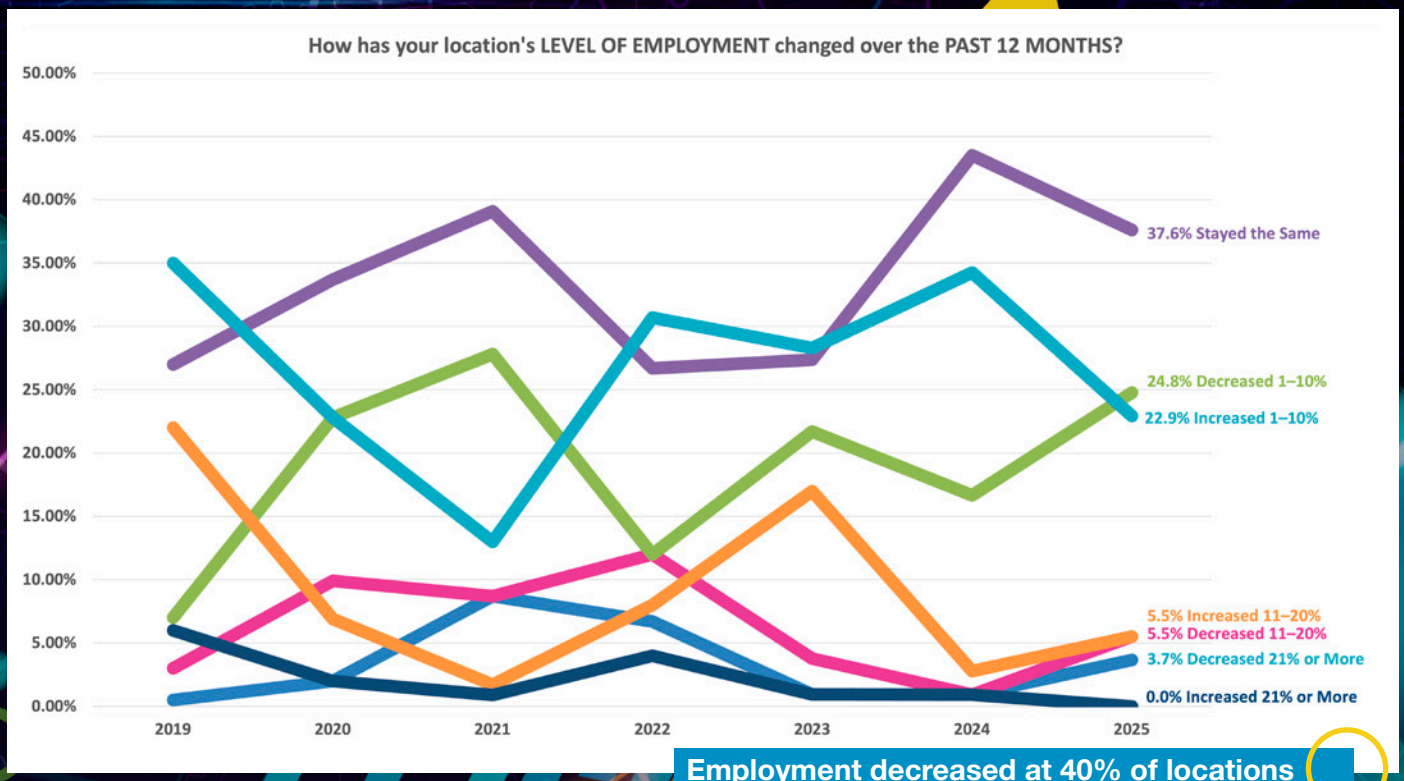
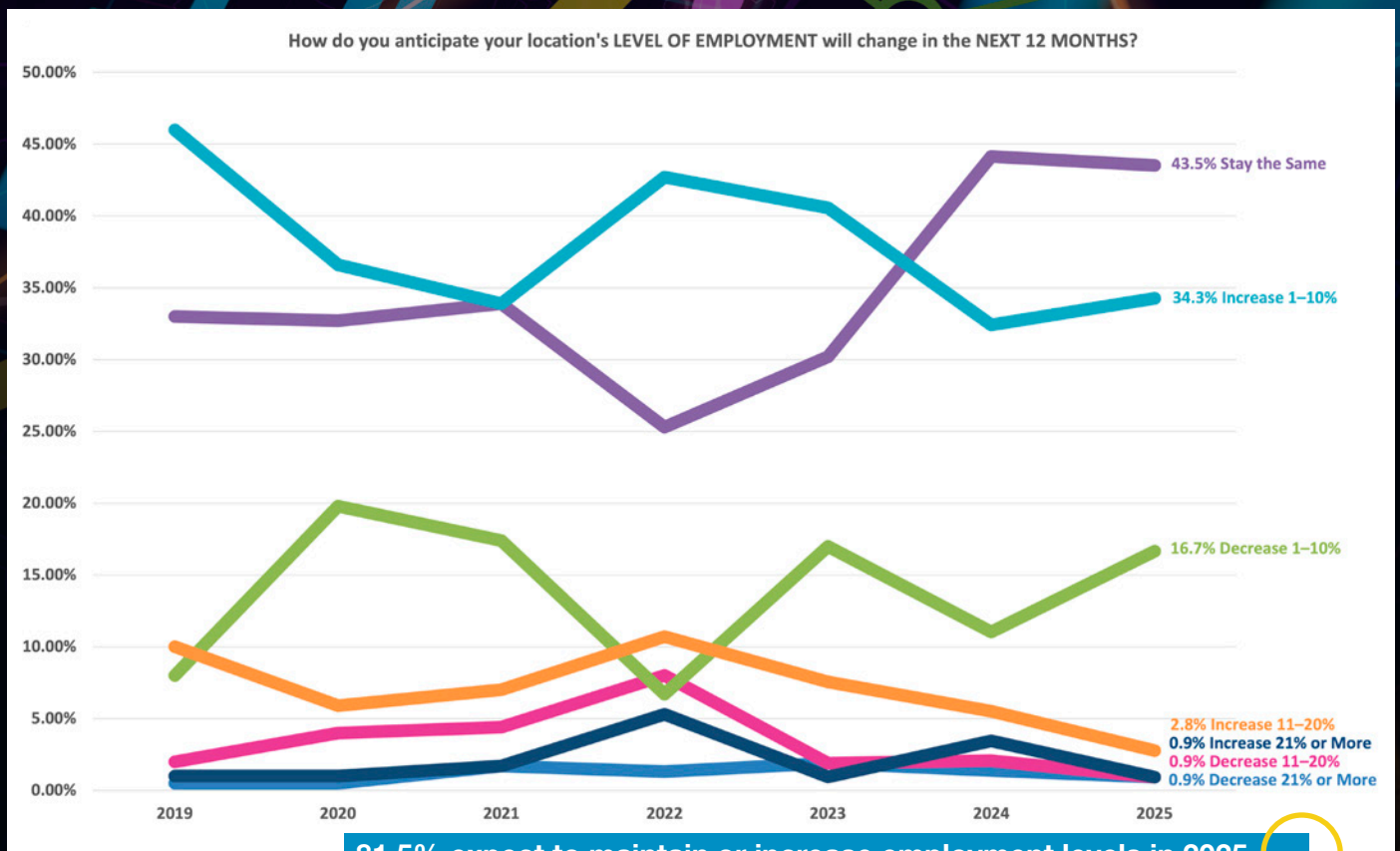
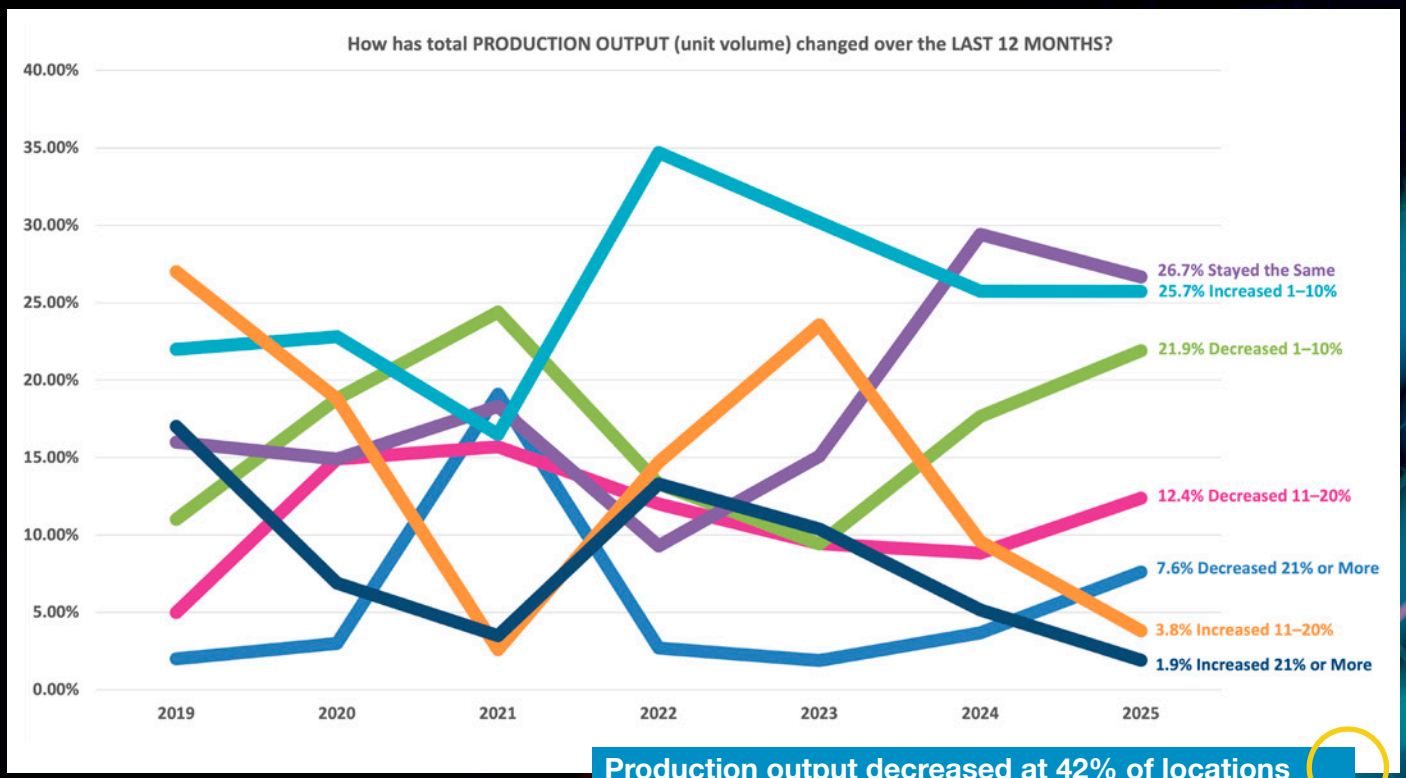


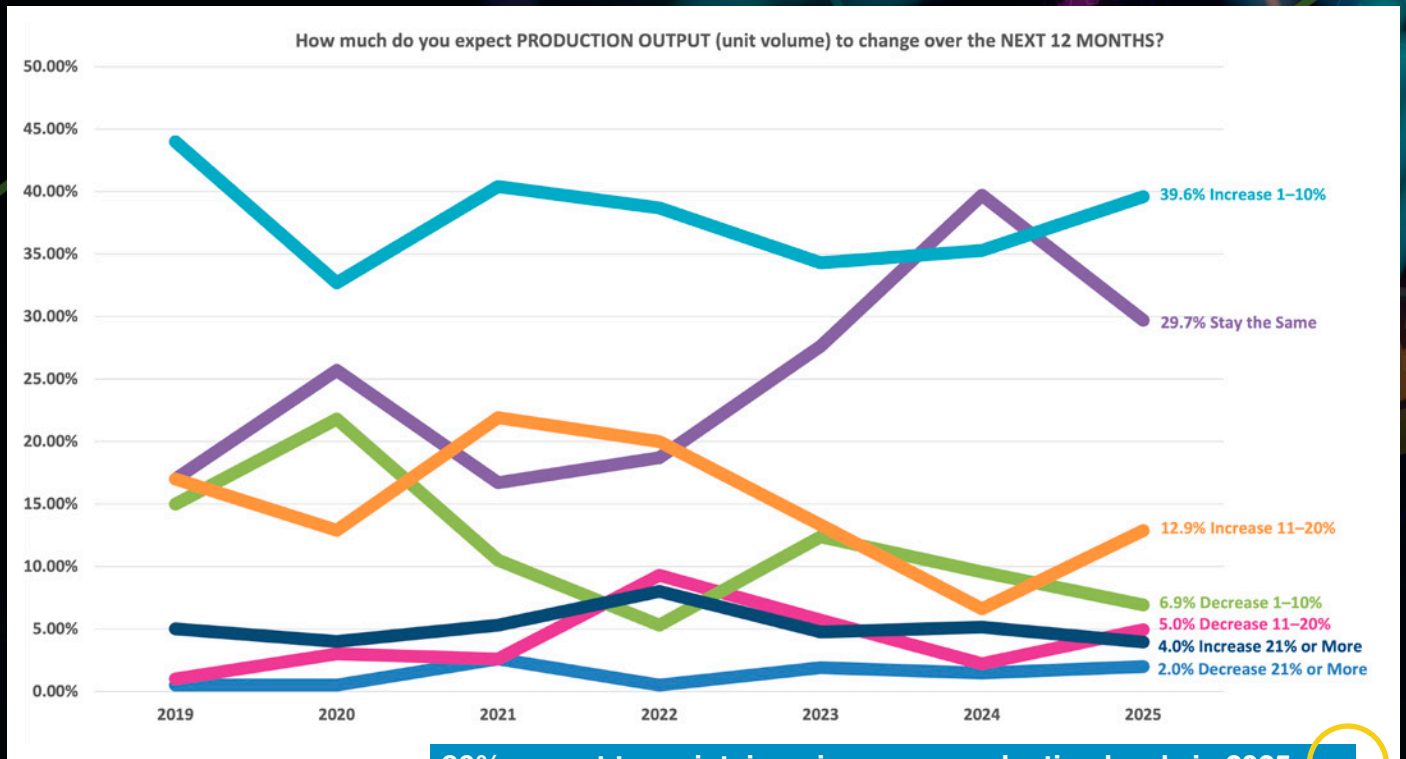
Employment decreased at 40% of locations



81.5% expect to maintain or increase employment levels in 2025



Production output decreased at 42% of locations



86% expect to maintain or increase production levels in 2025

The State of Gear Machine Tools 2025

Challenges, opportunities, and emerging trends

Aaron Fagan, Senior Editor

As the gear industry steps into 2025, manufacturers are navigating a landscape shaped by geopolitical uncertainties, evolving workforce dynamics, and rapid technological advancements. Alongside *Gear Technology*'s annual State of the Gear Industry survey, we like to gather insights from leading machine tool manufacturers on the challenges, opportunities, and trends defining the year ahead.

Global Uncertainty Shapes Industry Outlook

Manufacturers cite geopolitical tensions and economic instability as primary concerns. Peter Wiedemann managing director of Liebherr-Verzahntechnik GmbH underscores, "U.S./China tensions. European political instability. European bureaucracy." Felix Scholz, managing director of Liebherr Gear and Automation Technologies, Inc., adds that uncertainty surrounding industrial tariffs is a lingering challenge. John Perrotti, chairman and CEO of Gleason Corporation, concurs, noting that, "As we enter 2025, geo-political uncertainties still remain." Shane Hollingsworth, vice president of sales at Kapp Technologies highlights the difficulty of positioning products effectively, stating, "It's been difficult to predict, and considering the worldwide landscape, it will be interesting to see how the U.S. market converges or diverges from the rest of the world's major economies."

Perrotti further elaborates, "While global instability continues, we are focusing on leveraging our strengths in automation and precision manufacturing to ensure long-term competitiveness. The companies that can rapidly adapt to geopolitical shifts will be the ones that thrive."

Amid these concerns, reshoring efforts and supply chain shifts offer optimism. Wiedemann highlights India's growing role in global supply chains, stating, "New (potential) suppliers will need to continuously invest in sophisticated technology." Scholz points to the "positive trend of reshoring activities bringing manufacturing back to the United States." Jeffrey Smith, president of NIDEC Machine Tools America, also sees growth as the primary objective: "The biggest challenge is the same as always—grow!"

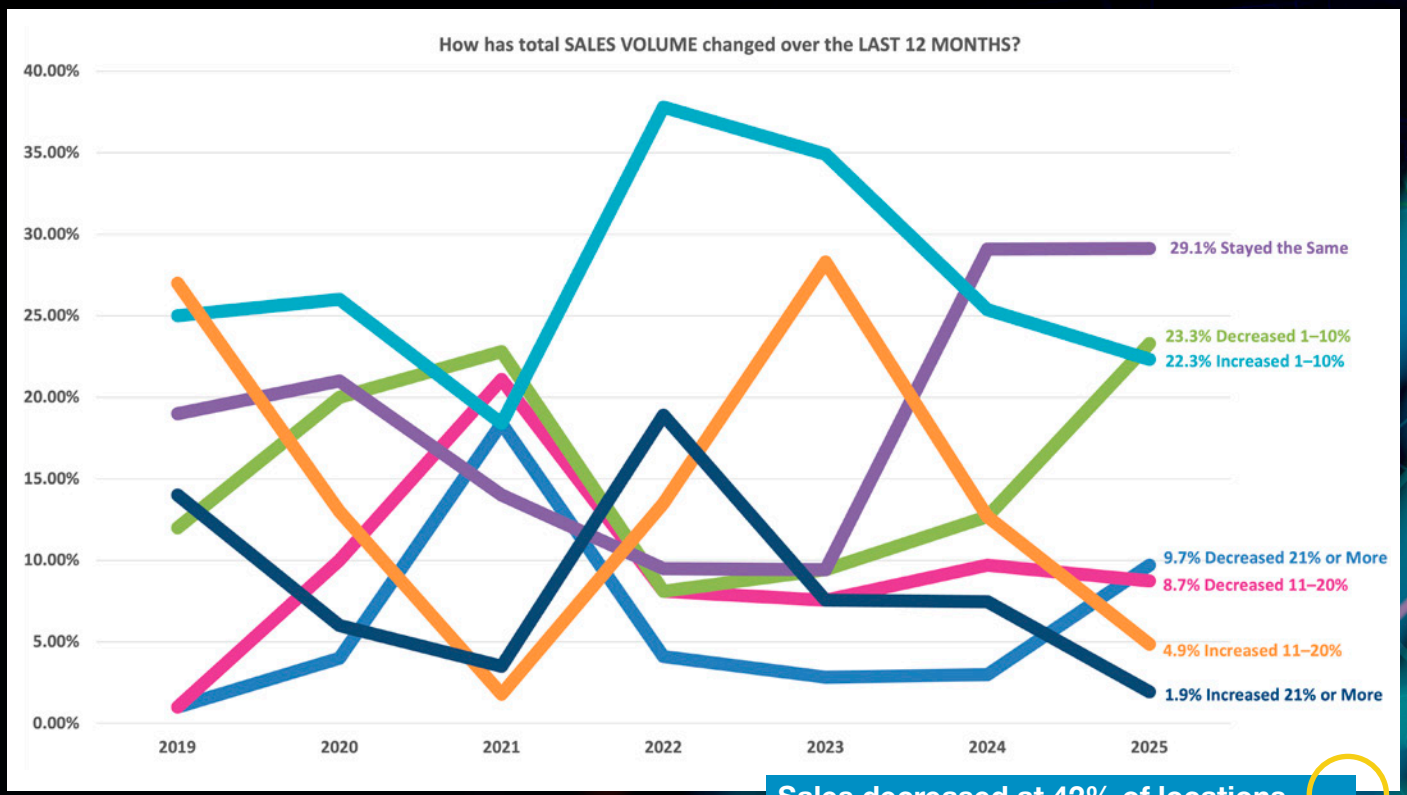
Bridging the Skills Gap

The industry continues to grapple with workforce shortages, but companies are evolving training programs to meet changing demands. Gleason Corporation offers a broad range of training options, from fundamental classes to specialized technology training, while Liebherr emphasizes its ongoing commitment to in-house training for employees and customers alike.

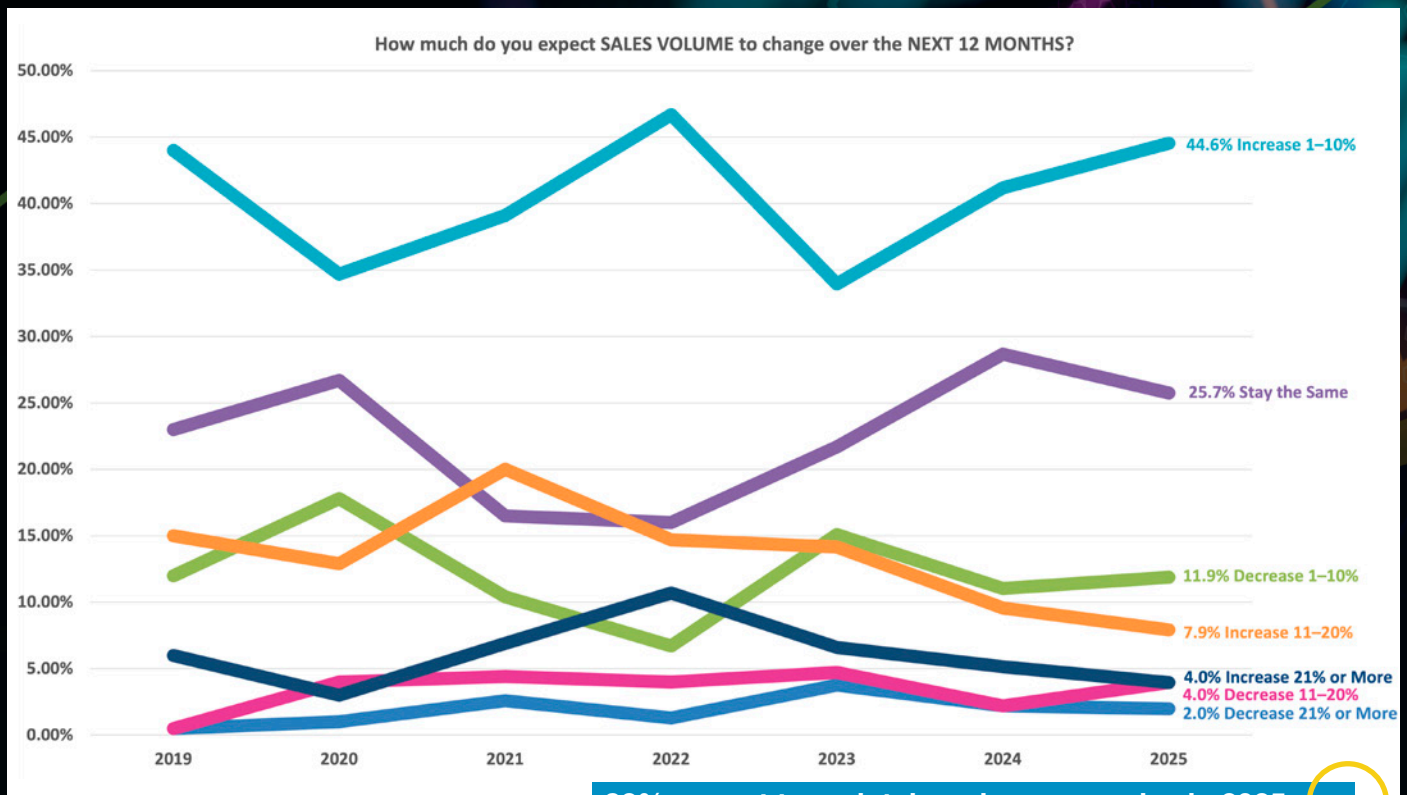
Peter Wiedemann, managing director, Liebherr-Verzahntechnik GmbH.

Felix Scholz, managing director, Liebherr Gear and Automation Technologies, Inc.

John Perrotti, chairman and CEO, Gleason Corporation.



Sales decreased at 42% of locations



82% expect to maintain or increase sales in 2025

Shane Hollingsworth of Kapp Technologies underscores the challenge of onboarding new employees in such a specialized industry: "The world of gears is quite unique, and most new employees start with no experience. Utilizing not only in-house training but also industry courses such as AGMA's is key for our future employees."

Meanwhile, GMTA's Claudia Hambleton sees apprenticeship-style training as a crucial tool: "We still have a large skills gap, but more companies are working to close it with educational opportunities and real-world skills." She also notes that "Online and virtual learning is one of the few positive outcomes of the pandemic. The opportunities to learn new information are extensive."

Smith at NIDEC takes a straightforward approach: "Education at its core still remains the same—people need information and experience to dovetail as fast as possible to get the knowledge to stick."

Perrotti adds, "We are heavily investing in cross-training and skill development because the modern gear industry requires a workforce that is adaptable and ready for next-generation technologies."

The Rise of Smart Manufacturing

The adoption of Industry 4.0, IIoT, and Industry 5.0 continues to transform manufacturing. Liebherr-Verzahntechnik GmbH is focused on developing digital tools to enhance productivity, while Gleason Corporation integrates digital twins and smart-loop manufacturing to improve precision and efficiency.

Perrotti explains Gleason's approach: "Binding design, manufacturing, and metrology together with digital solutions is one of our core strategies." Meanwhile, Liebherr's Peter Wiedemann emphasizes the need for data-driven decision-making, stating, "We are constantly designing new digital tools for our customers to support them in keeping productivity up, identifying potential bottlenecks in the production environment through data analysis, and defining the right corrective actions, such as preventative maintenance."

Regarding the role of AI in manufacturing, Perrotti states, "Artificial intelligence and machine learning will play a critical role in predictive maintenance and production optimization, making factories more efficient and resilient."

E-Mobility's Uncertain Trajectory

The e-mobility market remains a wildcard. While China continues to lead innovations, North America's demand has not met expectations. Felix Scholz notes, "The market demand for e-mobility in North America did not match predictions and will remain an uncertainty for the U.S. automotive market."

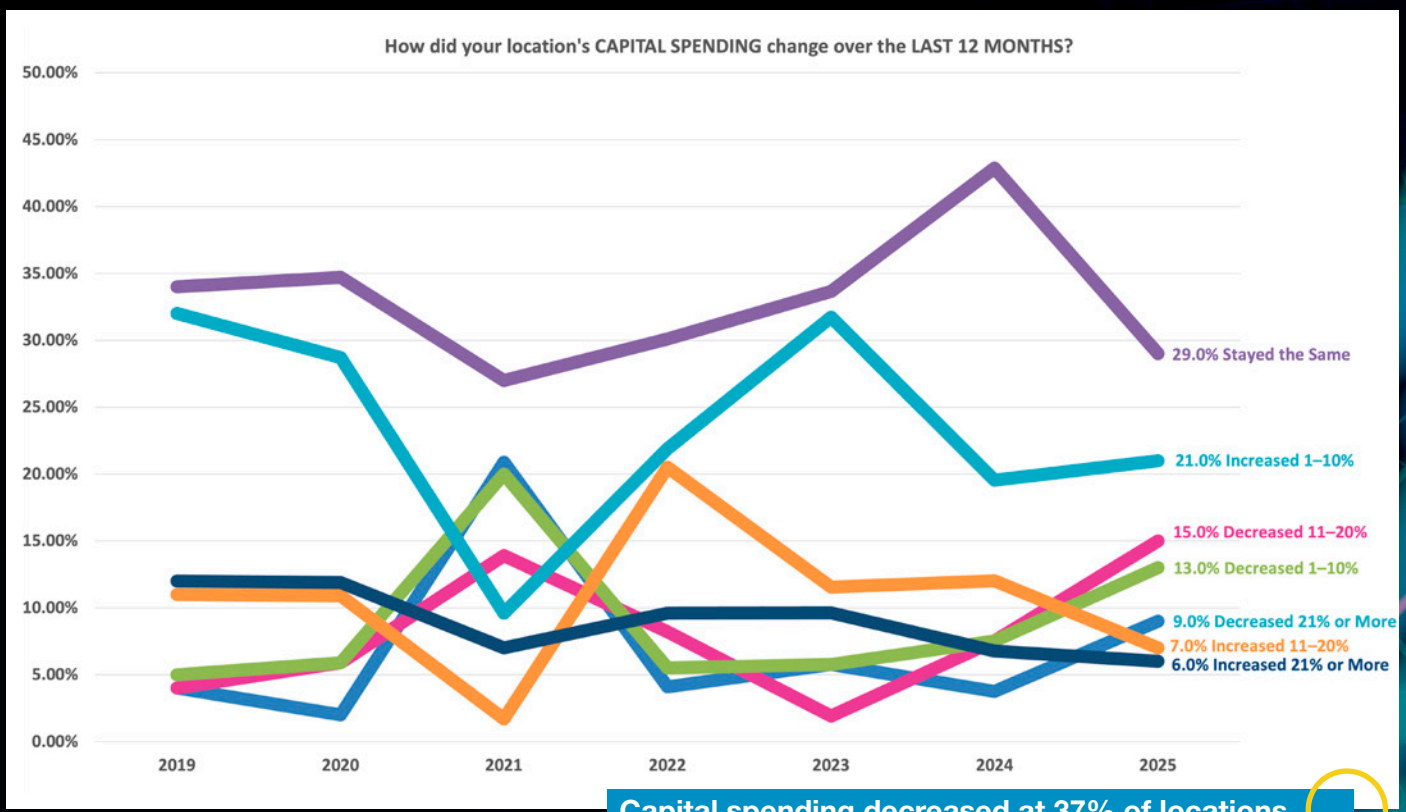
Hambleton from GMTA adds, "We have been greatly impacted by the hesitation in the EV market. Hybrid vehicles seem to be the most viable option right now." John Perrotti sees a mixed picture, observing that "E-mobility is still growing, but, in most markets other than China, it is growing at a slower rate. Plug-in hybrids have gained momentum in the U.S. market, but incentives are disappearing, which may put downward pressure on the growth rate."

Jeffrey Smith, president, Nidec Machine Tools America.

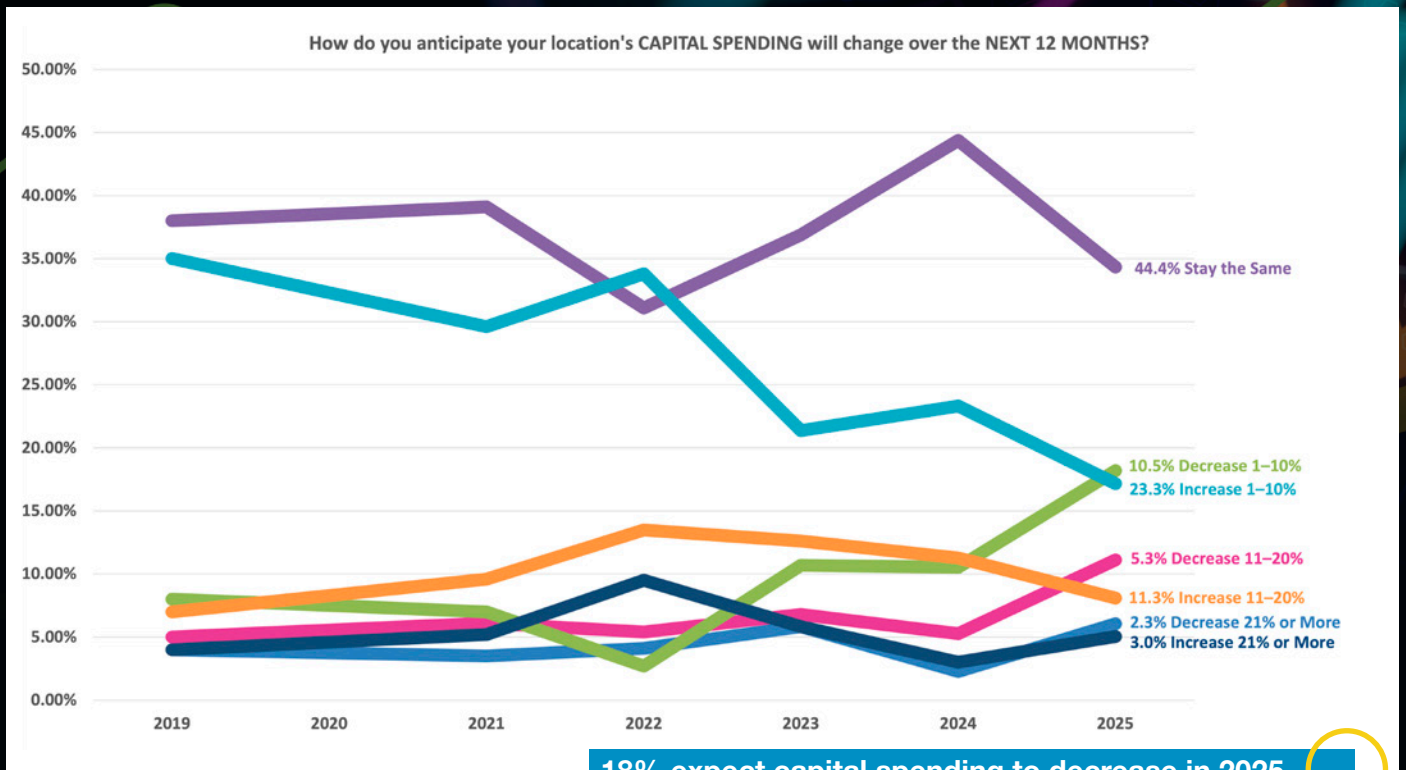
Shane Hollingsworth, vice president sales, Kapp Technologies.

Claudia Hambleton, office manager, GMTA.

Scott Yoders, vice president sales, Liebherr Gear and Automation Technologies, Inc.



Capital spending decreased at 37% of locations



18% expect capital spending to decrease in 2025

Sustainability Is More Than a Trend

Manufacturers are taking a proactive approach to sustainability. Scott Yoders, Vice President Sales at Liebherr Gear and Automation Technologies, Inc., highlights their real-time energy monitoring system, allowing customers to track and optimize energy consumption: "This helps our customer base reduce their costs and also makes a significant contribution to sustainability."

Gleason Corporation similarly integrates energy efficiency and emission management into its long-term strategy. Perrotti adds, "This is a continuous, long-term strategy also in 2025."

Industry Blind Spots

Beyond well-known issues, some challenges are not getting enough attention. Peter Wiedemann calls for pragmatic U.S.-Europe trade agreements to counteract bureaucratic inefficiencies.

Perrotti points to aerospace, defense, and robotics as growing markets that deserve more focus, adding, "Western economies are still running short in protecting and rebuilding key industries to become less dependent on Asian supply." Jeffrey Smith also highlights the growing role of AI and automation in manufacturing: "Generalists with a good comprehension of a variety of skills will be needed. In manufacturing, we can see this as cobots and industrial AI come to market."

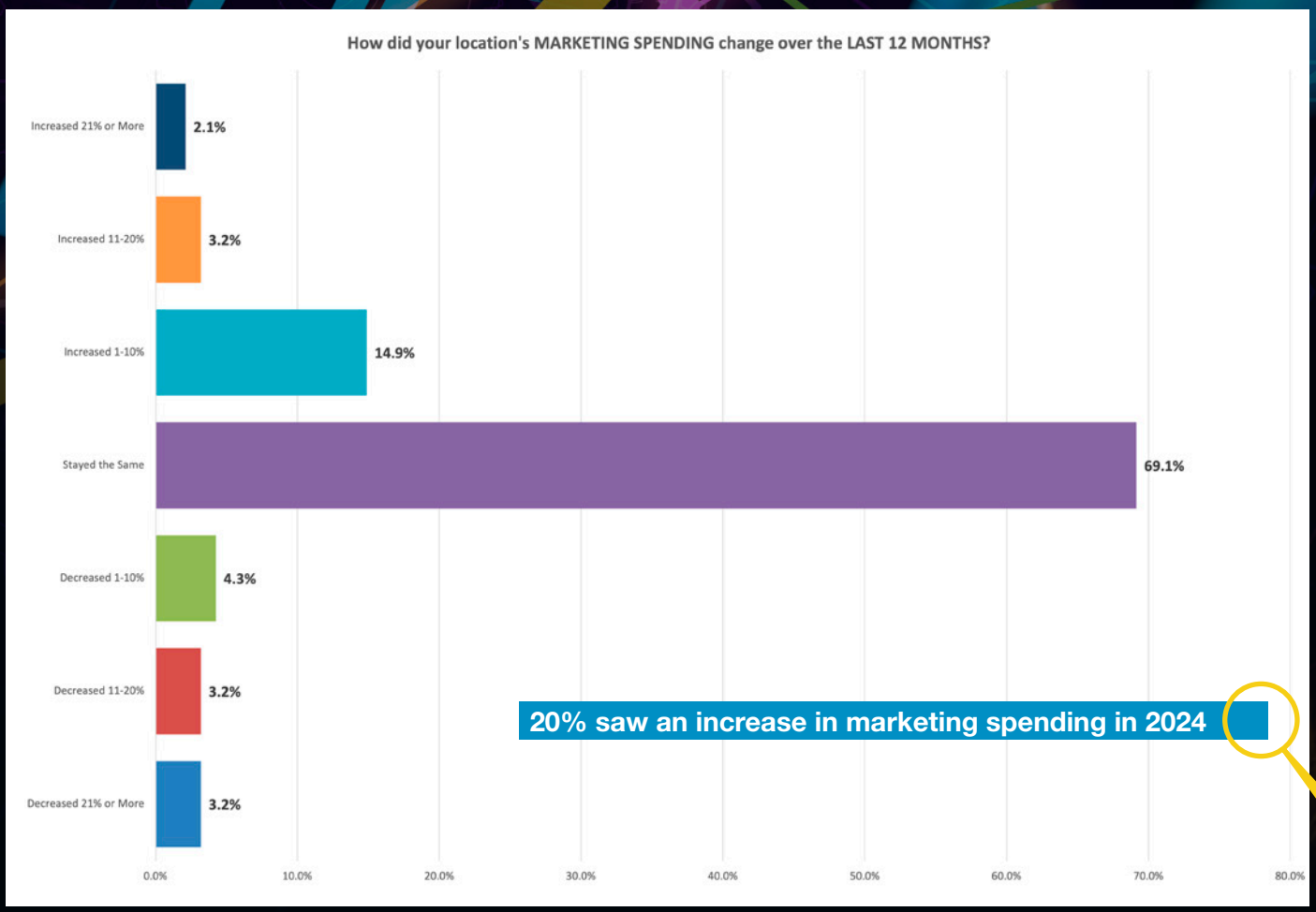
Policy Landscape: Waiting for Clarity

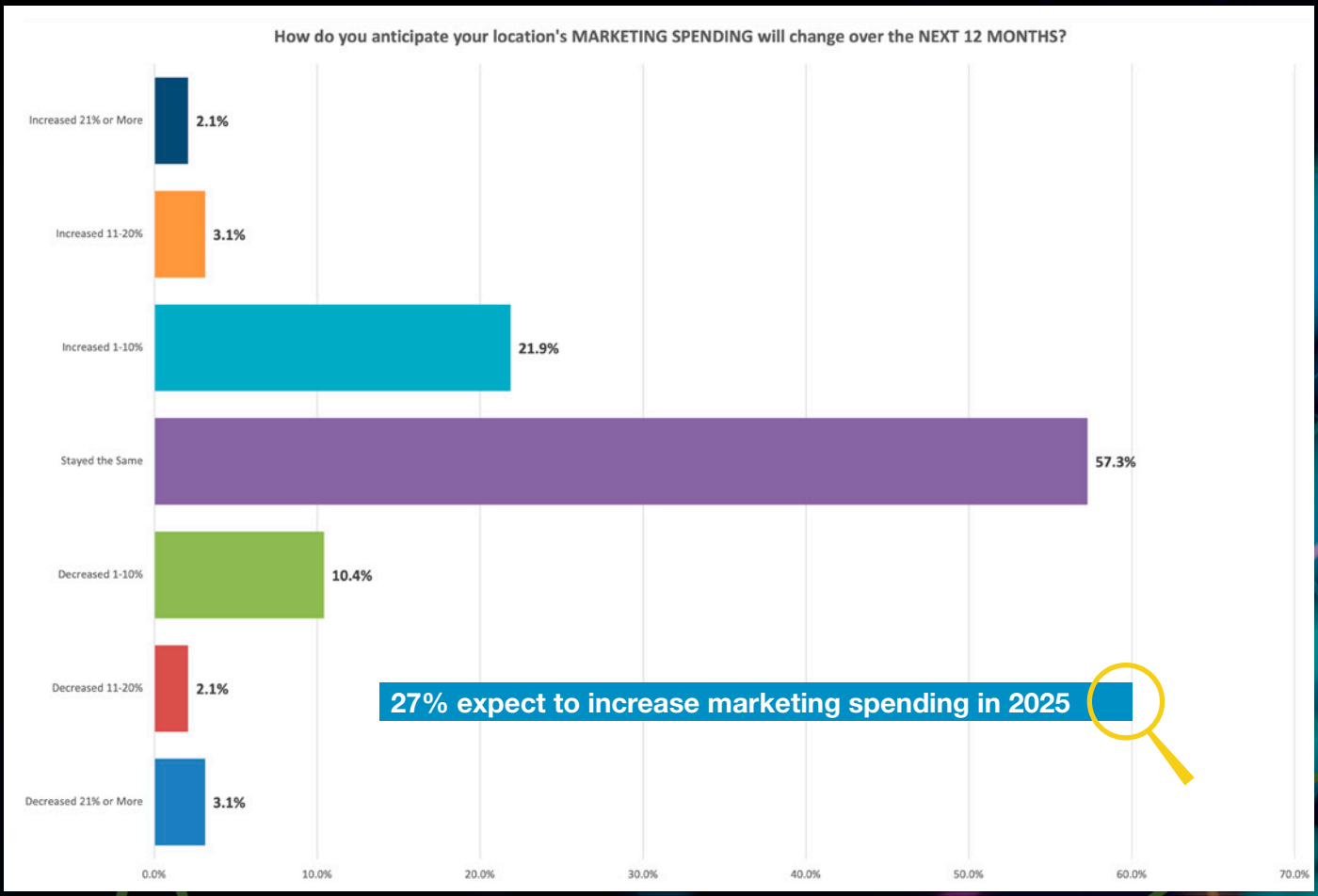
Recent U.S. trade, energy, and workforce policy shifts create both challenges and opportunities. While Gleason Corporation and Kapp Technologies are cautiously monitoring domestic energy policies, NIDEC's Jeffrey Smith emphasizes flexibility in response to changing political landscapes: "Given the switch in parties in power, we are being cautiously optimistic, taking care to prepare for as many outcomes as possible."

The Road Ahead

Despite challenges, manufacturers remain optimistic about growth, innovation, and new market opportunities. As Shane Hollingsworth aptly puts it, "We want all of our organization to feel we are in the boat and all heading in the same positive direction, even if we hit a few waves along the way."

The year ahead will test the resilience of the gear industry, but with strategic investments in technology, workforce development, and sustainability, companies are poised to navigate the uncertainties of 2025—and beyond.





In what ways has your company implemented AI, and how do you feel about it?

"Document search."

"We are working on adding it to our CNC programming through software."

"AI is still in its infant stage in manufacturing."

"None yet."

"We have made limited progress using Copilot, but not for internally generated data. It brings benefits for web research and software development."

"Order processing, options selections—improved the overall time."

"None."

"We don't implement AI yet."

"In product design and responding to expectations."

"We are currently in a testing phase in all departments."

"We don't have this topic on the agenda, and little knowledge about AI."

"In the advanced gear metrology field, the AI does not have much to contribute. Most of the software solutions are black boxes."

"We are in process of implementing AI in our design & technology center."

"Still working on it. I do not have yet a clear picture."

"We do not use AI."

"Production planning."

"Just chatbot. Not so fearful."

"Not at all."

"Not yet. In some areas of analysis and research, it will help the Industry."

"Only in coding area. We are using AI to improve system management."

"We are currently using it in creating documents, communication, marketing and research in sales."

"Doesn't exist."

"Not implemented."

"We are watching what is happening. I have concerns about copyright infringement and accuracy of the large language models required for AI to be of value."

"Primarily in machine vision in support of final part inspection and internal inventory/part handling and management. I personally feel excited about the prospects of expanding our use of AI across all parts of our organization."

"AI has selective potential."

"Have not implemented AI."

"We have always had robotics. Not sure if AI has caught up to our industry yet to make a difference, but it is coming."

AI (continued)

"Not applicable ."

"At the moment we haven't implemented inside the company. We think it can be an opportunity for better understanding the market industry variation."

"Not up to speed."

"None, and I really do not have an opinion of it as yet."

"We have not implemented any AI."

"No implementation."

"Basic use in database and as digital assistant in meetings."

"We are developing a qualified database that may be used as the LLM for AI."

"Minimal usage related to improved internet search tool."

"Very early stages of using."

"Not implemented."

"We have not yet implemented it."

"Limited use of AI—don't know enough about it yet."

"We are implementing custom AI throughout our business and feel that it has a tremendous positive impact on our business."

"No IA implemented."

"No, it doesn't help small businesses at this point."

"Just for some office jobs like reports, presentation etc. My feeling is neutral so far."

"We are learning about it."

"We have not implemented AI and I am feeling rather negative about it."

"It hasn't yet. I am glad of this as AI is still in its infancy and poses a huge risk until it is strongly regulated and its datasets are effectively controlled to prevent compounding biases."

"It is in the beginning stage yet."

"Still experimentating, it is ok but need to define the use."

"Only around email, policies, sense checking documents."

"Marketing and research."

"I am not aware of any AI projects in my area at this time."

"None."

"Prospect mining, feel pretty confident it will pay off."

"In a bit of automatic drawing."

"Engineering, HR, marketing, tooling answers, heat treat. Think it's great!"

"We don't."

"None, but intrigued."

"Simply ChatGPT for productivity improvements. Low level application as of yet."

"We have had 'Lunch and Learns' with IT on ways to use AI in your daily work activities. On a personal level, I use it regularly to solve problems."

"We occasionally use AI to generate text or summarize web search results. We think most of the problems AI could help us with could also be solved by conventional computing."

"Limited, but I like it."

"Very little. Still trying to understand it"

"Only using AI for press releases and other marketing tasks."

"We have not implemented any AI into our company yet."

"Nothing tangible."

How do you anticipate U.S. trade policies in 2025 will affect your supply chain and costs?

"Will get better."

"We are expecting them [costs] to increase."

"They will increase the demand for our American-made products."

"Likely to increase costs but outlook is clouded due to not having a clear direction from the Federal Government."

"Not too much, due to access to local supply chain."

"Will affect but I don't know how much."

"Depends on the new policies."

"Hinder procurement and increase costs."

"From European perspective there will be most likely a cost increase."

"We produce in Europe. The future U.S. policies will not be friendly!"

"Do not see major change."

"We expect relevant effects due to US trade policies."

"We try to buy material in big stock at the beginning of the year."

"In a positive way we expect."

"Probably not at all."

"It is too early to comment. It depends upon how Europe, the Middle East and Ukraine situations respond to the not-yet-clear Trump Policies. Oil prices and climate change issues will also come to the forefront."

"Not at all."

"I have no idea."

"Unsure at this time. We use all American made products in our gear production. It will be interesting to see if demand will create shortages and allocation again. It could push prices up again for steel and other products."

"2025 U.S. trade policies that have yet to be announced will likely put a damper on near-term growth and cause an increased costs. Trends will likely continue during the new regime's policies."

"Not at all."

"Increase the cost of doing business."

"I expect supply chain costs to increase."

"Neutral."

"Most likely decrease demand due to higher prices."

"Depending on how the elected administration does, it could harm current customers."

"We will do much better, even if cost of raw materials rises."

"I believe (hope) costs will drop somewhat."

"Increased cost of materials."

"The business will remain similar."

"Increased cost."

"Negatively."

"Uncertain on direct impact but likely neutral based on balance of positive and negative changes to our industry."

"Potential tariffs could have a big impact. This is an unknown for now."

"They will have a significant impact on supply chains and business costs due to tariff and protectionism policies and the regionalization of production."

"High potential to have a substantial impact on my business."

"Minimally."

TRADE POLICIES (continued)

"In 2025 everyone will be passive and cautious. Effects will show up later."

"Raw material prices will be adversely affected; may see some growth from domestic customers."

"I think no impact."

"Probably there is no good news in the coming months."

"Costs will go up."

"Minimal. Maybe raw materials."

"Positive."

"I expect supply chain and costs to continue to rise."

"None."

"I expect it will increase costs."

"Don't anticipate any negative effect."

"HELP!"

"Will increase costs."

"Should make the industry more competitive."

"Positive."

"They will increase, but not sure by how much."

"I expect they will stay the same, as over 50 percent of or supply chain is in Northern Illinois and, of the remaining 50 percent, 40 percent is based in the United States."

"Expecting increased input costs due to tariffs."

"Tariffs will likely increase our cost for raw materials and some purchased parts."

"Tariffs and the strong U.S. Dollar may force higher prices in the future. The strong USD hurts the global market for domestic suppliers."

"Tariffs would have a significantly negative effect on our business."

"Highly unpredictable but likely negative."

Describe the importance of sustainability in your company's overall strategy, including specific initiatives your company has implemented, if any.

"We have tried to digitize files."

"Not much."

"Not yet started."

"Not much. We recycle when we can."

"We have updated corporate literature, but it plays a minor role in product development and manufacturing operations."

"Very important. Our customers are asking to comply."

"I believe sustainability is important to my employer. We are always looking at manufacturing techniques that reduce consumables. We are designing products that will reduce greenhouse gases."

"Sustainability becomes a more and more important aspect for the entire industry. We are developing an integrated management system in order to cover all requirements beyond a conventional quality management system."

"Important topic. We meet all government requirements."

"From the beginning our sustainability was based on original ideas and dedicated technology applications. The strategy will be the same: Do more with less."

"This is of paramount importance. We have implemented a detailed plan with several actions ongoing. First of all, we did it because we believe in it. In addition this is becoming mandatory to work with certain companies and countries."

"To maintain the ISO 14000, Reach and Rohs."

"It is important. We have installed solar cells in our plant roof."

"Most important concept."

"It is an important topic. We have implemented ISO 14001 standards and installed solar power plant."

"Nil."

"Sustainability is going to become a bigger driving force in our company. We are being asked by our customers to become sustainable. We use returnable dunnage now with our customers."

"Taken seriously."

"Both finical and environmental sustainability have been ongoing since the 1980s."

"We are focused on reducing our operations CO2 emissions through the purchasing and/or implementation of green energy."

"Sustainability is a BAD Word here."

"Global economies must improve to provide potential of sustainable development."

"None."

"We see CSR (corporate social responsibility) getting more embedded in the manufacturing sector. Large OEMs are demanding more carbon data, recycling data, energy consumption and efficiency data, etc…"

"It's only going to get more prevalent."

"Very important."

"This is important for us. We are implementing a program."

"Not important."

"Part of our values: reclaim of material, energy reduction."

"I have always tried to balance financial sustainability and environmental sustainability. This month I celebrate 50 years of being self-employed doing machine work and welding at the same location."

"Focus and investment on hybrid technologies to help customers improve efficiency."

"Sustainability is in the forefront. However, it takes a back seat as technology for sustainability is not there yet."

"There are some specific initiatives that we have implemented energy efficiency, waste reduction and education and awareness."

"It is important."

"It will become more important to our customers. Measures are available but are too expensive to sell them right now."

"Neutral. Limited focus beyond simply not being wasteful."

"Sustainability is very important in my company. We are focusing on a new product most suitable for the new drive of vehicle."

"Very important. We will change out heating system and install solar panels this year."

"Heading in that direction. Looking at ISO14001."

"Very important."

"We are actively looking at ways to decrease our carbon footprint and energy costs through the use of solar panels and other energy saving initiatives, but they need to make sense for a return on investment."

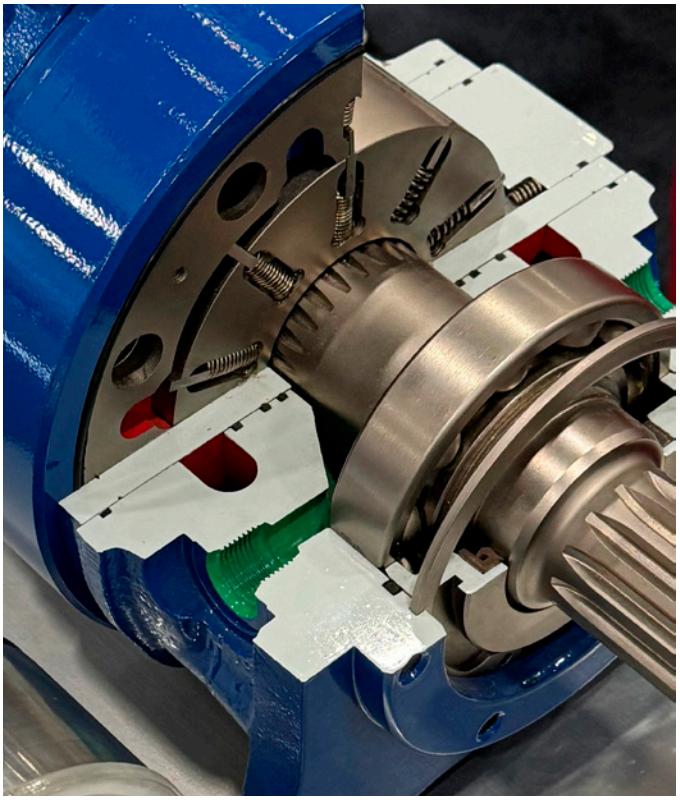
"Highly important."

"Top priority."

Outlook 2025

Gear manufacturers weigh-in on state-of-the-gear-industry today

Matthew Jaster, Senior Editor



The ever-volatile election cycle has ended. Gear companies—and metalworking organizations in general—must now shift their focus toward customers. Can they meet orders in a timely fashion? Is it time to strengthen the talent pool? How is their equipment stacking up against the competition? Overall, there is a feeling business will turn the corner in the 3rd and 4th quarters of 2025. *Gear Technology* spoke with representatives from Atlanta Gear Works (AGW), Croix Gear and Forest City Gear (FCG) on the state of gear manufacturing in 2025.

A Shifting Gear Market

The gear market—and metalworking in general—has witnessed a tumultuous couple of years in manufacturing. A couple of things happened with COVID according to Ruthie Johnston, CEO, Croix Gear.

"First what we found is that companies over bought and over stocked believing the panic orders that their customers placed to be in line to get their products. The supply change shortages didn't allow them to build. So, the shelves were full. With that in mind, customers were not buying as much. They were using up the stock they had."

In 2024, Johnston saw companies laying off nearer Q3 and Q4.

"The election happened, and we started to see the orders coming in for 2025. We have brought in new customers this year. We decided to enter some new market spaces. We are excited because have added outstanding talent to our arsenal to take us into '25 and beyond," Johnston said.

Croix Gear serves a remarkably diverse customer base. "We make gears for cars, forklifts, robots, commercial food mixers, tooth grinders for horses. The list goes on. We are in the process to be certified for aerospace, Johnston added. "We have customers that will be requiring more from Croix in this area. It will trickle down to our vendors and suppliers."

Atlanta Gear Works is a total-solution process-critical rotating equipment design, engineer, manufacture, and repair company headquartered in Dawsonville, Georgia, less than an hour north of Atlanta, at the entrance to the Blue Ridge Mountains. For more than 30 years, the company has served some of the country's leading manufacturers with innovative power-transmission solutions, high-quality products, and beyond-the-expected service. "For our business we see more carburized, hardened and ground gearing today. We have adapted by adding grinding capacity," said the AGW executive team.

AGW recently finished rebuilding two 50-year-old damaged gearboxes from one of the largest water pumping plants in the world—the W.G. Huxtable Pumping Station, which protects the livelihoods and lives of thousands of vulnerable

Ruthie Johnston, CEO, Croix Gear.

Kika Young, president of Forest City Gear.

SUSTAINABILITY (continued)

"Our company has continuously operated with a focus on our environmental impact."

"There is no national policy support for U.S. gear train development."

"We supply renewable technologies as an important piece of our customer base."

What role will emerging technologies (including, but not limited to IIoT, additive manufacturing, robotics, automation and artificial intelligence) play in your organization in the coming years?

"Small."

"Automation, Automation, Automation... We are trying to implement automation in all areas where it's possible."

"Need to implement IOT in the future but no definite timeline."

"Increase in robotics."

"We are already active in IIoT, need to have more standardization (rating practices) before additive manufacturing becomes useful."

"Slowly implementing some where there are benefits from such technologies."

"IoT and Robotics will be developed more and more."

"Very important role because the technologies are rapidly changing."

"Little to none."

"Don't know. We are currently using additive manufacturing in our test lab."

"AI will change the working world for all of us. Mainly seen positive as a support in daily business. However, there are numerous risks. Other emerging technologies have a limited effect on the heavy industry gearbox manufacturing."

"We do not have this topic dealt with in our Industry, but I believe it will be irrelevant. High costs are part of the impediments to this."

"Target is to maximize technology over operator capabilities."

"We are very much engaged with automation that we expect to play a key role to partially offset the labor cost."

"We are working on different coating technology like HiPIMS."

"It is important and we are working on it."

"We will have to upgrade out test facilities and add futuristic tech and knowhow."

"IIoT is one of very important things to manage all industrial process. It will not die."

"Those are currently important to our production. We are looking to bring IIoT in this year. We look at robotics, AI, and automation for any purchase of equipment. We have some of those in place now. Incorporation of 3D has many options for us now and the future from workholding design to prototype.

Labor is typically the number one cost of a company. If labor can be replaced through other means I expect our future workforce will look very different than it does today."

"Will increase opportunities for us to aid in the design of advanced gear systems."

"We use 3D printing and robotic welding some now. As a low volume (1 to 10 of a part number) manufacturer, robotics and many other forms of automation don't work."

"It is one of the most important issues to take into account for having better business."

"Adoption of AI is a fundamental part of our business strategy across all facets of our business. We expect to continue investigating ways to increase competitiveness and reduce cost through the application of new technologies."

"Emerging technologies is like counting your chickens before they've hatched."

"They are requirements for success."

"None. It doesn't work for our business model."

"It will continue to increase."

"Robotics and artificial intelligence."

"No primary role."

"We are currently researching these technologies. They will be instrumental in our manufacturing business."

"Additive manufacturing is currently being reviewed for continued applications along with automation."

"None."

"We will work on predictive maintenance."

"Growing exponentially."

I hope our product knowledge software provides a way to make my experience and knowledge available to others so they don't have to pay for learning what I have already paid for."

"Additive manufacturing projects are under investigation along with IIoT but implementation expected to be relatively slow."

"Continue to look for more opportunities for automation."

"Machine improvements will likely have a bigger impact than emerging technologies."

"Here I think we will only implement robotics."

"Significant impact that will require increased capital spending to benefit from these new technologies."

"Heavy on automation and AI."

"AM is a primary business stream; no others will be impactful in the near term."

"The new technologies will play bigger roles especially robotics and automation. Two reasons: decreasing labor market and lower prices of robots and automation."

"I think AI will be important at our company."

"Additive manufacturing."

"Hopefully a very big role."

"Maybe 5-8 percent overall contribution."

"Robotics and automation (lights out) are key strategies for us in the short term. We will be exploring AI and how we can potentially use this for quoting / estimating / planning / programming in the future."

"I suspect these emerging technologies will distract my organization from doing what needs to be done for our recovery and to meet growing demands."

"None."

"We do not make use of this tech."

"It will continue to grow at a steady pace."

"Not very much as we are a large job shop."

"Big role."

"Robotics and automation will become an important part of our organization."

"Significant as we move more into production."

"Huge."

"Every change in technology affects our products, how our customers use them, and what their expectations are. This is true in established as well as emerging markets."

residents in the rural Mississippi Delta. The importance of keeping Huxtable ready to pump is undeniable. And the key to readiness is keeping all ten of its identical 50-year-old gearboxes operational. The contract to repair the remaining gearboxes runs through 2026. AGW added a new Kapp Niles Gear Profile Grinding Machine ZP 24 in combination with two other Kapp Niles grinders in order to cut down on total repair time.

FCG announced the groundbreaking of new warehouse in October. The 50' x 100' climate-controlled warehouse will serve as storage for finished goods, while prioritizing storage space in the existing footprint for in-process items for Cut Teeth Only jobs.

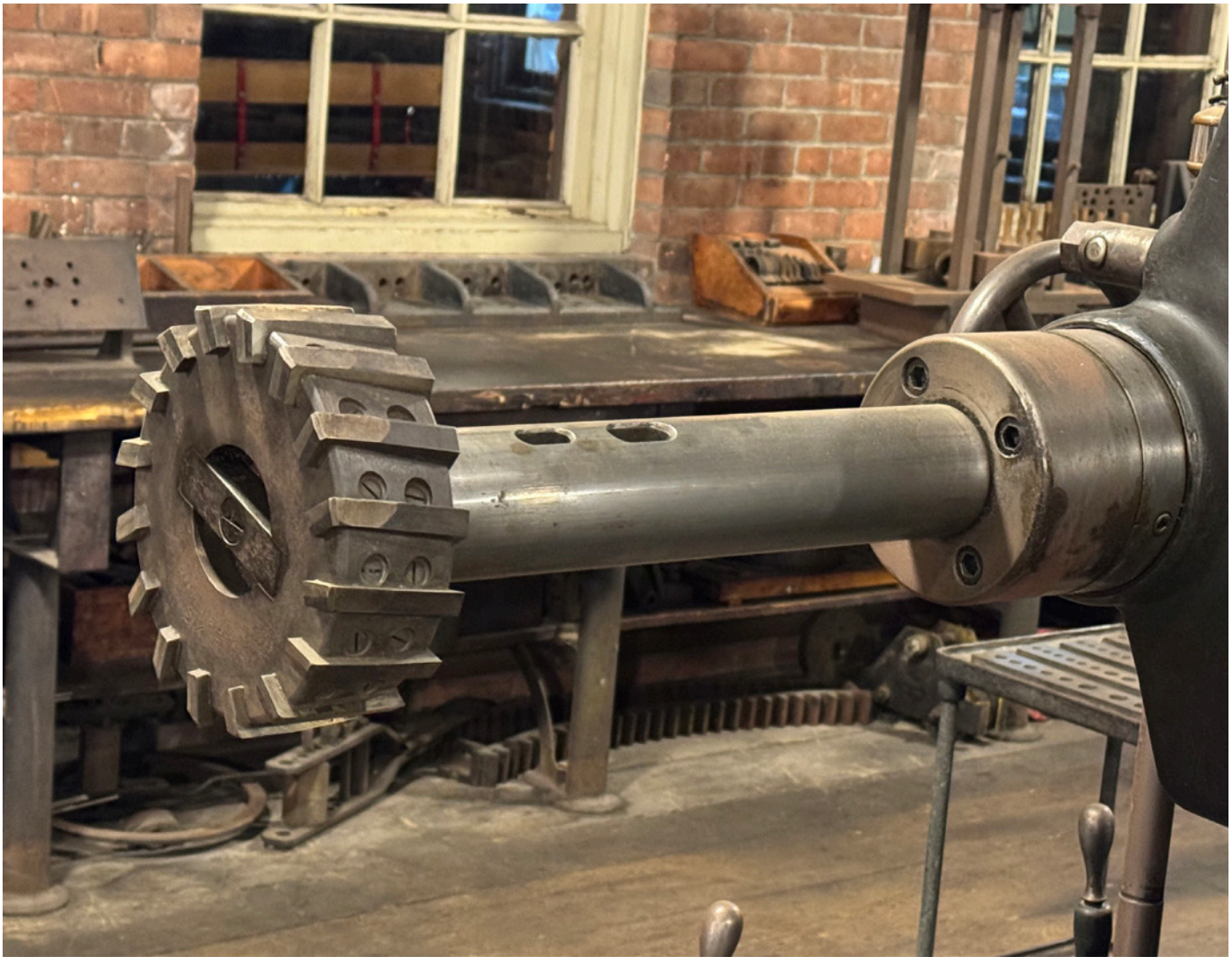
"Really since 2008, U.S. manufacturing has been on a roller coaster ride. From offshoring to the manufacturing renaissance, advances in 3D printing, IoT, AI advancements, robotics, COVID, remote work, and now (hopefully) a strong stance toward re-shoring—things have been interesting!" said Kika Young, president of Forest City Gear.

"For the industries we serve, we are seeing an uptick in quoting across the board, from industrial food applications to military, and defense to outer space and aerospace. Industrial applications, pump gears, and robotics are also holding strong, "Young said. "The new administration is very friendly toward U.S. manufacturing, and we are eager to continue our current growth trajectory. We are excited, literally, and figuratively, to keep being out of this world!"

Companies are looking for greater efficiency, collaboration, and meeting delivery dates. Some companies have sourced their gear manufacturing out which opens opportunities for companies like Croix Gear, according to Johnston.

While electric vehicles, and electric applications in general, still require some gearing, it is far less than a typical internal combustion engine and has had an impact on industry. Counterintuitively, FCG has seen an uptick in quote requests relative to EV gearing due to the higher quality requirements needed to offset the acoustic signatures that are no longer masked with an internal combustion engine, Young added.

"Gears in an EV engine need to be quieter because there is no noisy motor to cover up the sound. FCG does not have TS certification and refrains from automotive work, EV or otherwise. However, it is becoming apparent that battery production (specifically lithium requirements) nor the electrical grid can support widespread EV use at this time. While FCG doesn't dabble in the automotive world, we hold that the gearing within automotive will stay strong across the board," Young said.



Utilizing Emerging Technologies

As a job shop, widespread automation has also not been an option yet for lower-volume work at Forest City Gear.

"I am personally interested to see what we can do with cobots soon. Adapting around COVID—when our main end-user was aerospace and most of the world stopped flying—was certainly a challenge! We moved our focus toward robotics during that time. At FCG we're constantly working to stay on the cusp of leading technology and being aware of market and economic changes. If you are not evolving, you are dying. Luckily, we can utilize the excellent resources, market research, webinars, and networking made available by the AGMA to further our efforts in these areas," Young said.

Atlanta Gear Works does not see an emphasis on robotics soon but according to the executive team, the company *will* be exploring additive manufacturing.

"At AGW, the focus will remain on reliability and uptime for our heavy industrial customers. "All of our customers and vendors say they are enthusiastic about 2025 and we're also very optimistic."

According to a recent report from BDO, many manufacturers were figuring out where they land on the innovation adoption curve as it relates to artificial intelligence (AI) in 2024. BDO anticipates 2025 will be the year that manufacturers advance their AI maturity. Manufacturing will see a variety of AI use cases proliferate. Beyond streamlining routine tasks, some manufacturers—especially those who were early adopters or early majority—will use AI in more sophisticated ways.

For instance, they may use AI to accelerate product development, including prototyping, machine-learning-informed engineering processes, and models that can simulate product performance and design. Other manufacturers may use AI to enhance employee experience. For example, AI can translate instructions into multiple languages in real-time. In doing so, manufacturers can teach new skills and programs to their workforce, despite language barriers, enabling more efficient upskilling across the enterprise.

Another significant trend will be building and maintaining a strong data infrastructure. However, many manufacturers continue to face challenges working with a dozen or more disparate systems that have unique and asynchronous data inventories, resulting in weaker data foundations.

In 2025, BDO expects manufacturers with greater data maturity will not only expand their AI use cases but also take a more data-driven approach to all operations to gain a competitive advantage. Some manufacturers, for example, will analyze plant floor data to optimize production practices and help cut costs. Others may leverage data to bolster their employee retention efforts, identifying turnover trends and understanding how employee churn impacts output quality from their warehouses.

Education and Training

Staffing gear manufacturing shop floors remains one of our industries' greatest challenges. Recent engineering graduates tend to focus on software, research and computer science. The gear industry needs system specialists able to manage the growing demands in both mechanical and electrical engineering.

"We have one fully–trained full–time mechatronics tech already part of our team," Johnston said. "We also have one that we have cultivated at Croix Gear. He is in his last year of school. I am looking to hire new engineers. I can find mechanical and manufacturing process engineers, but it is very difficult to find one that has gear training or knowledge."

FCG will continue to develop a local labor pool, starting in middle schools and high schools in the area. "We are active in many local organizations to stay proactive in this area and have recently joined the wonderful program, Craftsmen with Character, which is the brainchild of the brilliant Dave Hataj of Edgerton Gear. We are active with the National Tooling and Machining Association's apprenticeship program, several area robotics clubs, national manufacturing days initiatives, and much more," Young said.

In 2024, AGW added two engineers and 15 machinists and assembly technicians. As a result, the company has added a second shift. The executive team continues to focus its efforts on minimizing customer downtime.

Keeping an Eye on Changing Markets

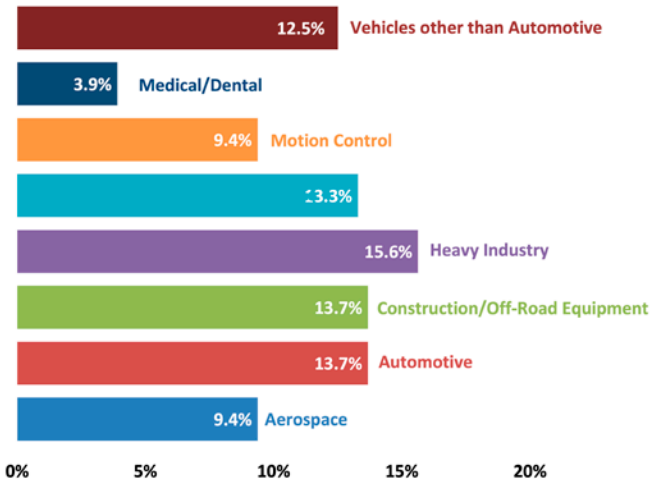
What will the EV and hybrid markets look like in 2025? How will wind, solar and clean energy projects fare under the new administration? What surprising end markets will gain momentum this year in gear manufacturing?

"FCG is very intentional in not letting any individual customer, or even end market, take too big of chunk of gross sales. As we saw through COVID, diversification is key to weathering the storm. While putting all your eggs in one basket might make you a lot more efficient (and a lot more money in the short term), it's just too risky an approach for us," Young added.

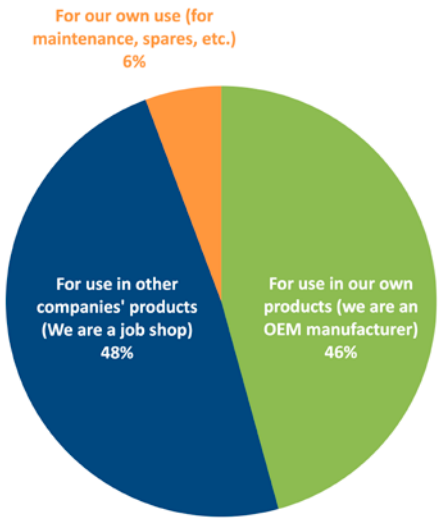
Big picture, we will keep a close eye on potential mergers and acquisitions and gear companies looking for potential buyers in 2025.

"I'm curious what succession will look like?" Johnston said. "There are so many buyers out there today!"

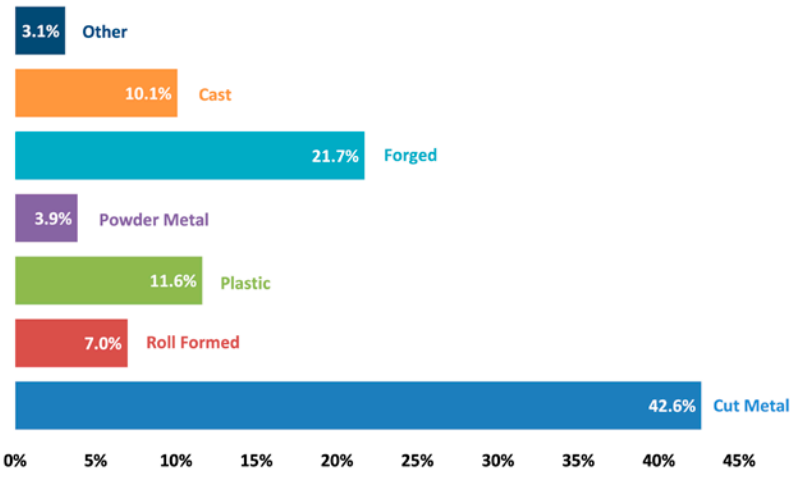
The gears (including sprockets, splines, worms and similar components) made at this facility are used for (check all that apply):



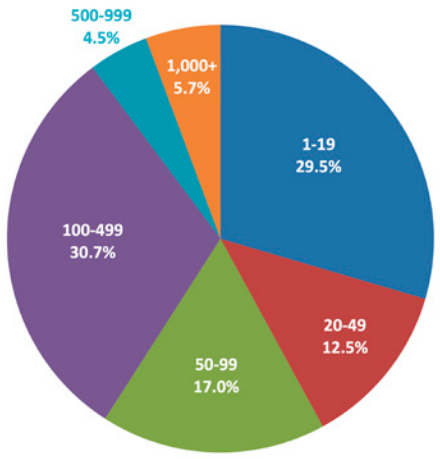
Gears (including splines, sprockets, worms and similar components) are manufactured at this location:



The gears manufactured at this location are (Check all that apply):

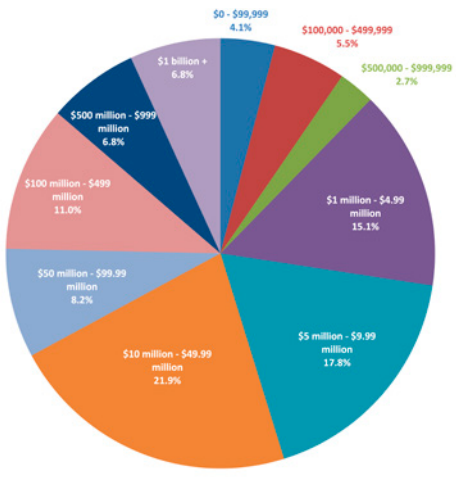


How many employees work at your location?

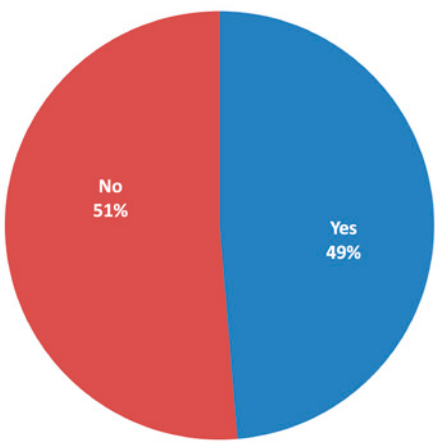


Which category best describes your job title/function?

What is the approximate annual revenue for your company?



Is your company currently a member of the American Gear Manufacturers Association (AGMA)?



Thank you to all who participated in this year's survey!

Moo-ving Forward!

Mary Ellen Doran, AGMA Vice President, Emerging Technology

I've always been a planner, and a new calendar feels like a blank slate of possibilities. 2025 promises an exciting year for AGMA Emerging Technology, with a packed schedule of programs. We began the year with a webinar featuring Noel Mack, CTO of LIFT: The National Advanced Materials and Manufacturing Institute. If you missed it, it is available on-demand on the AGMA website. Alongside committee meetings, we'll host eleven webinars (first Wednesdays) and live presentations at key AGMA events, including the Annual Meeting, SNL, and the Motion + Power Technology Expo.

This year, I had the opportunity to kick off my work at the Consumer Electronic Show (CES) in Las Vegas. It's a great way to preview trends shaping the year ahead. It also prompts me to find unexpected connections with new technologies. While I was there, a colleague asked me to name three things I'm keeping an eye in 2025. It was a casual question that led to an interesting reflection. My response: "Cybersecurity around AI, mechanical advancements for serial production of humanoid robots, and cow burps."

Cybersecurity remains a critical topic in manufacturing. As we saw in James McQuiggan's webinar presentation last June (still available on-demand) social engineering was the #1 root cause of hacking and malware. Phishing tactics are growing harder to catch. Akamai noted, "We see 61 billion credential stuffing attacks in 18 months." I am watching to see how multi-factor authentication changes and find new strategies for training employees to keep information safe.

On the humanoid robot front, 2024 saw impressive progress and record-breaking investment. At the start of the year, prototypes were expected to be years away, but by mid-year, we saw prototypes performing complex tasks. By year's end, robots were in industrial plants, with broader deployment accelerating. While the scientists will continue to teach the AI models, the challenge for AGMA members lies in helping to scale up production—from a $200,000 per unit prototype to a mass-produced unit costing $15,000-$20,000. I'm particularly interested in innovations to lightweight and reduce costs in actuators and gearboxes. With our experience in manufacturing engines and components for millions of cars annually, we have a clear pathway for scaling up the mechanical aspects of these robots. I saw some new solutions in the Schaeffler booth at CES that hold real promise, and I look forward to watching this space and bringing you information as others bring their ideas to market.

Now "cow burp" probably was not an expected answer. I can tell you that it was not on my shortlist in early December. But then I received the MIT Technology Review's 10 Breakthrough Technologies 2025 edition. Number four on their list is: Cattle burping remedies. The article highlights products making "real progress on one of the trickiest problems for climate change." The article states that, depending on the analysis, livestock emissions can contribute 11 percent to 20 percent of the world's total pollution. This new product is said to cut emissions by 30 percent. How is this applicable to the gear industry? I see everything as interwoven. Recent moves in the EV market stem partly from the need to reduce pollution. Should this livestock feed provide significant improvements in that sector—what are the ramifications for vehicles? Will this lead to the changing of some public policies? Will the research aid in the pursuit of biofuels? I just want to watch this space in 2025 to see how it folds into the overall picture.

As always, I encourage you to join in our activities. AGMA has four committees discussing 3D printing technologies, AI and related IIoT topics, electric vehicle technology, and robotics. Keep an eye out for more interesting posts on LinkedIn, and register for an event.

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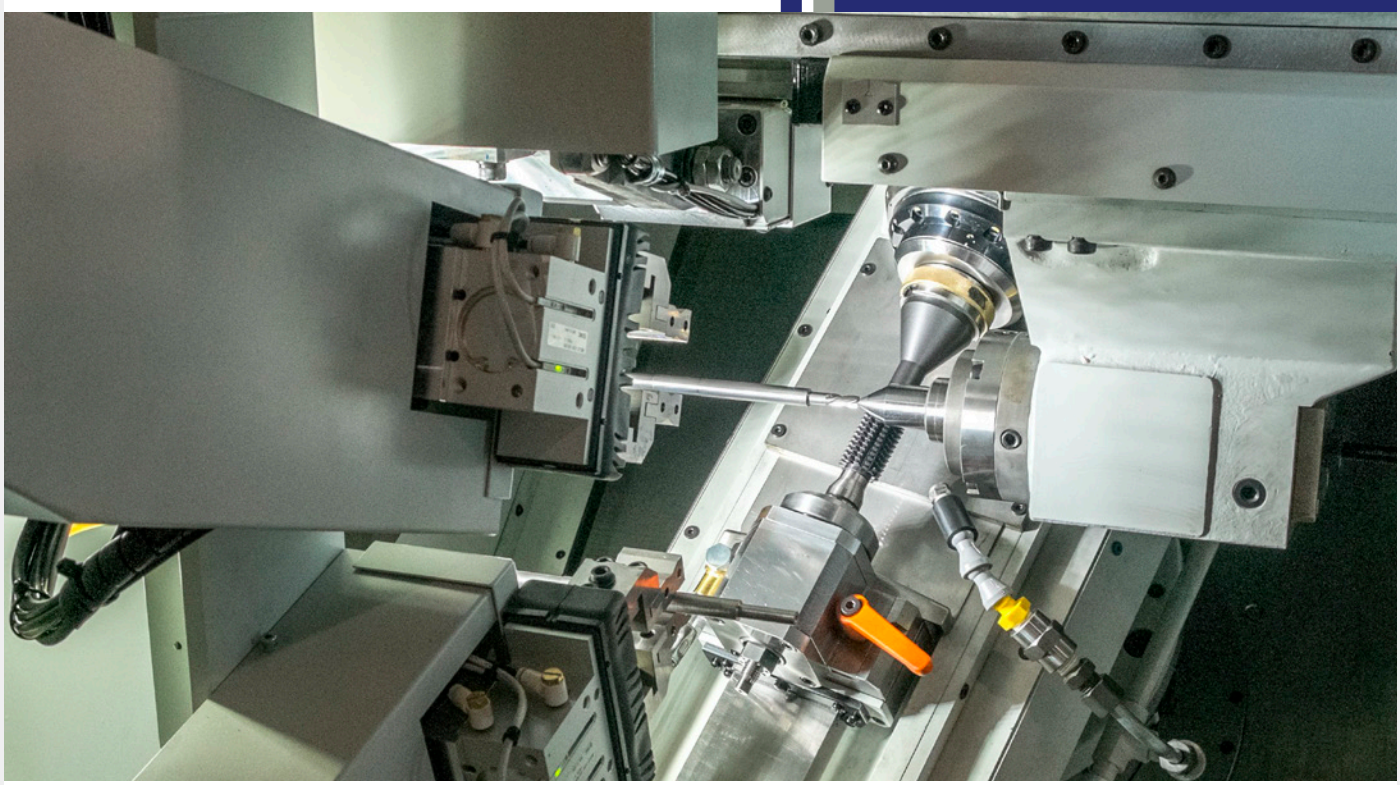
GMTA now represents SEIWA G-Tec within North America

Characteristics Artis HB056

- High rigid structure based on “Artis Concept”
- Slant type base platform contributes to comfortable workability and smooth chip disposal
- Built-in spindle both for tool with Max. 6,000 m^{-1} and work with 1,000 m^{-1}
- Dry-cut (standard), AquaCut®, and Wet-cut (option) are all available
- Hobbing and Skiving for hardened work part (option)
- Gears on 500 mm long shaft can be machined (HB056)
- Integrated high performance part loading/unloading system (HB056LS)
- Maximum part capacity of 40 pcs. on stocker

Scan to see the Artis HB056 in action.



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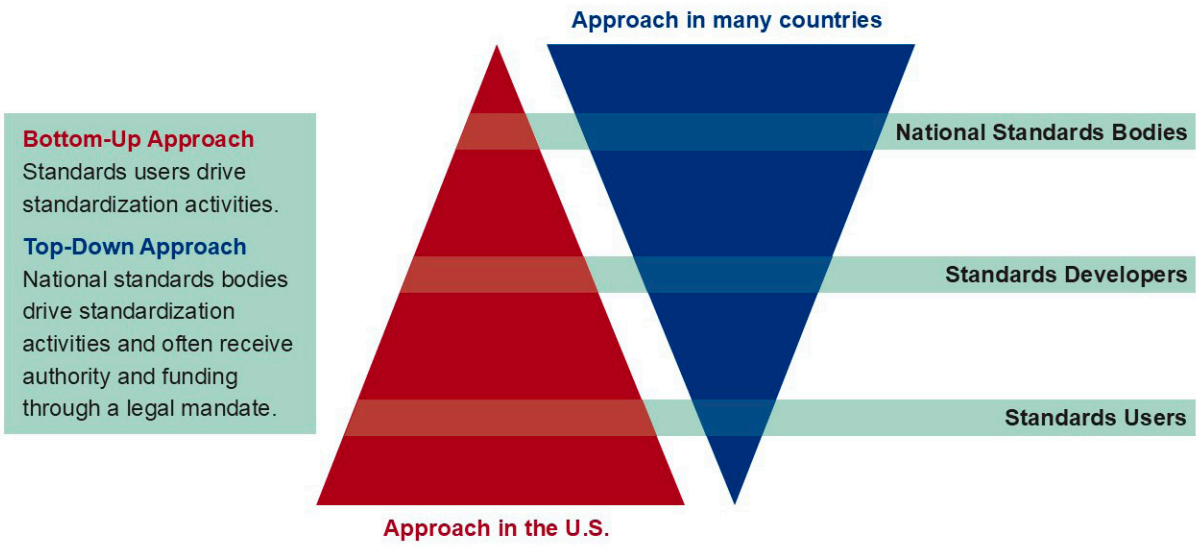
The Power of Standards

Phillip Olson, Director, Technical Services



Where would your business be without standards? Can you imagine if every gear manufacturer used different inspection and rating criteria? Or if you had to re-learn new gear nomenclature for each manufacturer you talked to? Standards are the documented set of generally accepted rules, guidelines, and requirements within an industry. They are based on proven and verified practices and provide a common language for an industry. AGMA has standards covering all aspects of gearing, from design, to inspection, to materials, to assembly, and to specialized applications such as wind or aerospace industries.

Outside of AGMA there are standards for almost every good and service you can imagine. Such as Quality Management (ISO 9001), IT Security (ISO SAE 21434), Environmental Management (ISO 14001), and Food and Environmental Safety (NSF/ANSI 61) just to name a few. Standards are behind the scenes in almost all products you use everyday. In fact, The U.S. Department of Commerce reports that 92 percent of U.S. goods exports are affected by standards and technical regulations *legacy.trade.gov/td/osip/documents/osip_standards_trade_full_paper.pdf*

In the United States, we have a "bottom-up" approach to standardization. In the bottom-up approach users of the standards *you* have the strongest voice to decide what to standardize, and how to write the standards. AGMA staff does not write standards. Instead, we coordinate diverse, volunteer stakeholders to ensure consensus processes are followed fairly and openly, which avoids monopoly or anti-trust issues. Overseeing AGMA is the American Nation Standards Institute (ANSI). ANSI's main roles are accrediting standards developing organizations such as AGMA, making sure organizations are not duplicating efforts (such as other organizations also writing gear standards), and facilitating U.S. participation on the global stage through ISO. The bottom-up approach offers speed and flexibility to those that use the standards to independently find solutions for their market. In the United States, when a standard exists, the government is less likely to write a regulation, and if a regulation is written it is more likely to cite the standard.

In contrast to the United States, many countries use a "top-down" approach to standardization. In a top-down approach the national standards body (often a governmental agency) has the most influence. Standards users are at the bottom of the pyramid, having the standards that affect them dictated mainly by other entities. In a "top-down" approach there is more central planning on what to standardize, how the standards are written, and in this system when regulations are written there may not be as much input from the affected stakeholders.

For more information see the ANSI website here: *standardsportal.org/usa_en/standards_system/introduction.aspx*

Now that you know that standards are everywhere, you may be asking, "Who is writing the standards that affect my business?" And the answer is, "If it's not you, it's your competitors." Every manufacturer has a way of running their business, designing parts, making parts, inspecting parts, etc. Some businesses even write down their way of doing these things. So, if you have these "in house" best practices, why not try to make them U.S. industry wide best practices, or even the worldwide best practices through standardization?

For gears the place to start is AGMA. Our website has a list of active standards projects here: *agma.org/committees/standards-projects/*

We are always happy to hear from industry about future standardization needs. Email us at *tech@agma.org* for more information.

Very High Cycle Fatigue Testing of AMS 6308 Steel

Thomas Tallerico

Lightweight and reliable gearboxes are required for helicopters and future electrical vertical take-off and landing aircraft. Mechanical gears in these applications experience more than 10^7 fatigue cycles over their operating life and between maintenance intervals. High-strength materials have been shown to fail due to fatigue past 10^7 stress cycles (Ref. 1). In this fatigue regime, the initiation point for the fatigue crack shifts from the surface to internal defects in the material, and the fatigue stress versus cycles curve has a different slope than the low-cycle fatigue regime (Refs. 1 to 4).

Traditional methods of predicting gear fatigue strength past 10^7 cycles rely on empirical extrapolation of the 10^7 traditional fatigue strength of the material (Refs. 5 and 6). Extrapolation is used because data for gear steel strength past 10^7 cycles is rare due to the time and cost of testing to these high cycle counts using traditional fatigue testing methods. Ultrasonic fatigue testing is a material testing method that allows fatigue stress cycles to be generated in a specimen at 20 kHz. Correspondingly this method is practical for creating material fatigue data in the very high cycle fatigue regime (10^7 to 10^{10} cycles) (Ref. 1). Ultrasonic fatigue can lead to slightly different material fatigue strength predictions relative to predictions obtained with traditional fatigue test methods due to environmental effects, temperature rise, and the low stressed volume in the specimens (Ref. 7).

In this paper, ultrasonic fatigue testing results for "core hardened" AMS 6308 gear steel are presented. AMS 6308 is a gear and bearing steel with high tempering resistance and high hot hardness case targeted to high temperature applications (Ref. 8). The material tested in this paper is "core hardened" such that it is representative of gear tooth core material. Core hardening of the material is accomplished by masking the specimens and processing through the normal AMS 6308 case hardening heat treatment process. Core material strength is not directly applicable to the bending fatigue strength of gear teeth; however, understanding core material strength establishes a baseline for strength improvements achieved through case carburizing and could provide valuable information for the development of heat treatments for very high cycle fatigue strength. Since crack initiation shifts form the surface to internal location in the specimen in the very high cycle fatigue regime, achieving the right combination of case depth and residual stress could extend gear steel lifetimes. The results in this paper will be used to inform future ultrasonic AMS 6308 bending fatigue testing using the method described in Ref. 9 that is able to capture the effects of gear tooth heat treatment in a relevant bending fatigue stress environment.

Specimen Design

Past work by the author (Ref. 10), showed that using an axial ultrasonic fatigue specimen design as described in Reference 1 led to significant uncertainty of the stress state of the specimen since the ultrasonic horn used to excite the test specimen has an observable displacement noise level of ~0.05 µm. For the specimens in this paper, a new specimen design was carried out with the goal of reducing the uncertainty of the stress state to less than 1 percent. The dynamic modules of test specimens were measured using the method described in Ref. 1. A mean value for the measured material dynamic module based on seven specimens was 201.8 GPa. This measured value was used in all specimen modeling. Appendix A provides the specimen drawing (Figure 4) and specimen test results (Table I) for the dynamic modules of core hardened AMS 6308.

Appendix B provides the drawing for the developed AMS 6308 specimen (Figure 5). Minimum size end sections that are 10 mm long are used to reduce the slope of the stress versus displacement response of the specimen such that a 0.05 µm displacement uncertainty results in a stress uncertainty of ~1 MPa. Finite element analysis was used to achieve the specimen design. Figure 1 shows the FEA model results for specimen mode shape deformation and stress response.

The specimen manufacturing was carried out in a four-step process:

1. Premachining per drawing (Figure 6) in Appendix C.
2. Heat treatment per process defined in Appendix D.
3. Low-stress grind the gage section to desired dimensions.
4. Final machine the part to length. Appendix B provides final part geometry (Figure 5).

One error occurred during fabrication of the test specimens. The machining process used to final cut the parts to length led to scratches in the gauge section that resulted in premature fatigue failure of some preliminary specimens. After this observation of test results from preliminary specimens, hand polishing was used to improve the surface finish. However, the hand polishing was not a well-controlled process and should be noted as a possible source of error in the reported stress values in the "Testing Results" section.

This paper was originally published by NASA.

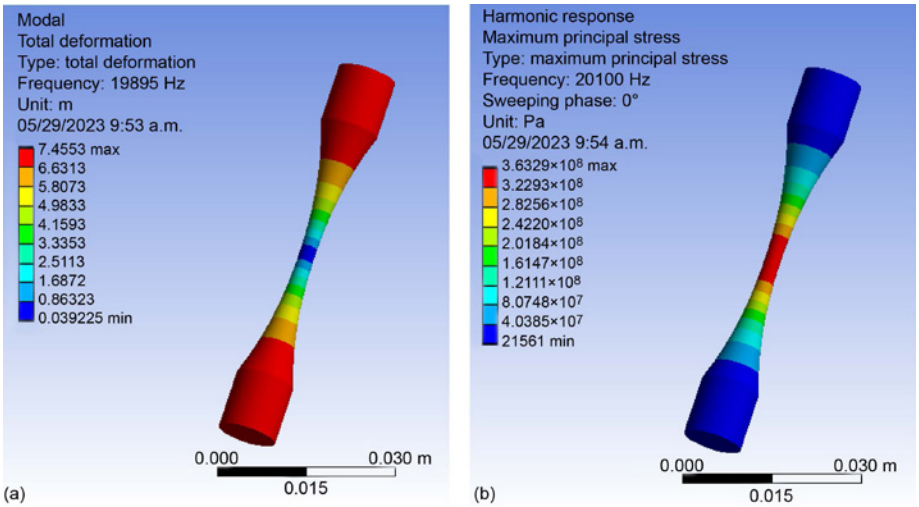


Figure 1—Developed specimen FEA models. To the left shows modal analysis result. To the right shows harmonic response of the specimen at 20,100 Hz.

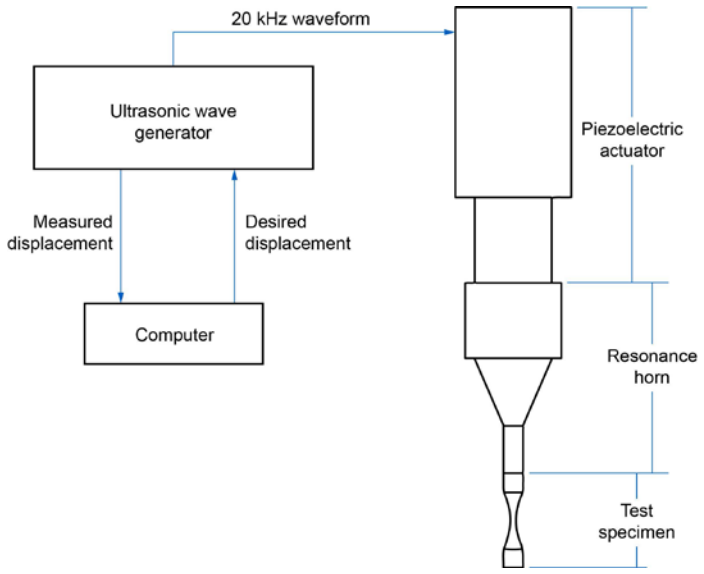


Figure 2—Schematic depiction of the ultrasonic fatigue rig.

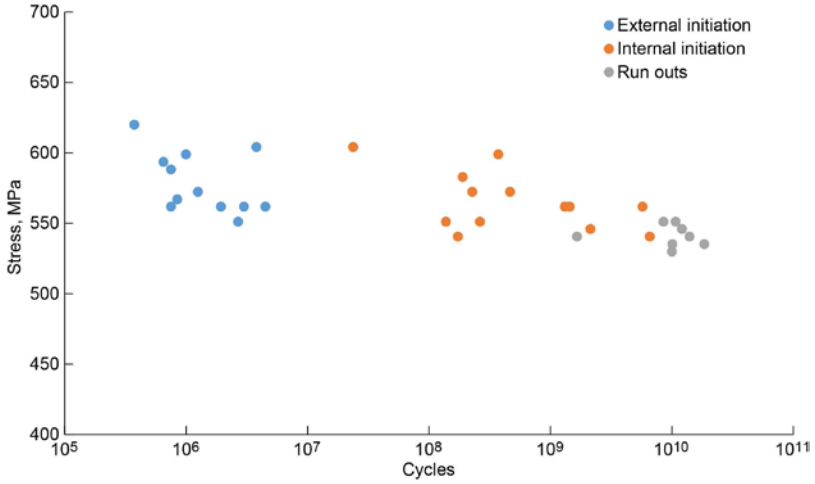


Figure 3—Peak specimen stress versus cycles to failure for core-hardened AMS 6308.

Experimental Setup

The experimental setup for the testing is shown schematically in Figure 2. A piezoelectric actuator-based ultrasonic fatigue tester is used (Ref. 1). The tester consists of a data acquisition system, an ultrasonic wave generator, a piezoelectric actuator, and a resonance horn. The tester runs using displacement control. A specified displacement is set by the user and the ultrasonic wave generator controls the amplitude and frequency of the 20 kHz electrical wave it supplies to the piezo actuator to achieve the required displacement with minimal energy consumption. The piezo actuator produces a very small displacement sinusoidal wave at the frequency provided by the wave generator. The resonance horn attached to the end of the actuator is used to amplify the piezo actuator's displacement to the target testing displacement. The resonance horn is designed to have a longitudinal mode at 20 kHz. If a specimen with a mode close to 20 kHz is attached to the end of the horn, the mode will be excited and stress/displacement cycles can be generated in that part corresponding to that mode shape of the specimen.

Testing Results

Thirty-three specimens were produced and tested. The results in terms of stress and cycles are shown in Figure 3. Stress is reported as calculated form FEA using the measured dynamic modules of the steel of 201.8 GPa. Many points are shown to fail due to external defects at less than 10^7 cycles. These test points are believed to have been affected by the manufacturing process damaging their surfaces as discussed in the "Specimen Design" section. Regardless, in ultrasonic fatigue, fractures that occur at less than 10^7 cycles are typically significantly affected by heat generation and correspondingly should not be considered representative of material strength.

Twelve total specimens fractured in the range of 10^7 to 10^{10} cycles with initiation sites internal to the specimens. Fatigue strengths fell in the range of 550 MPa around the expected strength for core-hardened gear steels. Seven total specimens were run out to 10^{10} cycles at stresses slightly less than 550 MPa. The lowest fracture strength for a specimen before 10^{10} cycles was 540 MPa.

Conclusions

In this paper, ultrasonic fatigue testing results for core-hardened AMS 6308 were presented. Fatigue data was collected for the material in the range of 10^7 to 10^{10} fatigue cycles. Failure strengths were found to be in the range of 540 to 600 MPa for the stress cycle regime past 10^7 cycles. Seven total specimens were run out to 10^{10} cycles at stress levels around or below 540 MPa. These results are not directly applicable to the bending fatigue strength of AMS 6308 in case-carburized gear teeth. However, these results provide a baseline strength dataset for future bending fatigue tests of carburized ultrasonic bending fatigue specimens and could provide some valuable information for understanding gear failure or for refining heat treatments to accomplish long-life gears for aviation applications.

Appendix A—Dynamic Modules Testing Results

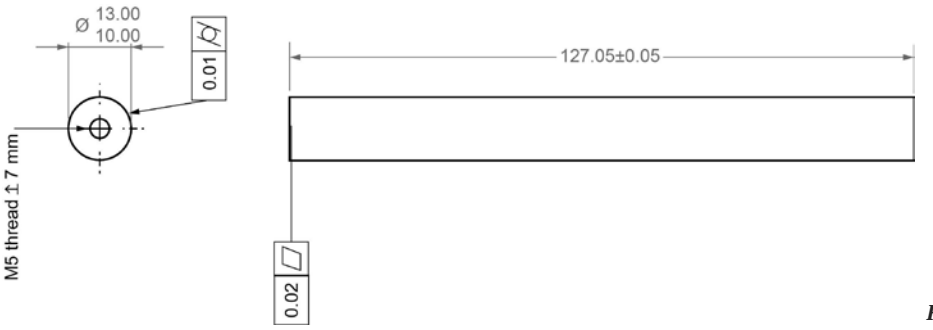


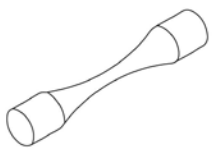
Figure 4—Dynamic modules testing specimen.

Specimen no.	Length, m	Density, kg/m^3	Frequency, Hz	Ed, Pa
1	1.27×10^{-1}	7.85×10^{3}	2.00×10^{4}	2.05×10^{11}
2	1.27×10^{-1}	7.88×10^{3}	1.98×10^{4}	2.01×10^{11}
3	1.28×10^{-1}	7.87×10^{3}	1.98×10^{4}	2.01×10^{11}
4	1.28×10^{-1}	7.87×10^{3}	1.98×10^{4}	2.02×10^{11}
5	1.27×10^{-1}	7.88×10^{3}	1.99×10^{4}	2.02×10^{11}
6	1.27×10^{-1}	7.88×10^{3}	1.98×10^{4}	2.01×10^{11}
7	1.27×10^{-1}	7.87×10^{3}	1.98×10^{4}	2.01×10^{11}

Table 1—Dynamic modules testing results.

Appendix B—Specimen Geometry

Notes:
- Dimensions are in mm
- Material is Pyrowear 53 through hardened to HRC42
- Min. 3.2 µm Ra all over except where specified
- Low stress grind gage section
- Inspection report required for gage diameter and gage runout



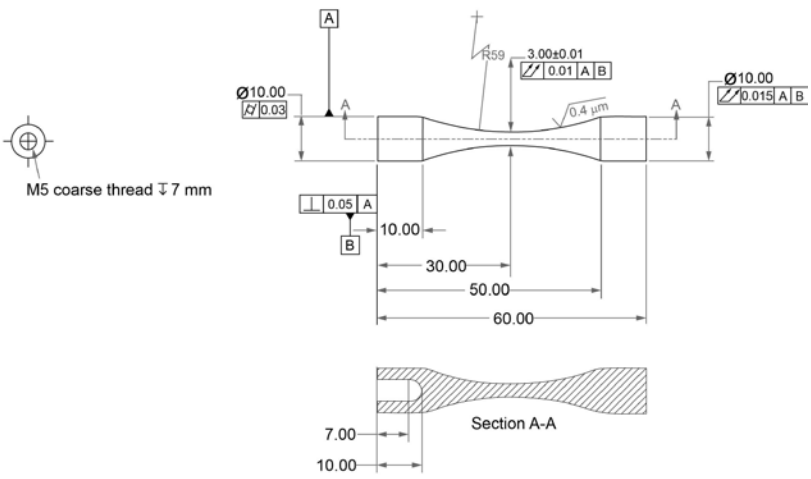


Figure 5—Final specimen geometry drawing.

Appendix C—Premachined Geometry

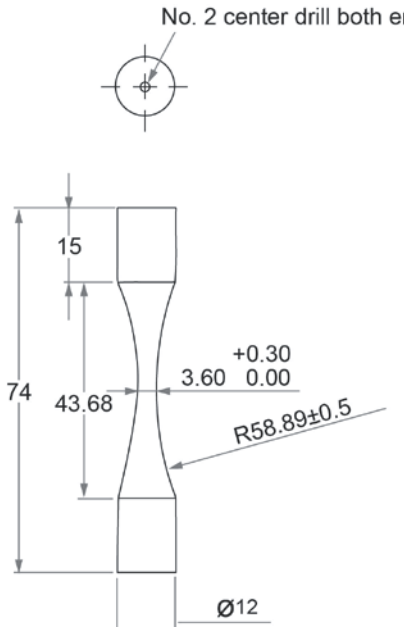


Figure 6—Preheat treatment and grinding specimen geometry.

Appendix D—Heat Treatment

1. Copper plate specimens
2. Heat to 1700 °F and hold 7 h in inert gas environment.
3. Slod cool to room temperature.
4. Reheat to 1675 °F and hold for 25 min in vacuum environment.
5. 10 Bar N_2 Gas Quench
6. Refrigerate to –100 °F for 30 min
7. Temperature at 400 °F for 2 + 2 h

NASA/TM-20240002274 9

Thomas Tallerico is a Research Mechanical Engineer at NASA Glenn Research Center, Cleveland Ohio. He conducts fundamental research on advanced drivetrains for aerospace applications including research on mechanical gears, magnetic gears, and electric motors.

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Cutting Tool Selection Criteria for Cylindrical Gear Manufacturing

Massimiliano Turci

Introduction

This paper is divided into two parts. The first part is a general digression on the pressure angle on cylindrical gears. The pressure angle is a variable that plays an important role in defining the geometry of gears and hobs, yet it is not widely discussed. This introduction serves as a prerequisite for the second part of the paper.

The second part will show an application case of choosing the most suitable hob to cut a given gear. In this selection process, particular attention will be paid to the pressure angle of the hob for cutting with modified rolling, i.e., with a reduced pressure angle compared to that of the gear.

Part One: the pressure angle α

Definition

Typically, in gear geometry training courses, time is spent on profile shifting as an inexpensive means of adapting to the imposed center distance and to balance specific sliding. It is noted that the profile shift has effects especially on gears with few teeth.

In schooling, at least in Italy, the profile shift x is often introduced only as a means of avoiding undercutting for gears with fewer than 17 teeth. This somewhat myopic and biased view learned at school age, is difficult to remove with on-the-job training, which occurs later.

Much less time is devoted to the in-depth study of the pressure angle mainly because any modification, a value different from the standard ones (fixed at 20 by dogma), requires the purchase of specific tools despite the fact that the pressure angle affects bending strength, tooth thickness at the tip diameter and contact ratio (noise reduction)(Ref. 1).

Therefore, it tends to be taught that the profile shift and the pressure angle have similar effects on the tooth shape, but intervening on the former is cost-free, while modifying the latter is expensive (Ref. 1).

Often overlooked is the possibility of cutting gears with tools that have different pressure angles from the gear, resulting in benefits on several fronts. These type of tools are called "corrected lead" (Ref. 2), "short-pitched" (Ref. 3) or "modified rolling" hobs.

Before proceeding to analyze this possibility, it is worth noting that the involute geometry (and thus the shape of the tooth flank) is solely determined by the base circle from which the involute curve is "unrolled." It is not the module or the pressure angle that defines the involute, but the base circle. The standard Equation 1 is not the definition of the base circle, but rather that of the base pitch. In Equation 1, the only truly physical quantities are the number of teeth (which can be counted) and the diameter of the base circle, which, although not visible to the human eye, uniquely defines the shape of the involute curve. Infinite combinations of module m and pressure angle α can lead to the same base pitch and thus the same base circle diameter, if multiplied by the number of teeth.

$$d_b = zm\cos\alpha \tag{1}$$

where
d_b is the base diameter
z is the number of teeth
m is the module (without subscript, considering spur gear)
α is the pressure angle

The module is therefore a conventional quantity used to define the size of the teeth (so much so that in AGMA documents, diametral pitch is found instead of the module). To simplify the approach, only spur gears are considered, so module and transverse module are the same.

A bit less conventional is the definition of the pressure angle, but there isn't just one: there is a distinction between the operating pressure angle and the reference profile pressure angle (Ref. 4).

The logical sequence for defining the shape of gear teeth starts with fixing the base diameter and the number of teeth (and then cutting it from root to tip circle). The base pitch p_b will then be uniquely determined.

$$p_b = \frac{\pi d_b}{z} \tag{2}$$

But this formula is also valid

$$p_b = \pi m\cos\alpha \tag{3}$$

At this point, there is only one degree of freedom: either the module or the pressure angle is fixed. Any combination of module and pressure angle that leads to the same base pitch will also result in the same shape of the tooth flank.

At an industrial level, however, it is convenient to follow the reverse path, having standardized the pressure angles and modules (Refs. 5,6).

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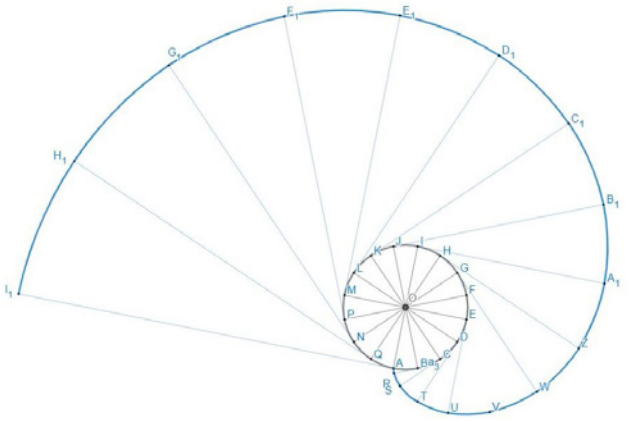


Figure 1—Involute of circle.

As explained very well in (Ref. 7), since the phenomenon of cutting interference is greater when the hob's addendum is larger, meaning when the distance from the tooth tip to the pitch circle is greater, it follows that reducing the hob addendum value is sufficient to reduce interference. Essentially, it involves rolling on a circle closer to the center of the gear.

Decreasing the pressure angle α, while keeping the base circle diameter d_b and therefore the profile tooth shape, means reducing the pitch diameter d, according to the formula (4). This is why reduced pressure angle hobs are discussed.

$$d_b = d\cos\alpha \tag{4}$$

The main advantage of using this type of hob is the reduction in interference and thus the increase in the length of the contact profile, resulting in less stress on the tooth tip and consequently improving the efficiency of the hob itself.

It should also be noted that a hob with a lower pressure angle has a lesser tendency to transmit manufacturing and assembly errors to the tooth profile.

With this awareness, in the next of this first part of the paper, a sensitivity analysis of the pressure angle on the form diameter will be presented for various numbers of teeth. There will be the focus only on symmetric tooth profiles; a thorough treatment of the pressure angle on asymmetric tooth profiles can be found in (Ref. 8).

Case 1: "Classic" Gear, Profile II DIN 3972, Hobbing

The first analysis was performed on a standard gear, for academic purposes only, with no practical application. It was chosen to start with a hobbed gear module 1, with 23 teeth, pressure angle 20 degrees, x=0 and reference profile II DIN 3972 (Ref. 9).

Two phases were undertaken. In the first phase, the geometry of the reference profile of the tools was defined with different pressure angles to achieve the same geometry of the flank of the starting gear (including tooth thickness) and the same tip and root diameters. In the second phase, these tools were used to generate gears with different numbers of teeth.

Tool Preparation

On a spreadsheet, the geometry of the "master" gear with a pressure angle of 20 degrees has been entered, as indicated in bold in Table 1. On the same spreadsheet, the column α has been populated with values from 17.5 to 22.5 degrees with a step of 0.5. For each row, the module has been calculated using Equation 3, keeping the base pitch of the reference gear fixed. The tip diameter d_a, root diameter d_f, and tooth thickness (span measurement) have been set equal for all rows. The pitch diameter d and V-circle diameter d_v have been calculated on the same spreadsheet. These values have been entered into the *KISSsoft* calculation software to obtain the values indicated in red. In Figure 2, the geometries of the gears with pressure angles of 17.5, 20, and 22.5 degrees are visible. The rightmost 3+3 columns of the table constitute the definition of the tool reference profile for each gear. These profiles have been saved in the software's database.

m	α	x	d	d_v	$d_{b\,calc}$	d_a	d_f	d_{Ff}	W_{k3}	h_{aP0*}	ρ_{aP0*}	h_{fP0*}	h_{aP0}	ρ_{aP0}	h_{fP0}
mm	°	-	mm	mm	mm	mm	mm	mm	mm	-	-	-	mm	mm	mm
1.017	22.5	-0.18352	23.394	23.020	21.613	25.000	20.500	21.709	7.702	1.239	0.197	1.173	1.260	0.200	1.193
1.013	22.0	-0.14657	23.310	23.013	21.613	25.000	20.500	21.696	7.702	1.240	0.197	1.180	1.257	0.200	1.196
1.010	21.5	-0.10978	23.229	23.008	21.613	25.000	20.500	21.684	7.702	1.241	0.198	1.186	1.254	0.200	1.198
1.007	21.0	-0.07311	23.151	23.003	21.613	25.000	20.500	21.673	7.702	1.244	0.199	1.192	1.252	0.200	1.200
1.003	20.5	-0.03653	23.074	23.001	21.613	25.000	20.500	21.663	7.702	1.246	0.199	1.196	1.250	0.200	1.200
1.000	**20.0**	**0.00000**	**23.000**	23.000	**21.613**	**25.000**	**20.500**	**21.654**	**7.702**	1.250	0.200	1.200	1.250	0.200	1.200
0.997	19.5	0.03653	22.928	23.001	21.613	25.000	20.500	21.645	7.702	1.254	0.201	1.203	1.250	0.200	1.199
0.994	19.0	0.07312	22.858	23.004	21.613	25.000	20.500	21.637	7.702	1.260	0.201	1.204	1.252	0.200	1.197
0.991	18.5	0.10981	22.791	23.008	21.613	25.000	20.500	21.631	7.702	1.266	0.202	1.205	1.254	0.200	1.194
0.988	18.0	0.14667	22.725	23.015	21.613	25.000	20.500	21.625	7.702	1.273	0.202	1.204	1.258	0.200	1.190
0.985	17.5	0.18376	22.662	23.024	21.613	25.000	20.500	21.620	7.702	1.281	0.203	1.203	1.262	0.200	1.185

Table 1—Gear data for different modules and pressure angles, with fixed base pitch, tooth width, root diameter and tip diameter.

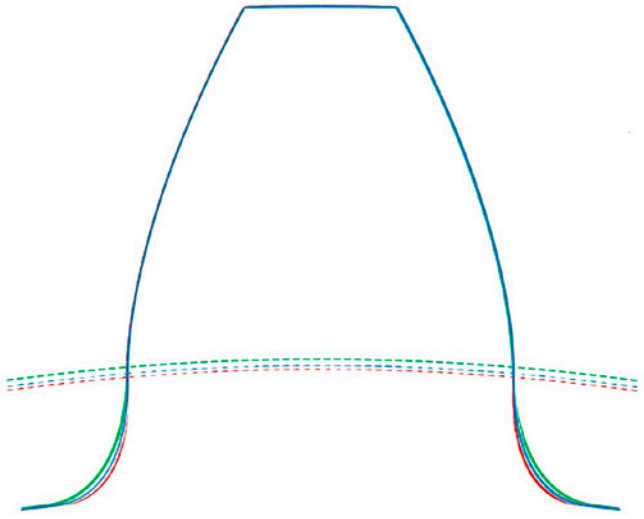


Figure 2—Different root form circles due to different pressure angles (red for 17.5 degrees, blue for 20 degrees, green for 22.5 degrees).

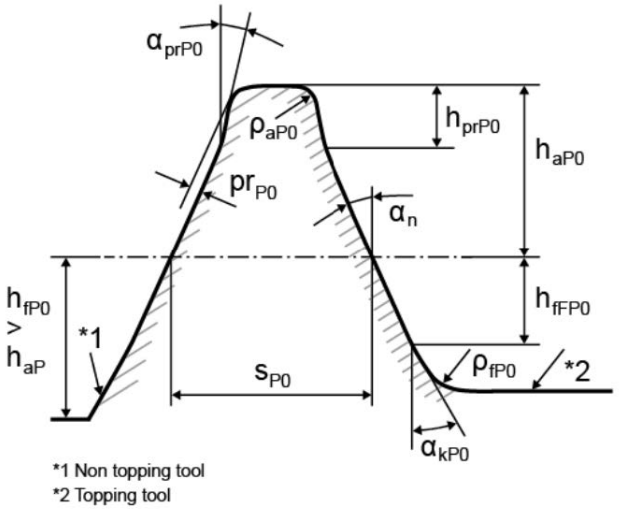
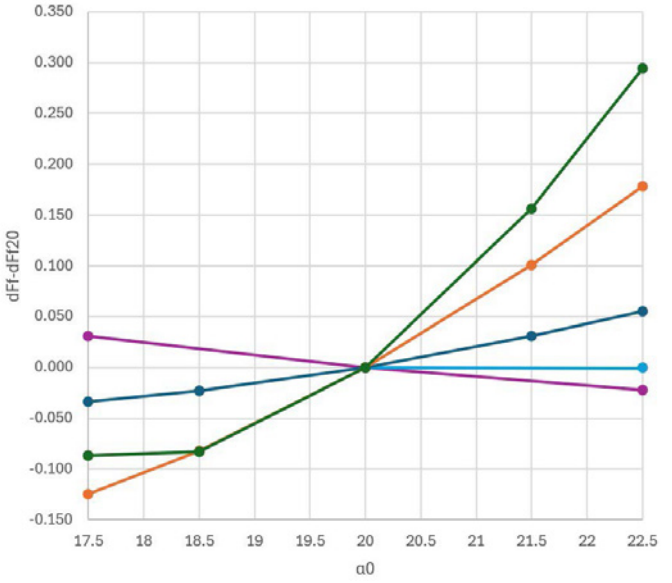


Figure 3—Reference profile symbols for hob in the d_b.



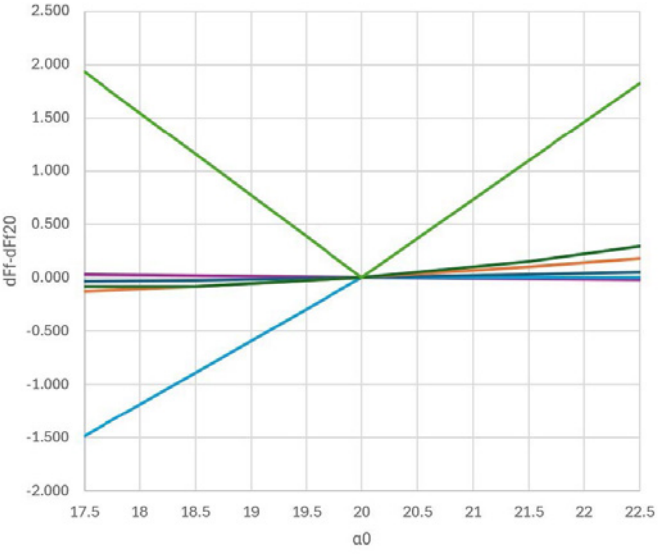


Figure 4—Variation of the root form diameter for different number of teeth z (see Table 2 for colors of z) versus hob pressure angles α_0. *In the upper plot the vertical scale is magnified between -0.15 and +0.35.*

Gear Generation

With the newly defined tools, gears with different numbers of teeth were generated. It was required that, for the same number of teeth, the gears must have at least the same tooth thickness and the same tip diameter (the root diameter cannot be imposed, having defined the hob).

The obtained results, especially the root diameter and the root form diameter, are indicated in Table 2. The cutting pressure angle α_0 identifies the hob defined in the previous section.

In Figure 4 (using the same colors), the difference between the obtained form diameter and that of the gear cut with the 20 degrees hob is shown for each number of teeth, for various hob pressure angles.

Analysis of Results

From the information presented in the previous clause, it can summarize that:

- Although the tooth height was requested to be the same on all gears, with different numbers of teeth, the obtained tooth height is not.
- The curvature of the involute flank is the same whatever the number of teeth.
- The tool's pressure angle affects the root form diameter of the cut gear, especially with a high number of teeth.
- The impact of the tool's pressure angle on the gear's root diameter is often negligible, being two orders of magnitude smaller than its effect on the root form diameter (≈1/100).
- If the tool's pressure angle is greater than that of the gear,

m	α	z	m_0	α_0	d_{Ff}	d_a	d_f	d_{Ff}-d_{Ff20}	d_f-d_{f20}	undercut
mm	°	-	mm	°	mm	mm	mm	mm	mm	-
1	20	11	0.985	17.5	10.430	13.0	8.488	0.031	-0.012	yes
1	20	11	1.000	20.0	10.400	13.0	8.500	0.000	0.000	yes
1	20	11	1.017	22.5	10.378	13.0	8.489	-0.022	-0.011	yes
1	20	17	0.985	17.5	14.494	19.0	14.494	-1.485	-0.006	yes
1	20	17	1.000	20.0	15.979	19.0	14.500	0.000	0.000	no
1	20	17	1.017	22.5	15.978	19.0	14.495	-0.001	-0.005	no
1	20	23	0.985	17.5	21.620	25.0	20.500	-0.034	0.000	no
1	20	23	0.991	18.5	21.631	25.0	20.500	-0.023	0.000	no
1	**20**	**23**	**1.000**	**20.0**	**21.654**	**25.0**	**20.500**	**0.000**	**0.000**	**no**
1	20	23	1.010	21.5	21.684	25.0	20.500	0.031	0.000	no
1	20	23	1.017	22.5	21.709	25.0	20.500	0.055	0.000	no
1	20	46	0.985	17.5	44.068	48.0	43.524	-0.124	0.024	no
1	20	46	0.991	18.5	44.111	48.0	43.508	-0.082	0.008	no
1	**20**	**46**	**1.000**	**20.0**	**44.193**	**48.0**	**43.500**	**0.000**	**0.000**	**no**
1	20	46	1.010	21.5	44.294	48.0	43.508	0.101	0.008	no
1	20	46	1.017	22.5	44.371	48.0	43.520	0.178	0.020	no
1	20	92	0.985	17.5	89.887	94.0	89.572	-0.086	0.072	no
1	20	92	0.991	18.5	89.891	94.0	89.525	-0.083	0.025	no
1	**20**	**92**	**1.000**	**20.0**	**89.973**	**94.0**	**89.500**	**0.000**	**0.000**	**no**
1	20	92	1.010	21.5	90.130	94.0	89.523	0.156	0.023	no
1	20	92	1.017	22.5	90.267	94.0	89.561	0.294	0.061	no
1	20	1000	0.985	17.5	999.712	1002	998.515	1.930	1.015	no
1	20	1000	1.000	20.0	997.782	1002	997.500	0.000	0.000	no
1	20	1000	1.017	22.5	999.611	1002	998.365	1.829	0.865	no

Table 2—Gear data for different number of teeth z and different hob pressure angles α_0.

the root form diameter increases with the cutting angle, except in cases of undercutting.

- For hob with pressure angles less than gear, the relationship is typically the opposite, although verification is advisable.

Case 2: Gear HCR 20 Degrees Hobbing and Grinding

As a second case study, a 52-tooth HCR gear with a 20 degrees pressure angle for automotive use, cut with a hob and finished by grinding, was selected. High contact-ratio or HCR gears are gears defined with a contact ratio greater than 2.0 (Ref. 10), sometimes called also long-addendum gears. The drawing also indicated semi-topping and tolerances on diameters and tooth thickness. To simplify the study, calculations were done without considering tolerances on tooth thickness and diameters. It was chosen to position on the maximum tip diameter and average tooth thickness.

Comparison was made only between the case with a 20-degree hob (as per drawing) and 17.5 degrees (actual), on this gear. Then, an analysis was carried out on what happens when using this same hob with a 78-tooth gear, with the same reference profile and tooth thickness as the Z52 gear.

Z52 Geometry

The gear in Figure 5 was cut with the hob in Figure 6, specially designed for this gear with a pressure angle less than that of the gear to reduce wear on the tip. The geometry of the obtained gear exactly reflects the requested one.

A comparison was made between the geometry obtained with the indicated hob and a hob with the same pressure angle as the gear and the same values of protuberance and protuberance angle as the previous hob.

Figure 7 shows different geometries of the gear hobbed with a hob with pressure angle of 20 degrees in green and of 17.5 degrees in red. The involute profile is the same. In the same picture there are four elements: tooth form and hob profile for both cases. Involute profile is the same, root diameter is the same, but also after grinding, root form is different. In Figure 8 only hobs are shown.

It is evident that the use of a hob with modified rolling brings benefits to the root form diameter after grinding (Figure 9), which is lower. In fact, to avoid meshing interference, it is important that the start of contact occurs in the part of the tooth where the involute is. That is, it is important that the root form diameter is lower than active root diameter (SAP, Start of Active Profile): $d_{Ff} < d_{Nf}$.

DATI COSTRUTTIVI DENTATURA	GEAR DATA	I
Numero denti	NO. of teeth	52
Modulo normale	Module	1.948
Modulo circonferenziale	Transverse module	2.368
Angolo di pressione normale	Normal pressure angle	20°
Angolo di pressione circonferenziale	Transverse pressure angle	23°51'44"
Diametro primitivo	Pitch diameter	123.11
Diametro base	Base diameter	112.587
Diametro esterno	Outside diameter	126 $^{0}_{-0.20}$
Diametro interno	Root diameter	113 $^{0}_{-0.30}$
Inclinazione elica primitiva	Pitch elix angle	34°38'
Inclinazione elica base	Base elix angle	32°16'46"
Senso elica	Hand of elix	DESTRO
Lunghezza fascia teorica (b)	Theoretical face width	22
Spessore dente sul D.P. prima di rettifica Tooth thickness on D.P. before ground		2.195 $^{0}_{-0.04}$
Spessore dente sul D.P. dopo rettifica Tooth thickness on D.P. after ground		1.995 $^{0}_{-0.04}$
Misura fra due rulli, diametro rulli ø4 prima di rettifica Measurement over two pin, pin diameter ø4 before ground		128.005 $^{0}_{-0.11}$
Misura fra due rulli, diametro rulli ø4 dopo rettifica Measurement over two pin, pin diameter ø4 after ground		127.47 $^{0}_{-0.11}$
Diametro inizio evolvente (TIF)	Tru Involute Form Diameter	116
Inizio profilo attivo (SAP)	Start of Active Profile	116.4
Fine profilo attivo (EAP)	End of Active Profile	125.7

Figure 5—Table with data for gear Z52 from the gear drawing.

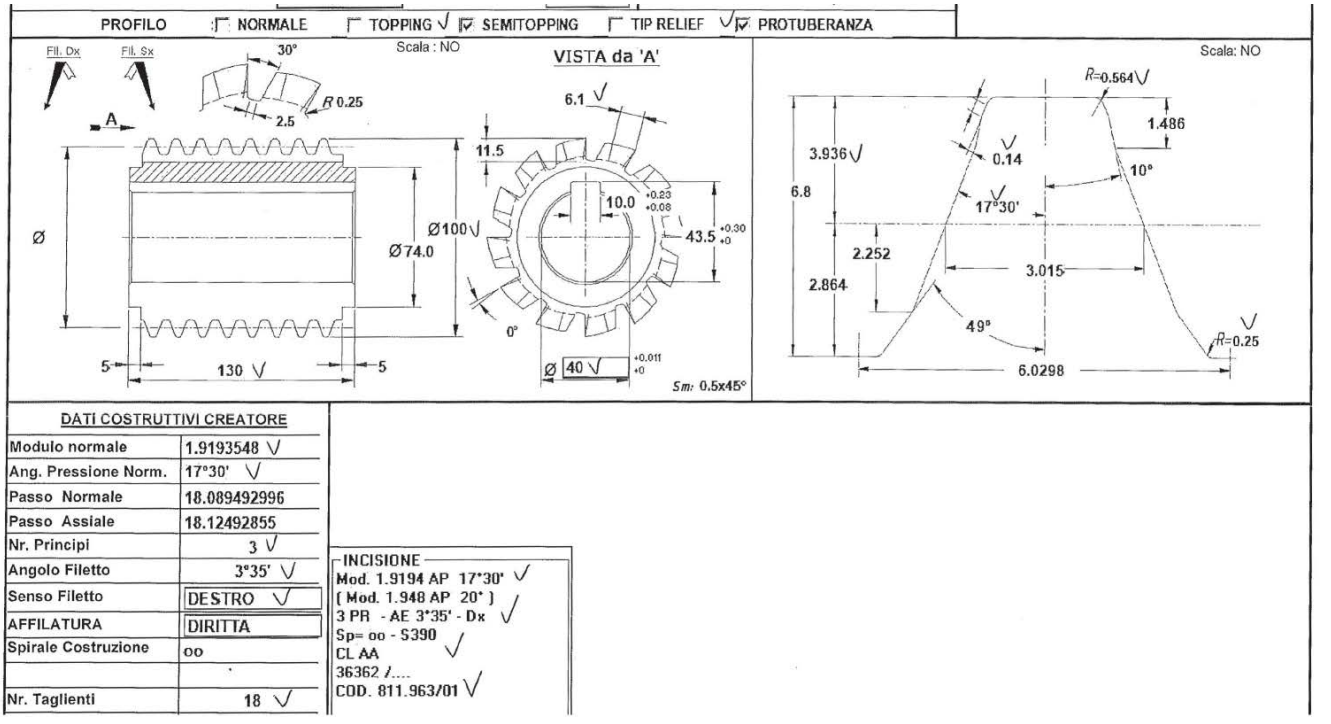


Figure 6—The hob used to cut the gear Z52.

Description	Symbol	Unit	Design	Cut	Difference
Pressure angle of the tool	α_0	°	20.000	17.500	2.5
Tip diameter	d_a	mm	126.000	126.000	0
Root diameter	d_f	mm	112.722	112.722	0
Root form diameter, hobbed	$d_{Ff\,temp}$	mm	118.267	117.074	0.625
Measurement over 2 pins, hobbed	$M_{dk\,temp\,4}$	mm	128.005	128.005	0
Root form diameter, grinded	d_{Ff}	mm	117.476	116.112	0.604
Measurement over 2 pins, grinded	$M_{dK\,4}$	mm	127.470	127.470	0

Table 3—Comparison for gear manufacturing of the gear Z52.

Z78 Geometry

The same hob with a 17.5-degree pressure angle and protuberance was used to cut a gear with 78 teeth that had the same reference profile and thickness as the one with 52 just examined.

Complication arose due to the presence of the grinding step following the hobbing. Thus, two cases were examined: one with the same stock allowance also left on the Z52 gear, the other with the same root diameter as the design one. The results are shown in Table 4.

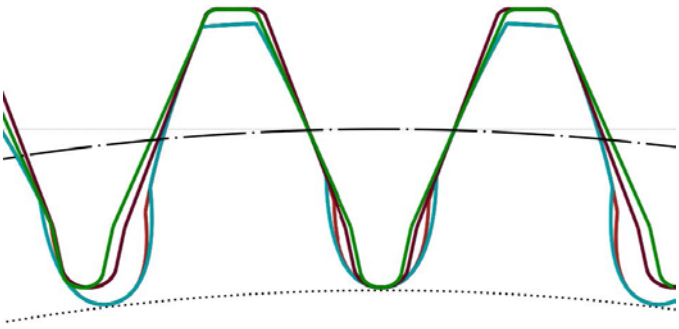


Figure 7—Gear Z52 hobbing by hob with α= 20 degrees (green shades) and α = 17.5 degrees (red shades). The base circle is dotted. The dash-dotted circle is tangent to the reference line of the hob (the same in both cases).

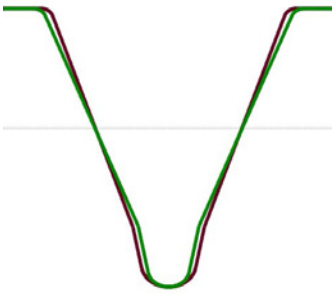


Figure 8—Hob with α= 20 degrees (green) versus α = 17.5 degrees (red).

Z52 Strength

Although the scope of this paper focuses on production, it was deemed appropriate to investigate the consequences of modified rolling on tooth strength.

In both examined cases per gear Z52, the tooth flank shape is identical. Therefore, the contact pressure during operation is not affected by the production process with modified pressure angle, nor will it affect the resistance to macropitting.

The situation is different concerning the tooth root bending strength because the radius of curvature of root fillet is indeed different in the two cases.

The FEM solver of the same software used for all previous calculations was used. A pair of identical Z52 gears with face width b = 10mm in a 1:1 ratio was assembled, and an arbitrary load of T = 450 Nm @ 10 rpm was applied. The absolute value of the calculated stress is not important; rather, the comparison between the stresses at the tooth root between the two geometries is crucial.

The results shown in Table 5 and indicate another advantage in using a hob with modified rolling for this gear: there is not an effective reduction of stress at the tooth root.

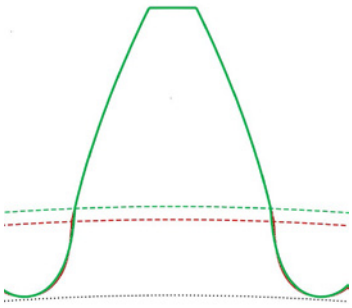


Figure 9—Root form circle (dashed) after grinding for the gear Z52 hobbed by hob with α= 20 degrees (green shades) and α = 17.5 degrees (red shades).

Description	Symbol	Unit	Design	Same q	Same d_f
Pressure angle	α *hobber*	°	20.000	17.500	17.500
Tip diameter	d_a	mm	187.555	187.555	187.555
Root diameter	d_f	mm	174.277	**174.371**	174.277
Root form diameter, hobbed	d_{Ff_p}	mm	178.464	177.751	177.681
Measurement over 2 pins, hobbed	$M_{dk\,p\,4}$	mm	189.566	189.565	**189.485**
Profile shift coefficient, hobbed	$x_{E\,p}$		-0.6102	**0.4030**	**0.3785**
Root form diameter, grinded	d_{Ff}	mm	177.463	176.745	176.845
Measurement over 2 pins, grinded	$M_{dK\,4}$	mm	189.026	189.026	189.026
Profile shift coefficient, grinded	x_E		-0.751	-0.751	-0.751
Stock allowance	q	mm	0.188	0.188	**1.505**

Table 4—Comparison for gear manufacturing of the gear Z78.

Description	Symbol	Unit	Design	Cut	Difference
Maximum equivalent stress	σ_{emax}	N/mm^2	168.77	172.44	-2%
Diameter	$d_{\sigma emax}$	mm	127.19	127.30	

Table 5—Stress on the gear Z52 hobbed with hob pressure angle 20 and 17.5 degrees.

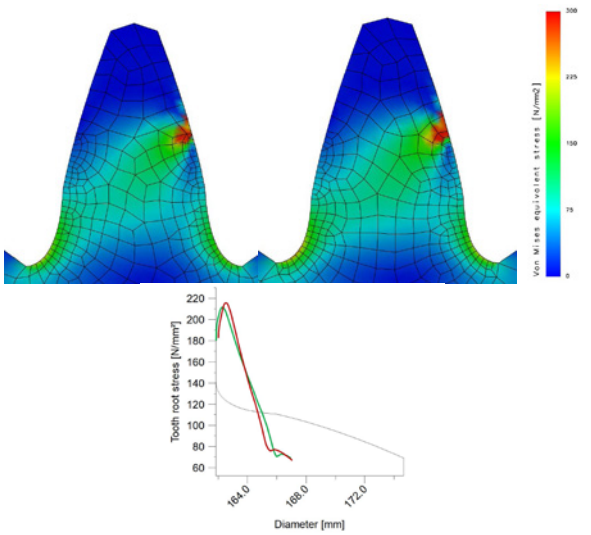


Figure 10—Von Mises equivalent stress on the designed gear (hobbed with hob pressure angle 20 degrees, green) and cut gear (hobbed with hob pressure angle 17.5 degrees, red). KISSsoft images with kind permission by KISSsoft AG.

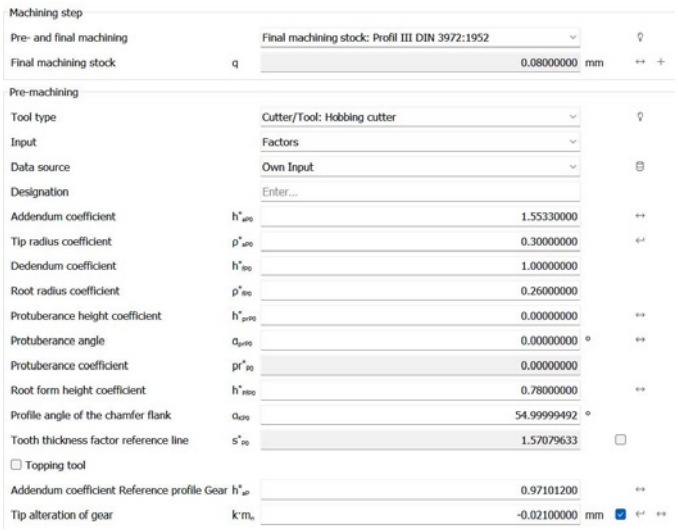


Figure 11—Windows with the definition of the profile designed for the gear Z30. KISSsoft *image with kind permission by KISSsoft AG.*

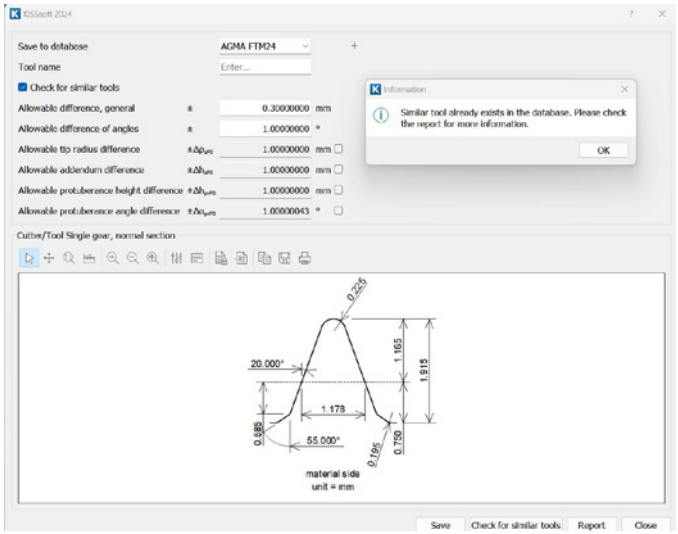


Figure 12—Window of the hob searching for the gear Z30. KISSsoft image with kind permission by KISSsoft AG.

m_n	0.75	mm
α_n	20	°
β	20	°
z	30	
x	0.36098	
d_a	25.9	mm
Hob	Profile III DIN 3972	
q	0.08	mm

Table 6—Gear data.

With only one case examined, it is not possible to establish a universal rule regarding the relationship between modified rolling and changes in bending strength. As seen in the "Analysis of Results" section, it is also not possible to establish rules for geometry. However, it is interesting to note that the tooth strength changes depending on the production process, particularly based on the pressure angle of the hob.

Part Two: Hob Selection

Some drawings of cylindrical gears was examined, and efforts were made to determine as quickly as possible which hob could be used to cut them. The search did not always focus solely on hobs with the same pressure angle as the workpiece but also extended to a broader range, paying particular attention to the results obtained. The production process also includes a grinding phase after heat treatment.

Part of the searching process was already described in Ref. 11 to which reference is made for the flow diagram. Compared to what was reported in that paper, the software used has undergone significant updates: it is now possible to easily save a new hob in the database and view its dimensioned geometry to compare it with the drawing provided by the toolmaker. The search for the modified rolling hob also extends smoothly to slightly different base pitches (which will result in a non-constant allowance as the grinding process takes place).

Manual and individual operations that the operator previously performed on the screen have been automated with the help of a Windows macro recorder. This allows for a quick and automatic generation of a list of usable hobs, with the geometric characteristics of the gear cut with each hob listed alongside.

Case 1: Industrial Gearbox Z30

A helical cylindrical gear of a small-sized parallel industrial gearbox is examined. The gear shown in Table 6 was designed with a profile II, achievable with a profile III hob + grinding. The drawing specifies "profile III + grinding," and the strength calculations were performed with this geometry.

The gear data, including the required profile, were entered into the workshop's calculation software (Figure 11). A search for suitable hobs was then conducted in the available database (Figure 11). It can be noted that the search can be extended by setting ranges for lengths and angles. The search results are in Table 7. Searching through a database of 850 records took only a few tenths of a second.

For this gear, the workshop did not deem it necessary to adopt modified rolling hobbing.

In Figure 13 and Table 8, the difference between the design profile (black) and the obtained profile (color coded) can be observed.

Name	m_n mm	α_n °	h_{aP0} mm	ρ_{aP0} mm	h_{fP0} mm	h_{prP0} mm	α_{Pr0} °	pr mm	h_{FfP0} mm	α_{KP0} °	Topping	ρ_{fP0} mm
Searching for	0.750	20.000	1.165	0.225	0.750	0.000	0.000	0.000	0.585	55.000	No	0.195
Existing tools												
Hob 1567	0.750	20.000	0.938	0.150	0.766	0.000	0.000	0.000	0.422	38.000	No	0.200
Deviation			-0.227	-0.075	0.016				-0.163	-17.0		0.005
Hob 1568	0.750	20.000	0.938	0.150	0.766	0.000	0.000	0.000	0.422	38.000	No	0.200
Deviation			-0.227	-0.075	0.016				-0.163	-17.0		0.005
Hob 1572	0.750	20.000	1.179	0.152	0.769	0.000	0.000	0.000	0.426	40.000	No	0.200
Deviation			0.014	-0.073	0.019				-0.159	-15.0		0.005
Hob 1573	0.750	20.000	1.179	0.152	0.769	0.000	0.000	0.000	0.426	40.000	No	0.200
Deviation			0.014	-0.073	0.019				-0.159	-15.0		0.005
Hob 1574	0.750	20.000	1.179	0.152	0.769	0.000	0.000	0.000	0.426	40.000	No	0.200
Deviation			0.014	-0.073	0.019				-0.159	-15.0		0.005
Hob 1575	0.750	20.000	1.179	0.152	0.769	0.000	0.000	0.000	0.426	40.000	No	0.200
Deviation			0.014	-0.073	0.019				-0.159	-15.0		0.005
Hob 1626	0.750	20.000	0.938	0.150	0.766	0.000	0.000	0.000	0.422	38.000	No	0.200
Deviation			-0.227	-0.075	0.016				-0.163	-17.0		0.005
Hob 1627	0.750	20.000	0.938	0.150	0.766	0.000	0.000	0.000	0.422	38.000	No	0.200
Deviation			-0.227	-0.075	0.016				-0.163	-17.0		0.005
Hob 1628	0.750	20.000	0.938	0.150	0.766	0.000	0.000	0.000	0.422	38.000	No	0.200
Deviation			-0.227	-0.075	0.016				-0.163	-17.0		0.005
Hob 1629	0.750	20.000	0.938	0.150	0.766	0.000	0.000	0.000	0.422	38.000	No	0.200
Deviation			-0.227	-0.075	0.016				-0.163	-17.0		0.005
Hob 1630	0.750	20.000	0.938	0.150	0.766	0.000	0.000	0.000	0.422	38.000	No	0.200
Deviation			-0.227	-0.075	0.016				-0.163	-17.0		0.005
Hob 1631	0.750	20.000	0.938	0.150	0.766	0.000	0.000	0.000	0.422	38.000	No	0.200
Deviation			-0.227	-0.075	0.016				-0.163	-17.0		0.005
Hob 1632	0.750	20.000	0.938	0.150	0.766	0.000	0.000	0.000	0.422	38.000	No	0.200
Deviation			-0.227	-0.075	0.016				-0.163	-17.0		0.005

Table 7—Result of the hob searching for the gear Z30 m_n 0.75.

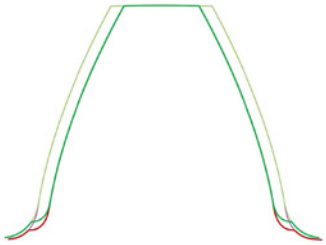


Figure 13—Geometry of the gear Z30 designed (green) and cut by "Hob 1572" (red), with and without stock allowance.

Description	Symbol	Unit	Design	Cut
Root diameter	d_f	mm	22.5356	22.5076
Root form diameter, grinded	d_{Ff}	mm	23.0117	22.9306

Table 8—Comparison for gear manufacturing of the gear Z30.

m_n	13.5	mm
α_n	25	°
β	0	°
z	11	
x	0.20053	
d_a	179.5	mm
d_f	120.8	mm

Table 9—Gear data of Z11.

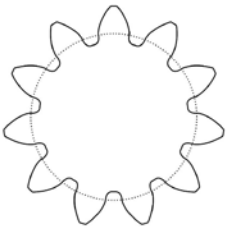


Figure 14—Gear geometry of Z11, with the base circle.

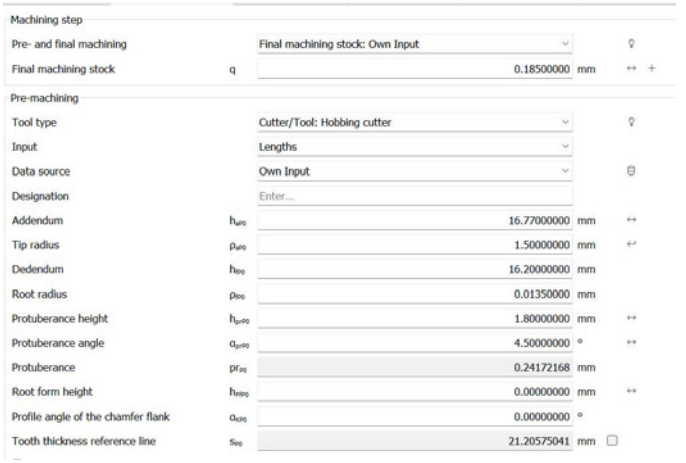


Figure 15—Window with the definition of the profile designed for the gear Z11. KISSsoft image with kind permission by KISSsoft AG.

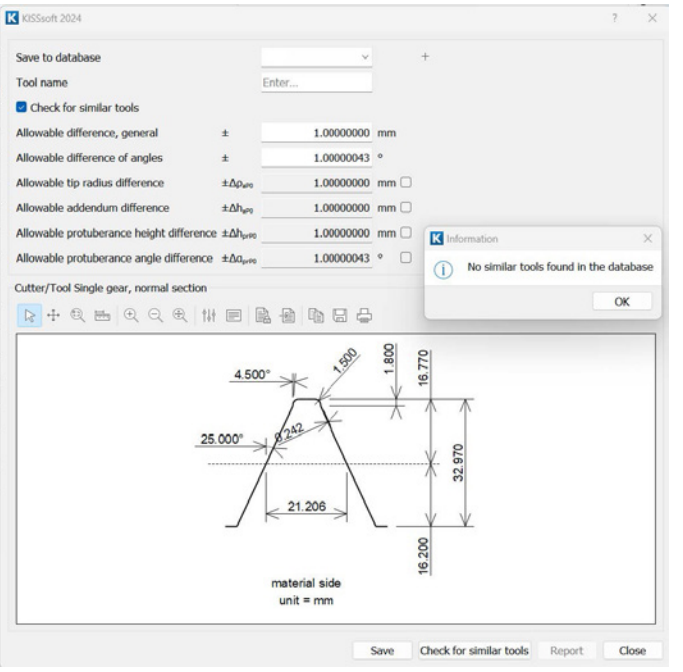


Figure 16—Window of the hob searching for the gear Z11. KISSsoft image with kind permission by KISSsoft AG.

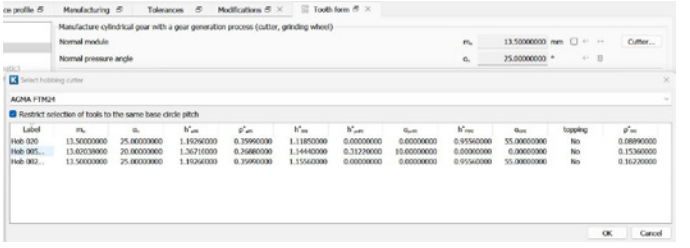


Figure 17—Window of the hob searching for the gear Z11. KISSsoft image with kind permission by KISSsoft AG.

Description	Symbol	Unit	Design	Hob 002	Hob 005	Hob 020
Hob pressure angle	α_0	°	25	25	20	25
Hob module	m_0	mm	13.5	13.5	13.02	13.5
Tip diameter	d_a	mm	179.5	179.5	179.5	179.5
Root diameter, hobbed	$d_{f\,tmp}$	mm	120.8256	122.1654	120.8021	122.1654
Root form diameter, hobbed	$d_{Ff\,tmp}$	mm	137.4522	135.283	137.2446	135.283
Root diameter, grinded	d_f	mm	120.8256	120.7787	120.7787	120.7787
Root form diameter, grinded	d_{Ff}	mm	135.7743	137.4447	137.4447	137.4447

Table 10—Comparison for gear manufacturing of the gear Z11.

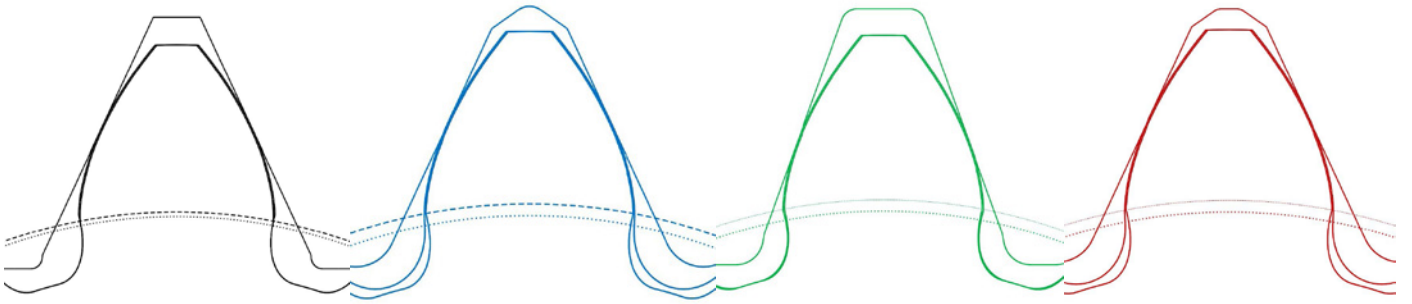


Figure 18—Comparison for gear manufacturing of the gear Z11: tooth form with and without stock allowance, base circle (dotted), root form circle (dashed) and hob.

Case 2: Tractor Gear Z11

A spur cylindrical gear for agricultural applications is being examined. The geometry is in Table 9 and Figure 14.

As in the previous case, after entering the gear geometry, a search was conducted in the current tool database to see if there was a suitable hob to cut the gear. The search did not yield any results (Figure 15 and Figure 16).

At this point, the decision was made to use modified rolling. In this case, there is no tool search feature like in the previous case, but there is the option to view all hobs that have the same base pitch as the gear with a tolerance of ±2 percent (Figure 17). The number of solutions found is fortunately small, so it is possible to calculate the three options individually. The results are in Table 10 and Figure 18.

Hob 002 and Hob 020 are very similar, only the root radius value ρ_{fP0} are different, but these hobs are not for topping, so the tooth form they generate are identical.

Hob 005 has protuberance and a lower pressure angle than the gear.

The gear is manufactured by the Hob 005.

The list of hobs to be examined could have been very long (as in the previous example). Therefore, it was decided to automate the generation of Table 10 with a VBA macro in *Excel*. This macro, in turn, calls a *Windows* macro recorded on *Jitbit macro recorder* (Figure 19) that simulates the operations (mouse clicks) that the operator would manually perform for each row indicated in Figure 17.

- The first line (in red) activates the *KISSsoft* window, where the file with the gear and the hob geometry are already defined.
- The second line (in green) activates the "tooth form" window with the tool's data.
- The third line (in blue) performs the calculation using the F5 shortcut.
- The remaining lines close any message or error windows that may appear when using an unsuitable tool by an ENTER key press.

In Figure 20 there is the portion of VBA code that calls this macro from *Excel* after inserting the tool definition into the *KISSsoft* file of the gear. In the Excel macro, there are "Wait" commands for the execution of operations on *KISSsoft*.

Open Issues

Taking into account what has just been described and what has already been reported in the two previous publications (Refs. 11,12), it is appropriate to address some open issues.

The procedure for automatically selecting the modified hob, however, computerized, can still be further optimized for speed. While for hobs with the same pressure angle as the workpiece, it is possible to use internal programming functions within the

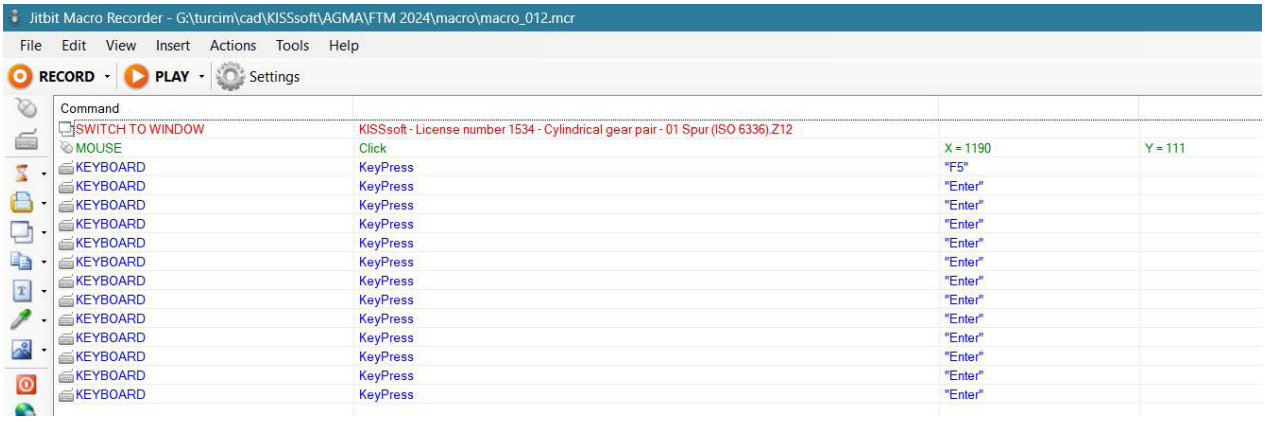


***Figure 19*—Jitbit macro *to run the tooth form calculation in* KISSsoft.**

```
Set a = New CKISSsoft
Call a.GetModule("Z011", True)
Call a.LoadFile(nomeFile)

Call a.ShowInterface(False) ' sara falso + pausa di qualche sec per far apparire l'interfaccia

Wait 1


response = ShellExecute(0, "open", NomeMacro, vbNullString, vbNullString, SW_SHOWNORMAL)

' pausa  per dar tempo di eseguire la macro

Wait 3

' si potrebbe pensare di salvare il file z11 via com invece del wait

FileCopy DirTmpKiss & "\KISS_0\z05result1.tmp", percorso + "\logdir\log" & i & ".txt"
```

Figure 20—Part of the VBA macro code.

software used, this is not the case for selecting and calculating with modified hobs. The method described in this paper indeed uses a Windows macro recorder. This type of macro requires predefined latency times, calibrated for the worst-case scenario (slower), as the processing time for each tool is not known in advance. It is advisable to investigate how to switch from asynchronous to synchronous execution, which is significantly faster. Thankfully, in the new version of *KISSsoft*, released after the first draft of this paper, there is a function to calculate the tooth form, avoiding the external macro recorder.

It would also be advisable to investigate the strength of gears cut by modified rolling hobs. Sometimes, there may even be two meshing cylindrical gears that have been cut each by a hob with a different pressure angle. This results in a nominal pressure angle α for the gear pair, a working pressure angle for the pair α_w, and two cutting pressure angles α_{01} and α_{02}, which are responsible for the form factor (geometry factor) in the strength calculations according to ISO 6336 and AGMA 2001 standards. At present, the standards do not explicitly address the use of two different hob pressure angles. The same applies to calculation software based on these standards.

Smart Editing of the Gear Data

Before the conclusions, it could be interesting and funny note that the use of a different couple of "pressure angle & module" helped a designer to get a gear drawing accepted despite the reference diameter d was greater than the tip diameter d_a, i.e., outside than the gear. Everyone was aware of the strange shape of the gear in Figure 21A, but neither the workshop nor quality control were able to process a gear with $d > d_a$, mainly due to the tooth thickness being defined on the reference diameter. But since $d = d_b/cos(\alpha)$, it was enough for the designer to decrease α to decrease d below d_a.

Also the root radius was modified to get the same root tooth form diameter. The data of the "two" gears are in Table 11 and the position of the reference diameters are shown in Figure 21B.

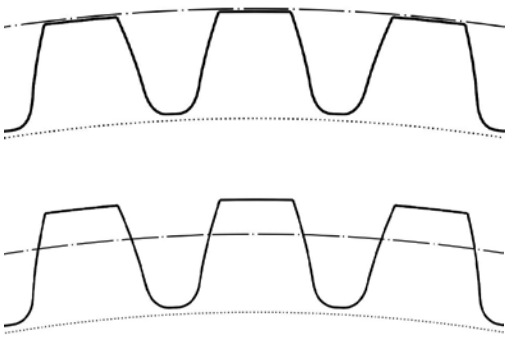


Figure 21—The original gear (A) and the edited one (B): same geometry of the involute but different data definitions (reference circle in dash-dotted, base circle in dotted).

Description	Symbol	Units	Original	Edited
number of teeth	z		62	62
module	m	mm	1.56	1.527974
pressure angle	α	°	20.5	17
base diameter	d_b	mm	90.5949	90.5949
reference diameter	d	mm	96.72	94.73438

Table 11—Edited gear data.

Conclusions

Cutting with a hob having a pressure angle lower than that of the gear can be driven by two distinct needs:

- "Dig" deeper into the workpiece and thus obtain a longer involute flank, effectively reducing the root form diameter.
- Enhance the hob's strength, particularly by increasing its thickness at the tip.

This technique is industry-specific: it is more common in transmission systems (automotive, agriculture), where the pressure angle is considered a variable, rather than a universal constant (either in design or production), as is the case of industrial gearboxes.

Opting to cut with a pressure angle different from that of the workpiece inevitably brings to complications in terms of calculation and management, especially when using a hob to cut a gear with a different number of teeth than the one for which it was designed.

This paper has presented the adoption of the selection of hobs with modified rolling, supported by extensive calculations on the company's hob database. The procedure adopted aids the operator in choosing the most suitable tool based on the geometry of the gear that would be produced with each analyzed tool.

Acknowledgments

The author wishes to thank KISSsoft AG—A Gleason Company for the software.

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Massimiliano Turci is a consultant in gear and cam-mechanism design. He is the team leader of the Italian technical staff of KISSsoft. His experience is primarily in the development of computational models for industrial gearboxes and vehicle transmissions. He has also served on the AGMA worm gear committee.

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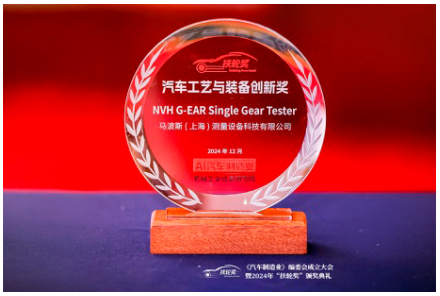
Marposs Corporation

WINS AUTOMOTIVE INNOVATION AWARD FOR GEAR TESTER



With the excellent "NVH G-EAR Single Gear Tester," Marposs won the "Auto Technology and Equipment Supplier Excellent Innovation Award" at the MM Vogel Automotive Sustaining Power Awards 2024. The primary purpose of the "NVH G-EAR Single Gear Tester" is to assess surface defects, machining distortions, and noise behavior on the individual component prior to the assembly into the gearbox.

With its solid and robust structure, the Marposs NVH G-EAR Single Gear Tester, is capable of testing gears under high speed and torque conditions. Besides, the device is feature-rich and able to satisfy inspection standards for auto parts manufacturers' supply quality.

In addition to being a great acknowledgment of Marposs NVH G-EAR Single Gear Tester's cutting-edge technology and industry leadership, receiving the "Auto Technology and Equipment Supplier Excellent Innovation Award "also validates the company's role in advancing automotive process and equipment innovation.

marposs.com

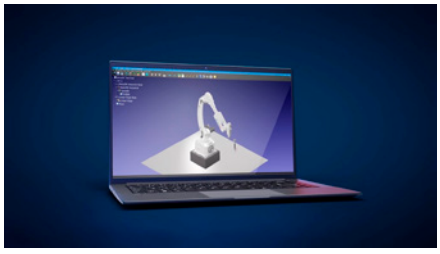
RoboDK

CELEBRATES 10TH ANNIVERSARY

RoboDK, founded in January 2015, is proudly celebrating its 10th anniversary. Since then, the company has grown from an academic spin-off into a global leader in robotic simulation and programming software. RoboDK now supports over 1,000 robots from 90 manufacturers and remains committed to making robotics accessible, affordable, and efficient for industries and educational institutions worldwide.

"RoboDK has significantly evolved over the past decade to become a leading software solution in the world of robotic simulation and offline programming," said Flore Cachera, marketing manager. "Our goal from day one has been to democratize robotics and empower industries with innovative and brand-independent tools."

From its beginnings at the highly prestigious CoRo laboratory at ETS University in Montreal, RoboDK has dedicated itself to breaking down barriers in robotics and promoting brand-independent programming. As businesses expand their automation capabilities, they need flexible software that adapts easily to changes in equipment, layout, and task requirements. Managing multiple brand-specific tools is costly and time-consuming, while a brand-independent solution like RoboDK offers the flexibility of a single, unified platform.



The software's considerable Robot Library has become a hallmark feature, offering users robust flexibility with support for an ever-increasing number of robot models. It now supports more robot models and manufacturers than any other publicly available robotic library.

"We are continually working to integrate the rapidly growing number of new robot arms and manufacturers," added Albert Nubiola, RoboDK's CEO. "In the past decade, there has been a growing trend towards automation. We are proud to be part of this journey by offering a cost-effective solution that enables automation solutions that were not possible before, making the return on investment of robots more attractive to users."

This milestone reflects a significant development in RoboDK's catalog of innovations. At the core of its offerings stands its flagship product, RoboDK for Desktop, which includes powerful features like multi-robot simulation, advanced path planning, and an extensive API.

robodk.com

Solar Atmospheres

ADDS TWO ADDITIONAL 2-BAR VACUUM FURNACES

Solar Atmospheres in Souderton, PA, is currently commissioning two additional 2-bar vacuum furnaces, expanding its capabilities to meet increased demand in the aerospace, industrial gas turbine sectors, and for specialized hydride/dehydride processing of Titanium, Tantalum, and Niobium. These vacuum furnaces, produced by Solar's sister company, Solar Manufacturing, feature large working hot zones (45" x 45" x 72") and are rated for operations up to 2400°F with a precise temperature uniformity of ±10°F.

Mike Moyer, Solar's Vice President of Sales, commented, "We're thrilled to add these advanced furnaces to Solar Souderton's lineup. Equipped with Solar Manufacturing's latest control systems, they ensure efficient, safe operation—meeting our customers' needs for competitive pricing and fast delivery. This installation reinforces our commitment to consistently high-quality service."

solaratm.com

Mazak

OPENS NEW CUSTOMER SOLUTIONS CENTER

As manufacturers continue to face shortages of skilled labor, Mazak helps them address the issue with the opening of its new Customer Solutions Center located

in Florence, KY. The secure facility specializes in the development of production-ready, custom automation solutions that allow manufacturers to overcome existing labor issues while increasing production output.

"The new center allows us to streamline automation development and project management," said Dan Janka, president of Mazak Corporation. This eliminates bottlenecks in design and timing during the construction of those custom solutions while keeping the experience all about the customer and their production needs."

The new customer-focused center is well equipped and provides a space for Mazak to set up custom automation cells as well as perform turnkey run-offs. Most importantly, the facility provides a secure location for customers who require that their parts and/or processes remain proprietary, such as those controlled by International Traffic in Arms Regulations (ITAR). Mazak engineers will also use the facility as a private location to perform research studies for the development of new processes, options and machinery.

Mazak's full portfolio of automation solutions ensures process consistency, improves quality, helps lower overall costs and reduces the risk of scrap. Automation ranges from simple barfeeders and overhead gantry systems to two-pallet changers, pallet pulls, load/unload robots and full palletized systems. Palletized systems can also include in-process measurement and surface scanning probes for part inspection and traceability.

mazak.com

Helios Gear Products

ANNOUNCES REGISTRATION FOR 2025 HELIOS GEAR SCHOOLS

Helios Gear Products is excited to announce that registration is now open for the 2025 Helios Gear Schools, featuring programs in three locations across the United States. These intensive courses are designed to provide both entry-level and experienced industry professionals with a comprehensive understanding of gear manufacturing.

- Charlotte, NC: February 11–12 (seminar course)
- Anaheim, CA: February 19–20 (seminar course)
- Chicago: May 13–15 (flagship full course)

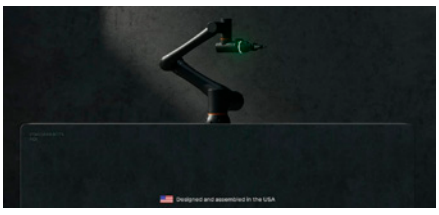
The flagship Chicago program offers a deep dive into gear manufacturing, including cutting, finishing, and final inspection. In addition to classroom instruction, participants will benefit from hands-on machine demonstrations at Helios Gear Products and plant tours at industry leaders such as Forest City Gear and Overton Chicago Gear.

Helios Gear Schools are ideal for manufacturing management, engineers, supervisors, set-up technicians, operators, and quality control personnel. Class sizes are intentionally kept small to ensure an interactive and engaging learning experience. Past attendees, like Harrison from Amarillo Gear, have praised the program as a "very good entry-level course," noting its interactivity and the value of the facility tours. For 2025, Helios Gear Products is partnering with industry experts from both Helios and Kapp Niles to offer participants diverse perspectives and real-world operational insights.

heliosgearproducts.com

Standard Bots

ACQUIRES READY ROBOTICS



By acquiring READY Robotics' automation IP, Standard Bots is able to accelerate the development of their AI-powered platform, and their mission to improve accessibility in robotics space. This IP purchase includes all the software, patents, and trademarks owned by READY Robotics.

Following this purchase, Standard Bots plan to bring their intuitive user interface and forthcoming AI platform to other robot makers, as well as NVIDIA Omniverse. In addition, they will make READY's unified APIs (which allow for the control of all major robot brands) more widely available.

"This acquisition marks a pivotal moment for Standard Bots. The READY team over many years wrote some amazing software - a unified API that talks to every major robot brand. With this acquisition, I'm more excited than ever about what we'll be able to offer the market in the coming months," said Evan Beard, Standard Bots CEO.

Before READY Robotics ceased operations last month, the eight-year-old startup had raised over $40 million to push the boundaries of industrial robotics. In a testament to their innovative spirit and technical expertise, READY partnered with companies like Toyota and NVIDIA to develop and deploy its ForgeOS across the country.

"Standard Bots' achievement in developing groundbreaking robotics and AI technology right here in the U.S. has been truly inspiring, and I am excited to see how Standard Bots will continue to democratize the robotics space using READY Robotics' technology. I firmly believe that Standard Bot's goal of empowering developers to more easily use robots is essential in moving the industry forward," said Kel Guerin, co-founder, READY Robotics.

"We're now in the process of integrating READY's IP into our operations and gearing up for a global release. READY's drivers, developed and built over the past seven years, will be instrumental in powering our new AI products. In line with our dedication to innovation and accessibility, we plan to leverage READY's work to offer a unified API and UI that developers can build upon to create bespoke robotics applications. The launch of this platform will represent a leap forward in our commitment to fostering creativity and collaboration in the robotics space," added Beard.

standardbots.com

FEBRUARY 11–13

Industrial IoT Conference 2025

The Industrial IoT Conference (Ft. Lauderdale, FL) explores the potential of intelligent machines, prescriptive analytics, sensor driven analytics, and block chain solutions. Attendees learn about the industrial IoT technologies that are driving the transformation in manufacturing, supply chain and operations. Attendees include implementors, manufacturing companies, supply chain professionals, service providers, IoT manufacturers and more. Topics include implementation, warehouse logistics, robotics, sensors, cybersecurity, data analytics and more.

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MARCH 1–8

IEEE Aerospace Conference 2025

The International IEEE Aerospace Conference, with AIAA and PHM Society as technical cosponsors, is organized to promote interdisciplinary understanding of aerospace systems, their underlying science and technology, and their applications to government and commercial endeavors. The annual, weeklong conference (Big Sky, Montana) is set in a stimulating and thought-provoking environment. The 2025 conference will be the 46th in the series.

geartechnology.com/events/5055-ieee-aerospace-conference-2025

MARCH 17–20

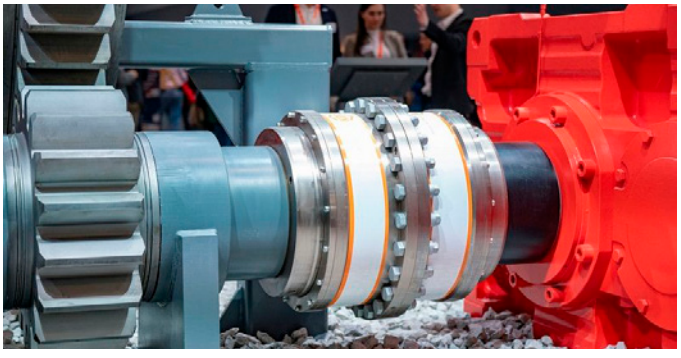
Lubricant Expo North America 2025

Lubricant Expo is North America's leading exhibition and conference event dedicated to the lubricant industry. Connecting lubricant solution providers with end-user buyers and the entire chemical and equipment supply chain, the show attracts thousands of engineers and executives each year. As the sister show to Europe's largest industry event, Lubricant Expo Europe, these two shows provide the largest dedicated exhibitions for lubrication solutions on a global scale, with a free to attend expo and conference that serves the interests of thousands of visitors representing more than 75 countries. Exhibitors cover the end-to-end chain of the industry, from finished lubricants and technologies for lubricant users, to the chemical ingredients and development devices for formulators and lab professionals. It is colocated with The Bearing Show 2025. See extended coverage of the event on page 25.

geartechnology.com/events/5109-lubricant-expo-north-america-2025

MARCH 31–APRIL 4

Hannover Messe 2025



From drive and fluid technology to digital platforms and IT security to industrial internet and robotics, Hannover Messe (Hannover, Germany) reflects the manufacturing industry's broad scope and provides important economic and social impulses every year. Additional 2025 topics include 5G technology, additive manufacturing, automation, sensors, e-mobility, material handling and more. Traditionally, drive technology and fluid power has been represented at Hannover Messe by many companies from Germany and abroad, especially in odd-numbered years. This will also be the case in 2025 when manufacturers will present their latest applications and components for intelligent and sustainable production.

geartechnology.com/events/5110-hannover-messe-2025

APRIL 7–13

Bauma 2025

From the digital construction site to alternative drives and tomorrow's construction methods, the most important topics will be discussed, and innovative solutions will be presented during Bauma 2025 (Munich). Topics include climate neutrality, drive concepts, digital construction, sustainability, and mining challenges. In view of the high-quality standards of innovation and relevance, it is not surprising that nearly 70 percent of Bauma visitors are top decision-makers in their companies. Bauma offers attendees the ideal opportunity to establish lucrative business relationships and to profitably network with the industry.

geartechnology.com/events/5114-bauma-2025

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ADDENDUM

Mandelbrot Meets Machine

Aaron Fagan, Senior Editor

Benoit B. Mandelbrot (1924–2010), the mathematician who coined the term "fractal," revolutionized the way we understand complexity in nature. His groundbreaking work introduced the concept of self-similar patterns—structures that repeat at varying scales—which appear in phenomena as diverse as coastlines, clouds, and market fluctuations. Fractals provide a mathematical framework for describing irregular shapes and dynamic systems, making them invaluable for tackling problems where traditional linear approaches fall short. Building on Mandelbrot's groundbreaking work, the application of fractals in engineering reveals exciting possibilities for gear design.

Nature's fractal patterns, like those seen in Romanesco cauliflower, offer inspiration for revolutionary gear designs inspired by the complexity of self-similar structures.

Fractal geometry provides a powerful framework for surface roughness analysis by modeling the microscopic imperfections on gear surfaces. Traditional surface roughness measurements, such as those outlined in ISO 21920-3-2021, rely on linear methods. However, fractal analysis goes beyond these standards by capturing the complexity of surface topography at multiple scales. This approach enables more accurate predictions of wear patterns, helping engineers select materials and coatings that improve durability.

Gear systems often produce noise and vibrations due to surface irregularities or misalignments. By designing gear teeth with fractal-inspired microtextures, engineers could create surfaces that dissipate vibrational energy more effectively. These designs would minimize the propagation of resonant frequencies, leading to quieter and more efficient operations.

Fractal analysis can also be used to study the evolution of wear over time. Unlike traditional linear models, fractal-based wear modeling accounts for the recursive nature of surface degradation. This insight can guide the development of gears that are more resistant to fatigue and cracking, extending operational lifespans in high-stress environments.

The application of fractals extends beyond surface optimization into the realm of nature-inspired engineering. In complex systems with multiple intermeshing gears, fractal mathematics can employ dynamic load modeling to show how stresses and loads propagate across the system. This allows engineers to anticipate weak points and optimize gear designs to handle dynamic loads more effectively, reducing the likelihood of failure.

Using fractal-inspired algorithms in topology optimization could lead to lightweight yet highly durable gear structures. These designs would be particularly beneficial in industries like aerospace and robotics, where reducing weight without compromising strength is critical.

Fractal patterns can now be replicated using additive manufacturing (3D printing) and other advanced manufacturing techniques. This capability opens the door to producing gears with intricate, fractal-based surface textures that enhance performance. For example, gears with fractal-inspired textures could improve lubrication retention, reducing friction and wear during operation.

Gears have long been seen as the unassuming workhorses of the mechanical world. But by leveraging Mandelbrot's fractal principles, these components can evolve into precision-engineered marvels. Imagine a compact robot with fractal-designed gears that deliver unprecedented efficiency and power density. Or envision wind turbines with gear systems optimized for minimal wear and maximum energy transmission.

This marriage of mathematics and mechanics isn't just theoretical. It's a glimpse into a future where engineers take cues from nature's playbook, unlocking possibilities as infinite as a fractal's edge. After all, if Mandelbrot's work can teach us about the patterns of chaos, why can't it guide the gears that drive our ordered world?

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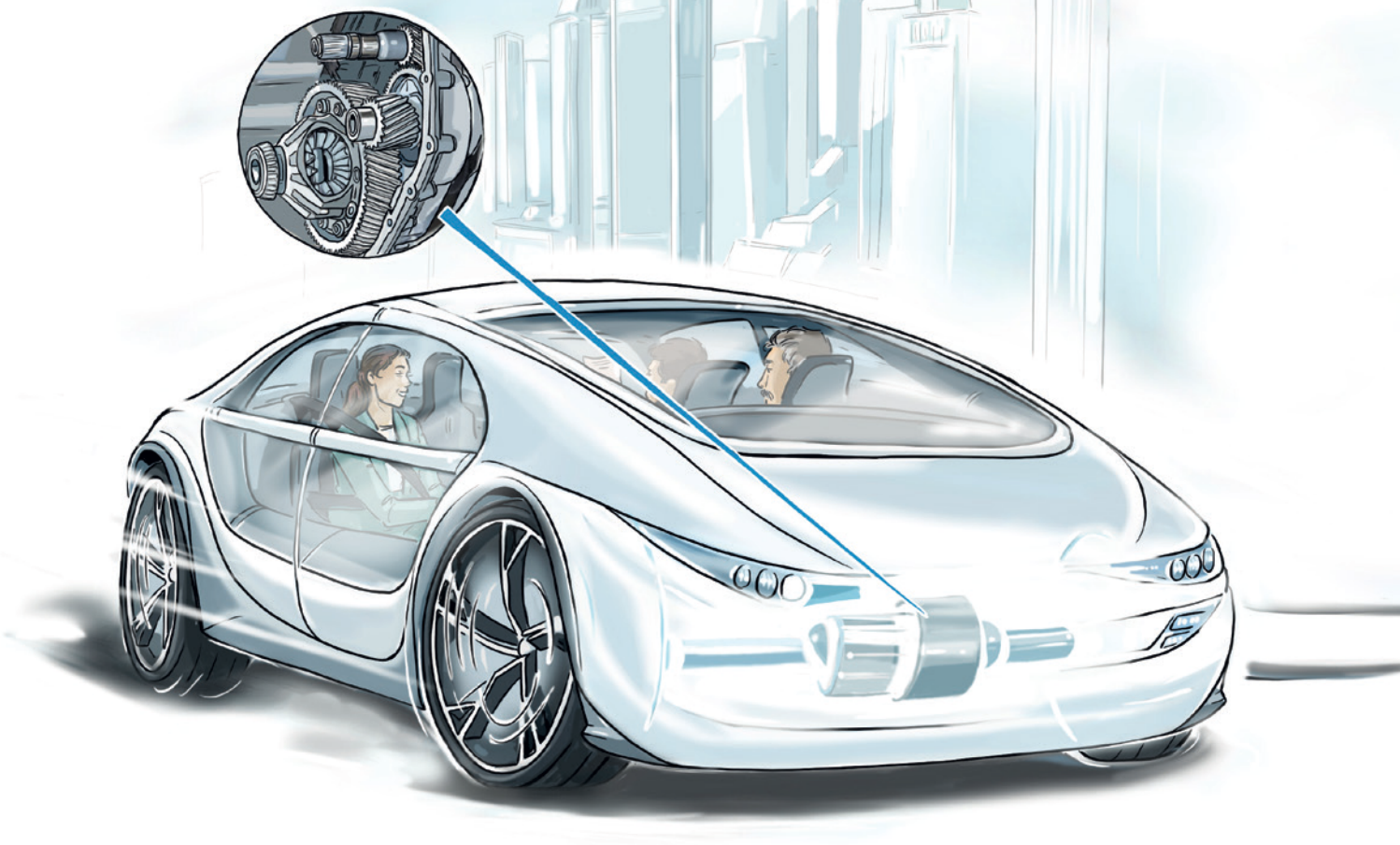
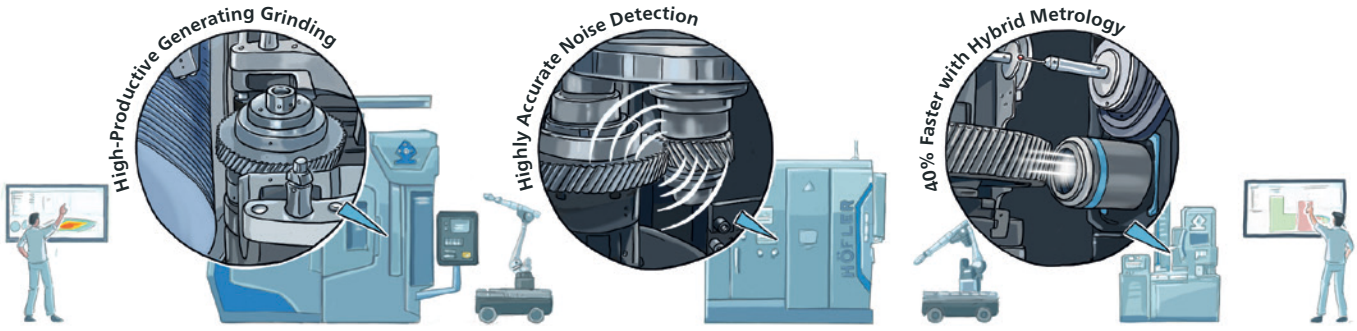


The future of mobility and energy generation requires new standards for developing innovative and efficient technologies. As one of the leading manufacturers of high-precision machine tools and measuring centers for gears, Klingelnberg is ideally equipped for the challenge. With expertise and dedication, Klingelnberg is developing solutions that make tomorrow's visions a reality.



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