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Design Principles of Bevel Gears:
Rationale for Zero Sum Profile Shifts
and Generating Gear Choices
Conjugate Bevel and Hypoid Gears



Better Gear Cutting Results Start with the Right Partner

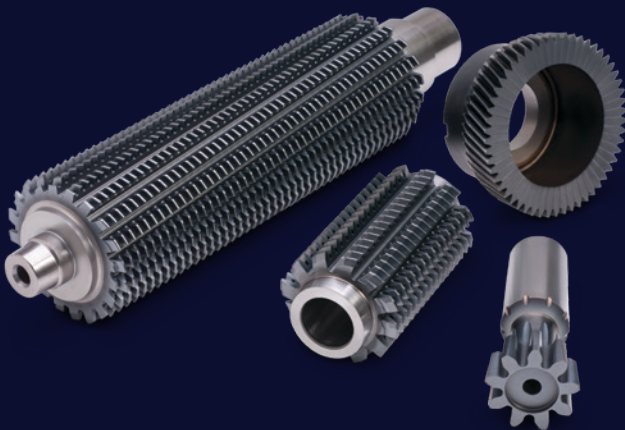
**Great gear cutting results come from more than tooling.
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- Skiving Cutters
- Shaving Cutters
- Rack and Saw Cutters
- Master Gears, Ring and Plug Gauges
- Advanced Coatings Available





GEAR CUTTING SOLUTIONS



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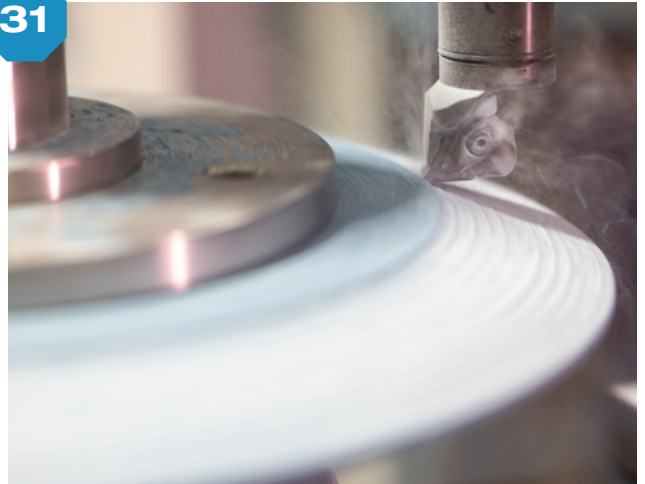
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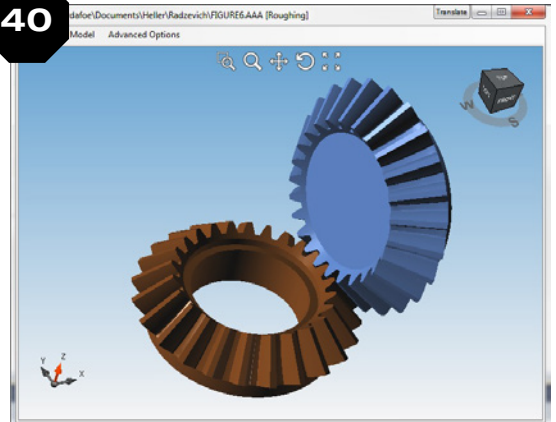
37 Design Principles of Bevel Gears: Rationale for Zero Sum Profile Shifts and Generating Gear Choices

This article demonstrates why bevel gears are designed with a zero sum of profile shifts—showing that independent shifts merely replicate what a modified pressure angle already achieves—and explains the practical benefits of using conical generating gears for tooth profile crowning.

40 Conjugate Bevel and Hypoid Gears

An excerpt from *Gear Technology Solutions* by Dr. Hermann J. Stadtfeld exploring the mathematics behind conjugate bevel and hypoid gears—from the fundamental laws of gearing and the conditions for perfect conjugacy to why real-world power transmissions require deliberate crowning rather than theoretically exact conjugate designs.

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Constructive Failure



Gleason's Intra SFTA system for axial alignment detection and component-to-component NVH testing. (Image: Gleason Corporation)



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GT REVOLUTIONS

A Blank Look



The gear blank is the quality ceiling of the finished gear. This article covers two areas of material specification that directly affect gear performance: controlling hardenability when sourcing blanks across global supply chains and specifying microalloyed steels for high-temperature carburizing.

geartechnology.com/a-blank-look

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EVENT SPOTLIGHT

WZL Gear Conference USA



The WZL Gear Conference USA will take place on July 15 and 16, 2026, at Klingelnberg America, Inc. This renowned conference brings together North American companies with the Laboratory for Machine Tools and Production Engineering (WZL) at RWTH Aachen University and offers a compact overview of current developments and research topics in gear technology.

geartechnology.com/events/wzl-gear-conference-usa-2026-03-26

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

AS SEEN IN PTE

The Year Ahead in Robotics

As someone who has spent more than four decades involved in the robotics industry, I can say unequivocally that this is the most exciting time ever. From a technology that was originally used predominantly by U.S. automotive companies, robotics has now spread to nearly every industry and every country around the world.

powertransmission.com/the-year-ahead-in-robotics





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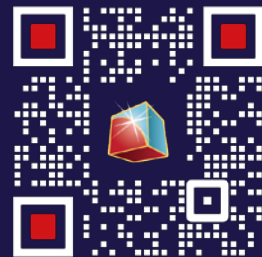
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Evolve Your Process at IMTS on Sept. 14-19, 2026, in Chicago.

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Self-Consuming Artifacts

Aaron Fagan, Senior Editor

I've been rereading *Self-Consuming Artifacts* by Stanley Fish, published in 1972, a classic of literary criticism on the experience of reading, and now I see its central thesis everywhere. Fish argues that certain texts don't deliver a meaning so much as put you through something. They build a framework, make you invest in it, and then show you its limits. The text, as he puts it, consumes itself: "it is self-sharpening and what it sharpens is you." I realize this sounds like an odd thing to bring up in *Gear Technology*, but one hopes every issue of the magazine is in some way an active experience that requires the reader to work, question their own assumptions, and possibly change their perspective.

The ouroboros, an ancient symbol of cyclical self-consumption. The serpent must pass through its own undoing to continue, not unlike an engineering ideal that has to break down under real-world conditions before it can be rebuilt into something that works.

As I was editing Dr. Stadtfeld's conjugate bevel and hypoid gear piece (p. 40), Fish's argument kept rattling around in my head. Dr. Stadtfeld thoroughly builds conjugacy up for pages: the fundamental laws of gearing, involute development, the generating gear principle, straight bevel geometry, and hypoid pitch surfaces. The tooth contact analysis results are unreal: zero motion error, perfect line contact, Ease-Off graphics you could set a drink on, and by Figure 11, you're a true believer. However, this is only the mathematically exact answer to the problem of two gears meshing; he then introduces fifty microns of offset error, fifty microns of pinion cone displacement, thirty arc-minutes of shaft angle change (numbers that would be unremarkable in any production gearbox), and the whole thing comes apart—contact migrates to the tooth edges, load concentrations spike, and what follows is noise, pitting, and tooth fracture. He calls conjugacy "a false objective," which is a stunning conceit to deploy after pages of proving it works. But that's exactly Fish's move, and Dr. Stadtfeld leads us through the construction, so the departure is meaningful.

Once I had that lens on, the rest of the issue started falling into place. Dr. Zarębski's piece (p. 37) on bevel gear profile

shifts is a subtler example: the elaborate formulation with independent coefficients produces geometry identical to the standard zero-sum approach with a modified pressure angle, but you have to go through the elaborate version to see that. In an interview (p. 18) with Lance Brown, MPMA senior technical instructor, he shares that a client once asked him to skip the involutometry and get straight to why their gears were breaking. He obliged—he's a good teacher—but you can hear in the interview that they would get theory whether they knew it or not. Without it, failure analysis is just pointing at damage.

The Productive Robotics story (p. 22) is four years of a concept consuming itself into a process. Not just self-consuming but recursive, a cobot manufacturer uses its cobots to deburr the gears its cobots contain. I won't belabor the whole issue into the same frame, though much of it fits. Fish thought the most honest texts were the ones that made you earn the disillusionment. That the getting-there mattered more than the conclusion. I think he was talking about reading, but he could have been talking about engineering. As it happens, I wrote this issue's Addendum "Constructive Failure" at the back of the book months before any of these pieces crossed my desk.





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MPMA: Built for What's Next

In early April, I had the honor of stepping into the role of President of the Motion + Power Manufacturers Alliance (MPMA). For nearly 25 years, I've had a front-row seat to this industry—learning from the engineers, executives, and innovators who make it run. That experience, built on relationships forged across every corner of the power transmission supply chain, is what I bring to this role.

I want to begin by acknowledging the people who made this moment possible. A decade of leadership from Matt Croson left this organization stronger, sharper, and ready for what comes next—a clear direction, a strong culture, and a staff team that consistently delivers well beyond expectations. To our Board, Executive Committee, and volunteers: your vision and dedication to this industry are the engine behind everything MPMA does. And to the MPMA team itself—thank you for the way you show up, every day, for our members.

We are now a year into one of the most significant changes in our association's history: the merger of AGMA and ABMA into MPMA. Founded just a year apart over a century ago, these two legacies are now united. And while any merger comes with its share of complexity, what I see most clearly is the promise MPMA holds in bringing supply chain—manufacturers, suppliers, customers—together in a seamless, powerful network.

At the center of everything we do is a simple, unwavering commitment: MPMA exists to serve its members. As the industry changes—and it is changing rapidly—so must we. From technology to workforce to policy, these aren't abstract trends—they're your daily reality. MPMA's job is to keep pace, to anticipate, and to respond.

So what does MPMA stand for? I think about our brand as resting on four pillars, each one a doorway into this organization—and each one designed to meet you where you are.

Technical. Standards are the backbone of what we do. MPMA maintains and advances more than 145 standards and publications that keep our industry operating with precision, consistency, and credibility. Whether you're a design engineer or a manufacturer navigating global markets at the ISO level, MPMA's technical resources are built for you.

Education. From entry-level operators to seasoned professionals, there's always more to learn—and MPMA has built a growing library of programs to support every career stage. In-plant training, online courses, and expanding on-demand programs mean that whether you're building a team or building your own career, we have a program that fits.

Network. MPMA connects you with more than 400 member companies across the full power transmission supply chain. Whether you're a CEO looking for market intelligence or a salesperson building relationships at Motion + Power Technology (MPT) Expo, MPMA is where the industry gathers.

Voice. This industry deserves to be heard, and MPMA is committed to amplifying that voice—in Washington, in global markets, and in the press. From federal advocacy to anti-counterfeiting efforts to industry media, we are building the platforms that make sure decision-makers know who we are and what we represent.

Operators, engineers, sales professionals, executives—every one of you has a home at MPMA. The doors into this organization are wide open, and we are actively building more of them.

I want to hear from you. The best associations are built by listening to the people on the floor, in the field, and at the helm of companies navigating real challenges. What's keeping you up at night? What gaps do you see that MPMA could fill? What would make your membership feel indispensable?

Reach out. Tell me what you're facing. This industry has given me 25 years of perspective, and now I have the platform to put it to work—for you.

MPMA is not a new chapter; it is a new book, and it's just beginning. I couldn't be more ready to write it together.

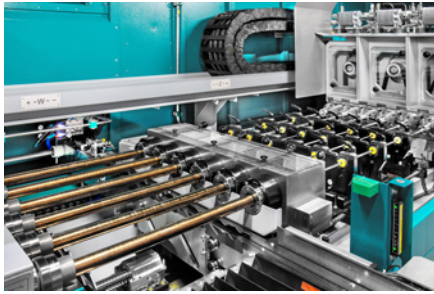
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Jenny Blackford
President, Motion + Power
Manufacturers Alliance (MPMA)

Nagel Precision

REIMAGINES DEEP HOLE DRILLING



Modern cutting tools are almost always equipped with internal cooling channels. However, the longer the tool, the more demanding the drilling of these channels becomes. This is where a new generation of deep hole drilling solutions comes into play—combining precision, flexibility, and a high level of automation.

With 1 to 4 spindles, drilling diameters ranging from 3 to 22 mm, and drilling depths of up to 1,250 mm, the system covers a wide range of applications. Especially for long workpieces, single-lip deep hole drilling offers clear advantages: a stable process and superior hole straightness, critical for the performance of modern tools with internal cooling. The machines are fully customizable and can be configured either as stand-alone systems or as fully integrated turnkey solutions, including automation. This allows manufacturers to seamlessly switch between single-part production and high-volume series manufacturing.

A key feature is the high level of automation. Optional robotic loading and unloading enables efficient, largely unmanned operation. At the same time, the system remains practical and user-oriented: setup processes are optimized to minimize downtime and increase overall productivity. “Our customers are looking for more than just precision—they need flexibility to adapt to changing production requirements. That’s exactly what our customizable deep hole drilling solutions deliver, explains Jason Collins of Nagel Precision.

The machines combine German engineering expertise with manufacturing and service capabilities in the

United States. This ensures short response times, local support, and close customer proximity, key advantages in demanding production environments.

“A major benefit is that we provide tools, service, and application expertise from a single source. This significantly reduces interfaces and increases process reliability,” adds Collins.

In addition to the machine itself, the solution includes tooling, application engineering, and service. This holistic approach ensures that all components are perfectly aligned, resulting in consistent quality and highly reliable processes. With its combination of precision, scalable automation, and customer-specific customization, modern deep hole drilling technology is setting new standards—especially for demanding applications such as high-quality coolant channel drilling.

nagelusa.com

SMW Autoblok EXPANDS MOTIACT LINE OF MECHATRONIC GRIPPERS



SMW Autoblok has recently introduced new long-stroke models to the MOTIACT lineup of mechatronic grippers. The MX-L 335 compact long-stroke and MX-L 520 long-stroke grippers are designed for EOAT (end-of-arm tooling) automation with higher workpiece weights and are suitable for use in machine tending, material handling, assembly, and other applications.

The MX-L 335 long-stroke gripper has a stroke of 55 mm (2.2 in.) per jaw, and boasts a high gripping force of 2.5 to 27 kN, the second largest gripping force in the MOTIACT lineup. The MX-L 520 has a stroke of 99 mm (3.9 in.) per jaw, and has a gripping force of 10 to 40 kN. These new models allow users to better select

gripping systems even more appropriately for handling heavy-weight workpieces.

Featuring aluminum housings with compact widths of 335 and 520 mm (13.2 in. and 20.5 in.), their lightweight construction allows them to provide robot arms with comprehensive load-bearing reserves for large workpiece weights. They can be directly integrated into the PLC of an automation environment via Profinet or Ethernet/IP.

Launched on the market in 2023, SMW Autoblok has steadily expanded its MOTIACT range to meet the requirements of other application areas. The gripping systems currently cover strokes of 3 to 99 mm (1.2 in. to 3.9 in.) per jaw and gripping forces of 40 to 40,000 N. This means that minute pick & place tasks and the handling of large metal components both benefit from the advantages of MOTIACT: an integrated absolute position sensor allows the jaw position to be precisely adjusted to the object to be gripped. The gripping force can also be infinitely adjusted with pinpoint accuracy. In the event of a power failure, both the gripping position and the gripping force are maintained at a 1:1 ratio. Even with a wide range of variants, this ensures fast, efficient and safe processes thanks to the precise adjustment feature of the gripper setting.

smwautoblok.com

Heimatec U-TEC FLEXIBLE CHANGING SYSTEM NOW OFFERED FOR LIVE TOOLS



Heimatec recently announced the availability of its u-tec flexible changing system on all live tools in the company’s product line. Tools are now available for the most popular machine tool models

in the market, according to Platinum Tooling Technologies Inc. President, Preben Hansen.

The company plans to include its u-tec flexible changing system on all live tools and angle heads.

The u-tec patented changing system allows a standard ER output live tool to accept various adapters for different applications. This allows users the ability to have quick changeover of tools on almost any lathe or mill, using a single tool, without having to

commit to a quick-change system on the initial purchase.

A facemill adapter can be quickly positioned into the standard holder, without the need for a new tool purchase. This significantly reduces inventory costs as well as changeover time for the busy shop.

U-tec allows great user flexibility and ensures a solid connection due to the polygon design built into both the tool and the adapter. This polygon connection helps guarantee the proper position

and alignment of the adapter inside the tool. Once the insert is properly positioned and the collet nut is clamped, the cutting tool will have excellent rigidity and torque transmission.

The unique collet nuts on the u-tec system have internal threading for clamping stability. This new tool adapter system enables the actual cutting tool to be brought into closer proximity to the bearing, thus further improving performance in use.

Every adapter in the u-tec system is furnished complete with the necessary clamping nut and holding wrench. U-tec adapters are available in various outputs such as arbor, Weldon, ER extension and blank styles.

The u-tec system is available for all major turning machines.

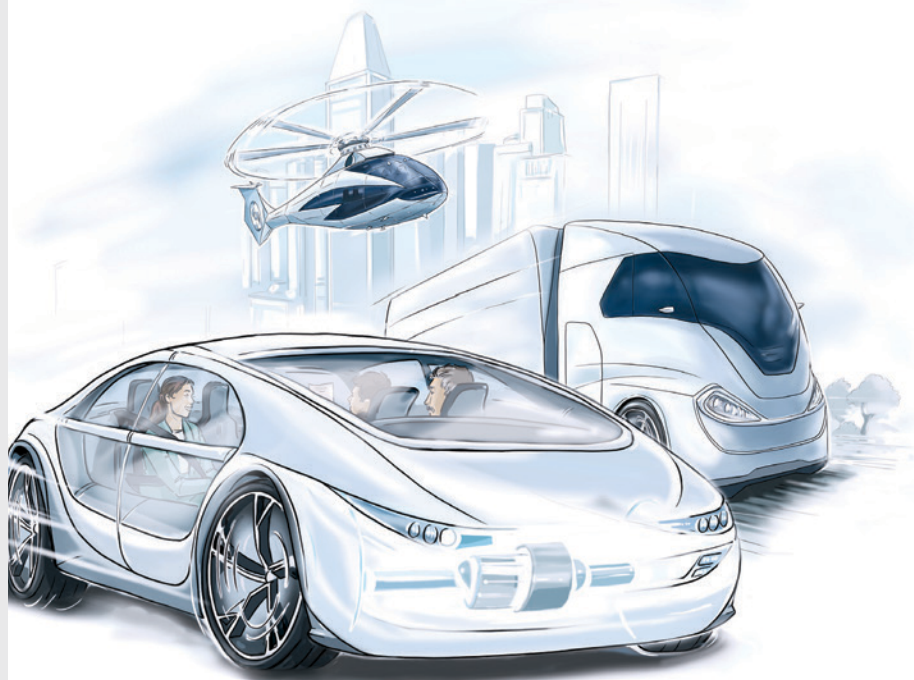
Heimatec currently manufactures more than 10,000 live tool types and has a full inventory at Platinum Tooling, their North American importer, headquartered in the Chicagoland area.

platinumtooling.com

heimatec.com/precision-tools

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During rinsing, it is decided whether high-purity components reach the required cleanliness limits or whether recontamination after cleaning leads to scrap. Three factors are particularly critical: ultra-pure water quality directly at the point of use (particles, organics/TOC, conductivity, pH); minimal carry-



over between process stages and a clearly defined rinsing strategy; and plant engineering and loop hygiene (suitable materials, well-designed piping and continuous monitoring).

In high purity component cleaning, cleanliness requirements are more demanding: permissible limits for the chemical composition of the component surface in atomic percent, extremely low outgassing rates and particle freedom in the submicron range.

These requirements result from extreme vacuum conditions in which the components are used, for example in EUV lithography, aerospace, or mass spectrometers for analytical applications. In these environments, cleanliness is a system characteristic.

The process chain must be designed to deliver technical cleanliness reliably and to prevent recontamination. Every contact medium must meet the same limits so the specification is not compromised. Otherwise, either the required cleanliness cannot be achieved or the component is re-contaminated after cleaning.

For ambient air and process air, limit values are generally manageable using cleanroom technology and HEPA/ULPA filtration.

Process water is often far more challenging. In rinsing, it must not introduce particles or organic residues onto the component otherwise, recontamination and scrap may occur.

Rinsing is not simply "washing off" cleaner. It is the controlled dilution of the liquid film that is carried over on the component surface with rinse water. Through dilution, remaining contaminants are removed and transported out.

The objective is to reduce contamination concentrations from stage to stage in

a defined manner below the relevant limits, both particulate and filmic/organic.

A component can only become as clean as the final rinse allows.

The decisive factors for high-rinse quality are water quality at the point of use and minimal carryover.

The required water quality depends on the applicable cleanliness requirements. In many cases, ultrapure water is used in the final rinses.

Water quality is influenced by the quality of municipal feed water.

Depending on hardness, conductivity and dissolved salts, pretreatment may be necessary, through activated carbon filtration, particle filtration, manganese removal or iron removal.

Typically, reverse osmosis is then used. Pressure forces water through a semi-permeable membrane, separating low-salt permeate from concentrate.

For the highest demands, further treatment follows via mixed-bed ion exchange or alternatively electro-deionization (EDI), which operates



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continuously without regeneration chemicals. Additional stages such as UV treatment for microbial reduction or degassing may be added.

Water quality is defined and monitored using parameters such as conductivity, pH and total organic carbon.

This is where sophisticated plant engineering is required. It must ensure excellent water quality at the point of use through minimal carryover, appropriate materials and effective loop hygiene. Rinse quality is

only as good as the system that carries it.

From the outset, the cleaning system must be designed to minimize carryover. This includes strict separation of media circuits. Each tank has its own piping, filter units and pump. Piping runs should be flow-optimized to prevent residual water from collecting anywhere.

Workpiece carries and racks must be designed to avoid scooping points and unnecessary surface areas where water residues can remain.

In transfer immersion systems, defined overflows and separation baffles between tanks are important. Drip times and vibration of carriers support carryover prevention. In chamber systems, a drain-optimized chamber design, complete draining and chamber cleaning between treatment steps are beneficial.

Water quality should be monitored directly in the cleaning system, at the point of use, using appropriate sensor technology.

Due to improved compatibility, V4A stainless steels (e.g., 1.4404, 1.4571) should be used instead of V2A. Weld quality must be ensured. Brass should be avoided entirely. PP and PVDF may also be suitable for piping, depending on the application.

bvl-cleaning.com/en/industries/high-purity

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large working area allows for a wide range of machining operations.

The application spectrum includes workpieces on high clamping towers, complex 5-axis geometries, and reliable deep hole drilling. The E-Pallet further supports the variety of machining operations. The smart interface provides power for fully electric clamping devices and sensors as well as hydraulics and pneumatics. This revolutionizes the classic machine table and enables the use of smart clamping devices which enable the use of intelligent software. Due to the horizontal design, machining benefits from optimal chip removal and good heat dissipation, resulting in maximum process reliability.

The double-sided swivel rotary table is designed for components up to \varnothing 840 x 770 mm and 600 kg and allows flexible machining of workpieces—up to 5-in-1 process integration of milling, turning, grinding, measuring, and gear cutting. The wheel magazine has space for up to 453 tools with a maximum length of 650 mm, a diameter of \varnothing 280 mm, and a mass of 22 kg. The spindle range offers variants up to 30,000 rpm as well as options for machining with 288 Nm and HSK-A 100 tool holders.

The high connectivity of the DMU 65 H monoBLOCK 2. Generation and Celos X control platform—available with Siemens or Heidenhain—pave the way for end-to-end digitization of production. The app-based, intuitive operation and exclusive DMG MORI technology cycles also make handling easier.

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Hypertherm Associates

HIGHLIGHT PLASMA AND WATERJET TECHNOLOGY AT FABTECH CANADA

Hypertherm Associates will highlight its advanced plasma and abrasive waterjet cutting technology along with production-enhancing software at Fabtech Canada 2026, June 9–11, in Booth #7050 at the Toronto Congress Center.

For future-ready abrasive waterjet cutting, the Maxiém 1530X JetMachining

Center, part of the recently enhanced Maxiém X Series, is the latest evolution in waterjet technology for cutting complex parts out of most materials, including metal, plastic, glass, ceramic, stone and composites. It also generates surface finishes that often eliminate the need for secondary machining.

Through its enhanced features, the Maxiém 1530X brings superior performance, versatility and productivity at an affordable price. It is engineered for shops that require intelligent

performance. Every detail was reimagined to deliver a cutting experience that's smarter and more intuitive.

The Maxiém X Series boasts the latest version of *IntelliMAX*, the *OMAX* premium software suite, which now includes IntelliVISOR Mobile app. IntelliVISOR Mobile enables remote live cut monitoring, system status and problem alerts, remote pause, and instant notifications from anywhere, and is available for iOS and Android operating systems.



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Other standard features on the new Maxiem include tank rub rails and an improved abrasive hopper. In addition to reducing the risk of rust, the rub rails prevent damage to the catcher tank and the workpiece during loading and unloading.



The new abrasive hopper is engineered to contain abrasive material within the hopper to avoid external spillage. The seven-pound-capacity hopper provides advanced incoming abrasive filtering and is compatible with an optional Abrasive Clog Detection system that automatically pauses the machine when a clog is detected. With the Abrasive Clog Detection system, an operator can immediately restore flow and keep the machine running.

For improved visibility on the cutting table, under bridge lighting is also

an optional feature available on Maxiem 1530X, as is the VersaJET, a completely software-controlled 5 Axis cutting head. VersaJET has a cutting range of 0 to 60 degrees for cutting beveled edges, angled sides, countersinks, and complex 3D shapes. The cutting head virtually eliminates taper on finished parts with automatic taper compensation. Through its high level of positioning accuracy, the VersaJET can cut parts that do not require secondary finishing.

For gouging and flush-cut applications, the Hypertherm Powermax SYNC Series will be on display, showcasing a new standard in air plasma cutting performance and ease of use. The series is designed to simplify operations while maximizing productivity and features built-in intelligence, automated system process setup, and advanced RFID-enabled SmartSYNC torches.

At the core of the Powermax SYNC Series is a patented single-piece cartridge consumable that streamlines operation, delivers up to five times longer consumable life, and provides trackable utilization data for improved

efficiency. The series offers a reliable, next-generation solution for professional cutting environments through enhanced cutting power, simplified gouging capabilities, and consistent performance across a range of applications.

For metalworkers who require high-quality cuts at a greater capacity and portability, the Powermax33 XP new air plasma system offers a recommended cutting capacity of 13 mm (0.5 in.) and a severance capacity of 20 mm (0.75 in.), delivering cutting power comparable to some competitive 45-amp systems. With a dual-voltage design, the Powermax33 XP can operate on either 120V or 240V power, making it well-suited for shop or field use.

Additionally, booth visitors will experience the latest enhancements to the company's XPR line, including expanded capabilities for the XPR460, designed to improve connectivity, productivity, and cut quality. A new control board enables Ethernet LAN capability and MTConnect protocol support, allowing real-time data access, advanced process monitoring,

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For simpler applications, a new Manual Set mode streamlines operation by retaining settings for repeat jobs, even after power cycles. The XPR gouging capability delivers wider, deeper, and cleaner profiles with minimal post-process cleanup, reducing labor and accelerating weld preparation, while extended arc reach improves access to tight or hard-to-reach areas.

The XPR460 continues to deliver industry-leading cut quality across mild steel, stainless steel, and aluminum, with SureCut technology for precise, bolt-ready holes and accurate bevels, and PlateSaver technology to optimize material utilization and reduce cost per part. Now featuring 460A Nitrogen/VWI capability for high-quality cuts on thick stainless steel and aluminum, along with new 460A Y-Top True Bevel technology for thicker mild steel, the XPR460 increases accuracy, consistency, and overall performance in demanding and automated cutting environments.

Engineers will also be on hand at Fabtech Canada to demonstrate *ProNest CAD/CAM* nesting software. It is designed for advanced mechanized cutting applications, including plasma, laser, waterjet and oxyfuel. *ProNest* offers standard features that include part design, CAD import, manual nesting, reporting, costing and quoting, and its fully automated interface reduces programming time from hours to minutes.

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processing, conveying technologies, pick-and-place applications in the food industry, and as a central vacuum system. Powered by a highly efficient IE4 motor with a patented asymmetrical rotor design, users benefit from energy savings of up to 50 percent compared to competitive products. The low-maintenance, compact vacuum pump has a pleasantly low noise level and also runs vibration-free.

An integrated, intelligent control system with frequency converter automatically adjusts the speed of the DHS 3000 VSD+ to the requirements, ensuring that the exact vacuum level required is delivered in each process section. This results in significantly lower energy consumption and reduced wear on all moving components. Overall, this also extends the maintenance intervals and service life of the vacuum pump. Companies that value stable performance and high process reliability and also need to reduce their energy costs will find the dry-running pump a robust, clean solution.

A wear-free gearbox ensures optimum power transmission from the motor to the screw.

“We have achieved a long service life for the gear wheels by using a cooled oil flow,” explains Carol Pignatelli, product manager from Atlas Copco. Because the DHS 3000 VSD+ does not use oil in any other way, there is no risk of oil emissions though carry over. “We have also equipped the DHS VSD+ with an air intake filter to protect operational process from dust and particles.”

The oil-free technology and simple, robust design also contribute to low maintenance costs.

A range of ergonomic advantages and straightforward handling make the DHS 3000 VSD+ extremely user-friendly: under a noise-reducing hood, it runs pleasantly quietly and vibration-free. The easy-to-use Elektronikon control system gives users a constant overview of the latest status updates on operating and downtimes, error and alarms.

“Atlas Copco supplies the DHS VSD+ as a complete plug-and-play unit that can be seamlessly and quickly integrated into any system,” concludes Pignatelli.

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Bringing the Shop Floor to the Head of the Class

A conversation with Lance Brown

Aaron Fagan, Senior Editor

Lance Brown spent 28 years at CGI, Inc.—a Carson City, Nevada-based manufacturer of precision drive systems founded in 1967 and best known for its work in medical robotics and aerospace, now part of The Timken Company—working his way from the shop floor into design engineering and tackling gear problems across some of the most demanding industries in the world. Now, as MPMA's first Senior Technical Instructor, he's channeling that experience into a growing education program at a pivotal moment for the organization. We sat down with Brown to talk about the career that got him here, what he's seeing in the classroom, and where MPMA's training offerings are headed next.

You spent 28 years at CGI, Inc.—a company that went from a family-owned precision gear house to part of Timken's industrial motion portfolio. Where did you start, and how did your role evolve?

I started with CGI in early 1997. I learned about the company quite by accident—I wanted to learn how to make gears from a hobby interest, and I also wanted to work for a reputable manufacturer, so CGI checked all the boxes. At the time, I wasn't even aware they manufactured their own line of industrial planetary gearboxes. Previously, I had worked in job shops where you rarely machine the same parts twice in a row. As my knowledge and experience grew, I moved into the drafting department and finally the design engineering department. I've always had an aptitude for gear and gearbox design.

Your career began on the manufacturing floor before moving into design and eventually technical sales leadership. How did that hands-on experience shape the way you approach gear engineering today?

The greatest benefit from my experience on the manufacturing floor was recognizing that it's common for engineers, especially new ones, to design features on a part, or even an entire part, that couldn't be suitably produced by the processes available at the time. When reviewing a drawing, we would have to ask ourselves, "How the heck am I going to get a tool in there to create a radius in an internal blind groove?" As a mechanical drafter, it was clear to see how those features could easily be over-designed. So, we would meet with our customer and discuss the issues feature by feature. Today we call this DFM—design for manufacture—and it's something I stress in all the courses I teach.

CGI has a remarkable footprint in medical robotics, aerospace, and defense. Can you share an application that was particularly challenging or rewarding?

All those sectors provided opportunities to engage in some incredibly diverse design projects. We designed a gearbox to operate just above the sea floor at a depth of 10,000 feet. We designed gears and gearboxes that live in space—in orbit, on the moon, and on Mars. CGI's catalog products,

without any customization, are in every application from pick-and-place machines to machinery that produces siding for residential construction.

But the most rewarding for me was the medical and robotics space. We collaborated with the top engineers in those fields, and I know that CGI continues to do so. One such application is a robotic surgical platform that, quite literally, saved my daughter's life. I'm not sure how to put a finer point on it after that.

You've been active on AGMA's Technical Division Executive Committee and multiple technical committees. How did that standards work complement what you were doing day to day?

It was wonderful—I miss being involved. It really opened my eyes to the breadth of the gear industry. It was empowering to know that each member company can have an impact on the industry at large, and it was refreshing to see that the technical standards and information sheets were in such good hands. I can't recommend strongly enough that people get involved with one or more of the committees. There's a minimal time commitment—about two hours every few weeks—for what I felt was a large return. Specifically, it helped me apply the standards with a deeper understanding of the methodologies contained in them. The opportunity to ask questions of the people directly involved in developing those standards is truly helpful as well.

You could have stayed in industry. What made you want to step into a full-time teaching role with MPMA, and what does it mean to you to be the organization's first Senior Technical Instructor?

I'm honored to be the first official instructor for MPMA. I've been teaching to some degree since I was a teen—it's in my blood. I truly enjoy sharing knowledge and, where I can, wisdom with others. I've had the opportunity to take gear design and gear failure classes with the best there is, including the late Bob Erichello, who was a great influence on me and was so active on AGMA technical committees. I hope to continue their level of excellence, experience, and willingness to share with those who are eager to learn.

You've already been teaching the Gear Failure Analysis course. Have there been any moments in the classroom that reminded you why this work matters?

Absolutely. There are failure modes that, based on my personal experience, I would have thought were rare. Yet on separate onsite presentations, I've had attendees bring specimens that showed the same failure mode—across multiple product types and industries. That really surprised me.

Another example: my colleague Terry Klaves and I will be in the middle of an example, and attendees from the same company will look at each other—their body language says, "Yep, that is exactly what we're dealing with." That opens up the opportunity to take the conversation to the next level and really enhances the experience for everyone in the room.

What do you see as the biggest knowledge gaps facing today's gear and bearing workforce?

I'm not sure I'd call it a gap, but there is sometimes a lack of practical experience in our industry—and probably all of manufacturing. Obviously, there's a ton of emphasis on software for simulation, rating, microgeometry, topological modifications, and so much more. But there's a real need to actually read through the technical standards and information sheets—not just the formulas, but the cautions. There's power in programming your own spreadsheet to handle some equations, to understand how they work together, and not just trust the output provided by software. That, in turn, will help you become a real power user of whatever technology you employ for the design or analysis of gears and geared systems.

Give us a sense of the range of your teaching. What subjects are in your wheelhouse, and what courses are you looking to develop next?

I've been blessed with the opportunity to participate in the design and successful application of many different types of geared solutions—spur and helical, worm, bevel, and many simple and compound planetary arrangements. Beyond gears, I've designed a number of different mechanisms to support the systems where our gears were critical for success. So, I have a broad range of experience that I'd like to bring to the classroom. In the future, I'd like to develop and offer new courses focused on the robotics and medical sectors, along with the current lineup of MPMA course offerings, which I find to be outstanding.



Lance Brown, MPMA Senior Technical Instructor

“But the most rewarding for me was the medical and robotics space. We collaborated with the top engineers in those fields, and I know that CGI continues to do so. One such application is a robotic surgical platform that, quite literally, saved my daughter’s life. I’m not sure how to put a finer point on it after that.”

—Lance Brown

How would you describe your teaching approach?

I try to be engaging. I’m all too familiar with technical presentations that just seem to drone on and on. I ask questions of the class, I encourage the same from them, and I come to the presentation prepared. I want the class to be fun as well as informative.

Part of your role involves developing new intellectual property for MPMA. What does that look like in practice?

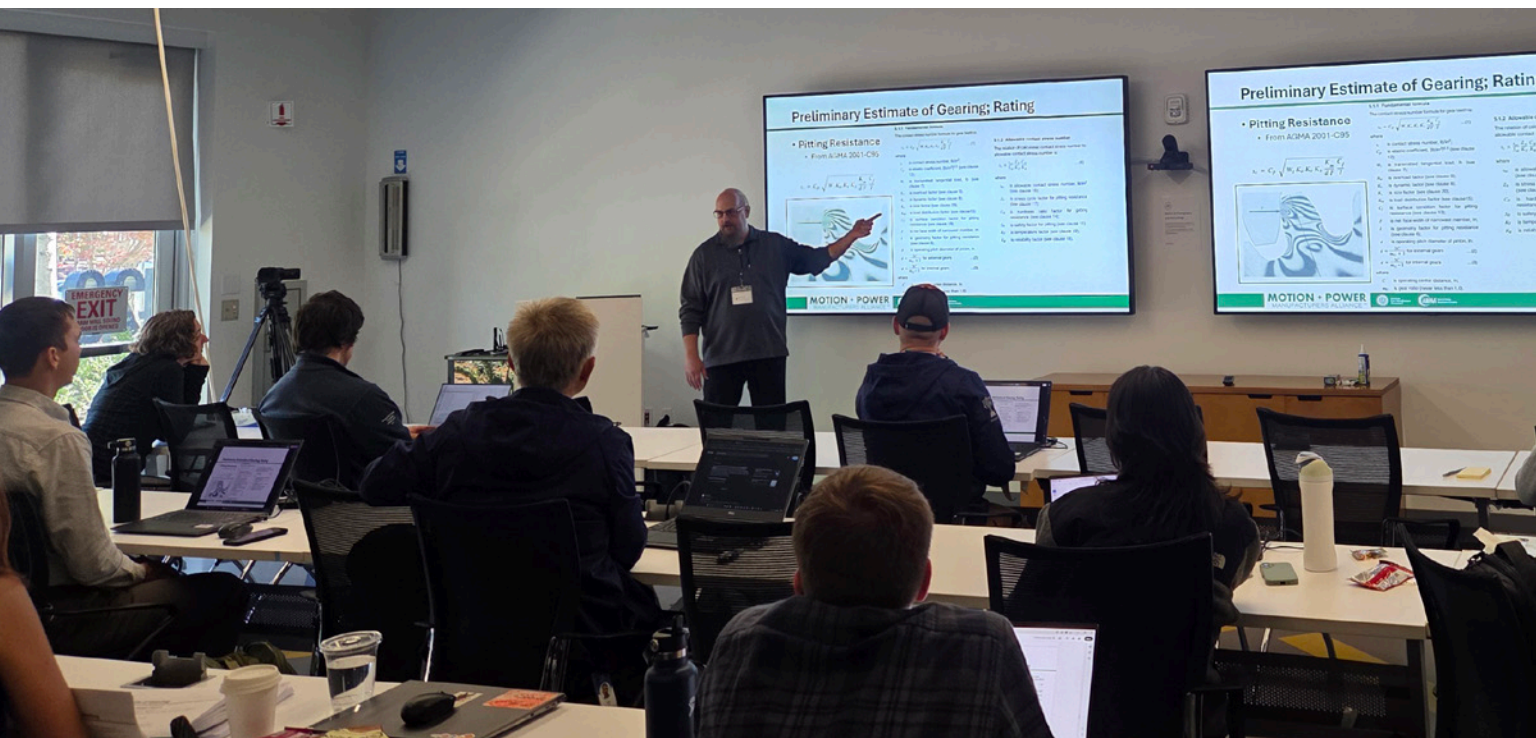
There are areas in our industry where technology is growing and changing the way we think about manufacturing in general, not just gears. While it’s important to knock the dust from your favorite calculator and do the math, it’s also imperative to stay abreast of technology. Modernizing some of the content is one of our focus points.

For readers who may not be familiar, explain what an MPMA onsite training is and how it works.

The process is actually very simple. A phone call or an email to any of the staff at MPMA is all that’s required to get the ball rolling. If the interested party is looking to have a specific class presented to them, we can work with the instructor to determine a date and time before we begin putting a quote together. After a couple of calls or emails, everything is set.

One of the things that sets onsite training apart is customization. How do you tailor a course to a specific company?

The ability to customize a class is very beneficial. Not all content is important to all consumers of the class. For instance, during an on-site tailored presentation of Gear Failure Analysis, the person organizing the class asked me not to “bore the group



Lance Brown conducting a custom on-site training for a group of robotics engineers.

with involutometry.” They said, “I have broken gears, and I want to know why.” I get it. We can go light on the theory and heavy on the application if that’s what’s needed.

Familiarization with the customer’s parts or gearboxes is always helpful—it’s a conversation that works best ahead of time, but even a tour before the class starts will help any instructor better understand the needs of the attendees. Reviewing drawings is also a great way to accomplish this, assuming they can be shared. Drawings and other documentation really help ensure that we’re all speaking the same language.

On-site training can be delivered in person or online. What are the advantages of each?

My personal preference is in-person training. The interaction with the attendees is much more fluid and instrumental in clearing up confusion when the subject matter gets a little deep. The break-time conversations can be really informative, as can the conversations that take place before or after class, when attendees are more open to discussing their examples with an instructor.

Live online instruction would be my second preference. Many times, especially if a company is onboarding new employees, they’d prefer to have them take the training right away rather than wait for a class that may be scheduled months out.

If a company is on the fence about investing in onsite training, what would you tell them?

Well, first, the expense of travel and hotel rooms for a group can be substantial. Terry and I taught an on-site class to 30 people last year. It would have been cost-prohibitive to send a group

that size to the national training center. And second, onsite training can be tailored to fit the focus of the company.

You’re stepping into this role at an exciting time—AGMA and ABMA have just merged to form MPMA, education programming has doubled in size, and the industry’s appetite for technical training is growing. What’s your vision for where MPMA education can go from here?

This is an exciting time. Our goal is to improve and increase our offerings and reach as many people as we can. We are working with existing and potential future instructors to flesh out new courses while at the same time modernizing our current courses. A big part of that is letting people know what we have to offer in education—in addition to all the other benefits of MPMA membership.

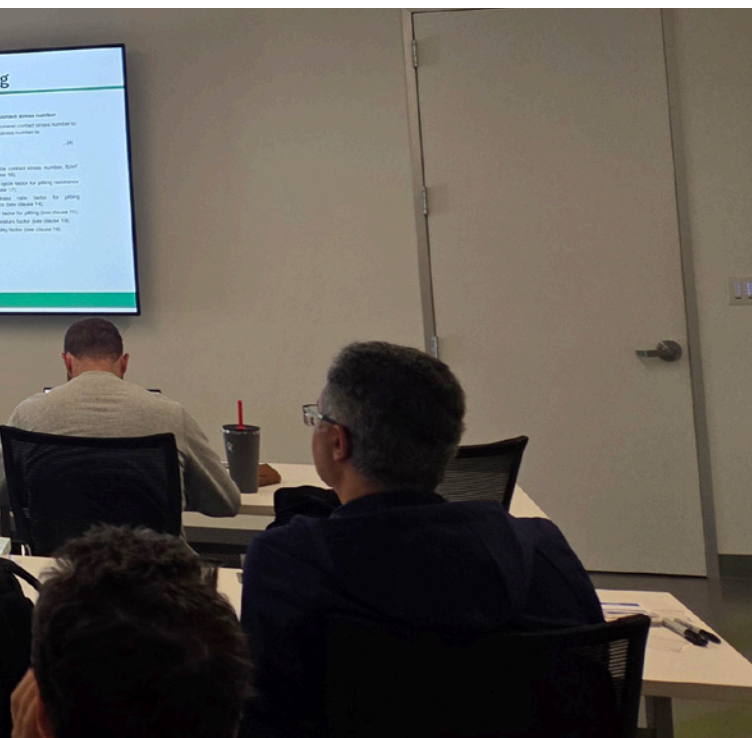
For more information about MPMA’s education programs, including on-site training options, visit motionpower.org or reach out to education@motionpower.org.



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Cobots That Deburr Their Own Gears

One collaborative robot manufacturer put its own product to work on an in-house production bottleneck and cut scrap from 10 percent to under one percent

Aaron Fagan, Senior Editor

An OB7 cobot picks from a loaded tray of spur gears at Productive Robotics' Santa Barbara factory. Each tray holds 30 to 50 parts, depending on size; the robot's grid function interpolates every pickup position from four taught corner points. (All images: Productive Robotics)

Every machine shop has a job nobody wants. The shop I worked in, you felt like you were being sent to “time out” if you had to go to the deburring station. At Productive Robotics’ Santa Barbara factory, where the company designs and builds its OB7 line of 7-axis collaborative robots, the robots they make do their own gear deburring.

Each OB7 ships with roughly 49 gears across its seven joints. They’re basic spur gears, but precise ones—AGMA Class 12 on average, with motor pinions reaching Class 14.

The material is nitroloy at about 28 Rockwell, which production manager Troy Kirby says behaves like hard stainless under an abrasive wheel. For years, finishing those gears meant operators standing at the bench, pressing parts by hand.

“I’ve spent thousands of hours behind the deburring wheel, unfortunately,” Kirby said during a recent *Gear Technology* webinar. “People just don’t like to deburr.”

Kirby’s gear career goes back to 1984, managing a Santa Barbara machine

shop that built hydraulic undersea manipulators and rack-and-pinion actuators for the U.S. Navy. He earned the Navy’s Reliability, Maintainability, and Quality Assurance Award in 1991 on a NASA project, then ran his own machining and gear manufacturing company until selling it in 2016. He joined Productive Robotics the next year to modernize their internal gear production. Once that was done, he turned to the problem everyone could see: thousands of parts piling up on the deburring bench.



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Where the Line Backed Up

Gear cutting wasn't the issue. The company's shapers and hobbers kept pace with demand. The trouble started after—as OB7 sales grew, so did the backlog of parts waiting for manual finishing.

Manual deburring also carried a brutal scrap rate. Parts flew out of operators' hands, slipped from the tooling, and hit the concrete floor. For precision gears going into robot joints, any floor contact meant scrap. Kirby estimated losses around 10 percent, not from poor

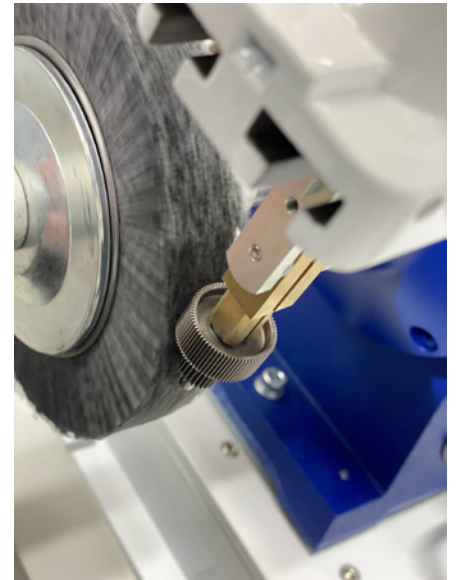
technique but from the basic difficulty of holding small parts against a spinning wheel.

"It would fly out of your hand, fly out of the tooling, onto the ground, on the concrete, under the table," Kirby said. "With our parts, they're just scrap as soon as they touch the floor."

Four Years of Development

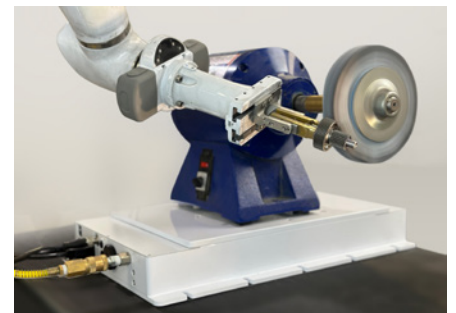
Having the robot hardware was a starting point, not a solution. Getting to a reliable automated deburring process

took about four years of tweaking gripper tooling, part fixturing, media selection, wheel placement, and table layout. The nitroloy at 28 Rockwell called for a specific abrasive: a 320-grit Scotch-Brite embedded nylon wheel, available from several manufacturers. Kirby's team now specs that media for customers running similar jobs.



A cluster gear contacts the 320-grit Scotch-Brite embedded nylon wheel.

The key development was a pneumatically controlled deburring platform. Early attempts ran parts directly against a stationary wheel, but as the abrasive wore down, contact pressure dropped, and results drifted. The platform fixes that with adjustable air pressure and an offset dial—the part meets the wheel with a uniform force regardless of wear.



The pneumatically controlled deburring platform sits beneath the blue motor housing.

"We developed our deburring platform," said Kevin Meister, the company's application specialist. "It uses air pressure to make sure that the part's

constantly hitting with the same amount of force.” Meister has helped over 100 companies automate processes ranging from welding to finishing.



A pinion shaft held by custom gripper fingers approaches the finishing wheel.

Two wheels sit on either side of the work area. The robot presents one side of the gear’s flanks to the first wheel, moves to the second for the opposite side, and works through the ODs, tooth flanks, tooth ends, gear faces, and bearing journals in one cycle. On the 0.3-module and 0.4-module, 20-degree spur gears demonstrated in the webinar, the process holds an edge radius of about 0.002 to 0.003 inches across tooth tips and flank edges.



A cluster gear at the second Scotch-Brite wheel.

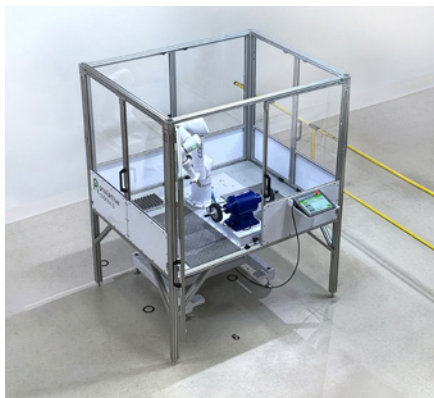
Open Cell and Enclosed Cell

Productive Robotics offers the system in two configurations. The open-cell version puts the robot, deburring platform, and part trays on Productive Robotics’ extra-large machine table. Operators load their existing shop trays—the system was designed around standard fixturing rather than custom holders—and the robot works through the tray while the operator does something else. Kirby said operators typically check back every half hour or so, inspect the last finished part, and adjust the offset if the wheel has worn slightly before reloading.



Inside the enclosed cell, the OB7 holds a part between dual deburring wheels. The offset and pressure adjustment dials are visible on the platform base.

The enclosed cell adds four-sided walls with access doors. Besides containing dust, the enclosure lets the robot run above the 10-inch-per-second collaborative speed limit without needing an external LiDAR scanner for human detection. Productive Robotics runs this version for both pre-heat-treatment deburring and post-heat-treatment finish polishing.



Overhead view of the enclosed deburring cell on the Productive Robotics shop floor. The aluminum-frame enclosure allows the robot to run above collaborative speed limits.

What Changed

Kirby called the throughput improvement a conservative 2x, though he said the real number might be closer to 3x. He attributed most of that gain not to faster cycle times but to the machine staying loaded and running continuously.

Scrap dropped from roughly 10 percent to under one percent. What remains

is almost entirely grip failures, a part not quite seated in the jaw, rather than process errors. And the operators who used to stand at the deburring bench now run other equipment, so the productivity gain extends beyond the single station.

Kirby said his operators treat the output the way they would any CNC process—inspecting a part at the end of a tray run, tweaking the offset if needed, and keeping the machine loaded.

Working the Angles

A good portion of the webinar Q&A focused on parts beyond Productive Robotics’ own spur gears. Meister pointed to the OB7’s seventh axis as the mechanical difference that matters for deburring—the extra joint lets the robot present parts to the wheel at compound angles that a 6-axis arm can’t easily reach.



A cluster gear mid-cycle, seen from below. The OB7’s seventh axis allows compound approach angles that a 6-axis arm can’t reach.

“I can reach around obstacles, or reach around the side of the wheel to present the part in a way that you might not be able to do with another robot,” Meister said.

Kirby said helical gear deburring would look nearly identical to their spur gear process, with the robot following the lead angle. He also mentioned a customer application deburring approximately 32-pitch internal ring gears for aerospace, using a smaller wheel adapted to the motor. That setup was in production within a day.

Meister estimated that a first pass at automating a new part typically gets 50 percent to 80 percent of the deburring done. Further iteration brought many of Productive Robotics’ own parts to the point where no hand finishing was needed. For part families with the same geometry at different sizes, Meister said a taught job can serve as a starting point, with adjustments for each size variant rather than a full re-teach.

Teach by Doing

The OB7 doesn't use traditional programming. An operator guides the arm through waypoints by hand, using buttons on a handle mounted to the robot. During a live demo, Meister taught a pick-and-place cycle in under two minutes, including recovering from a collision by adjusting one waypoint.

For tray work, a grid function handles part locations. The operator teaches four corner pickups and enters the row and column count; the robot interpolates the rest.

But none of this removes the need for process knowledge. The person teaching the deburring job still needs to know the angles, the dwell times, and the pressure. Since the robot repeats exactly what it's shown, a sloppy teaching pass means sloppy parts. Dialing in a new part takes some trial and error.

"It's some experimentation, and it's kind of fun," Kirby said. "My guys really enjoy running the robot to do that."

Loading Machines Too

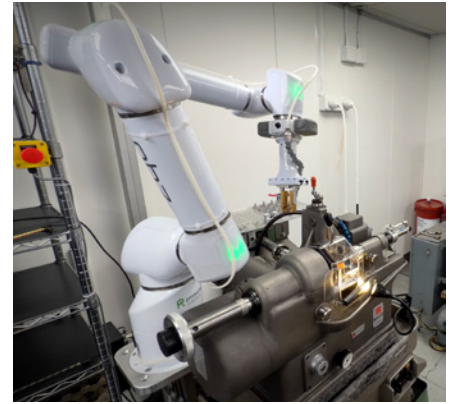
The deburring application wasn't the end of it. During the webinar, Kirby showed

OB7 robots loading and unloading the company's Mikron 132.02 and A33/0 hobbing machines—retrofits done entirely in-house, no integrator involved. The robot picks from standard trays, re-grips for machine-loading orientation, loads the workpiece, closes the door, starts the cycle through an I/O connection, then unloads and blows off the part before placing it back in the tray.



An OB7 Stretch alongside the Mikron A33/0 hobbing machine.

Kirby said they've run thousands of parts this way, cycling four different part numbers of similar configuration through the A33 on one setup.



The OB7 at the Mikron 132.02.

The whole package—deburring platform, compliance system, dual-wheel layout, tray-based fixturing, media specs—came out of four years of running real production volumes on real gears. Whether shops with different parts, materials, and tolerances see similar results is an open question, but Productive Robotics is at least running the proof of concept on its own floor every day.

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Single-Flank Testing for Modern Gear Production

Detecting gear manufacturing deviations through advanced single-flank testing

Jon Shaw, Managing Director, Gleason Metrology Systems Limited
Scott Fenley, Director of Technology, Gleason Metrology Systems Michigan



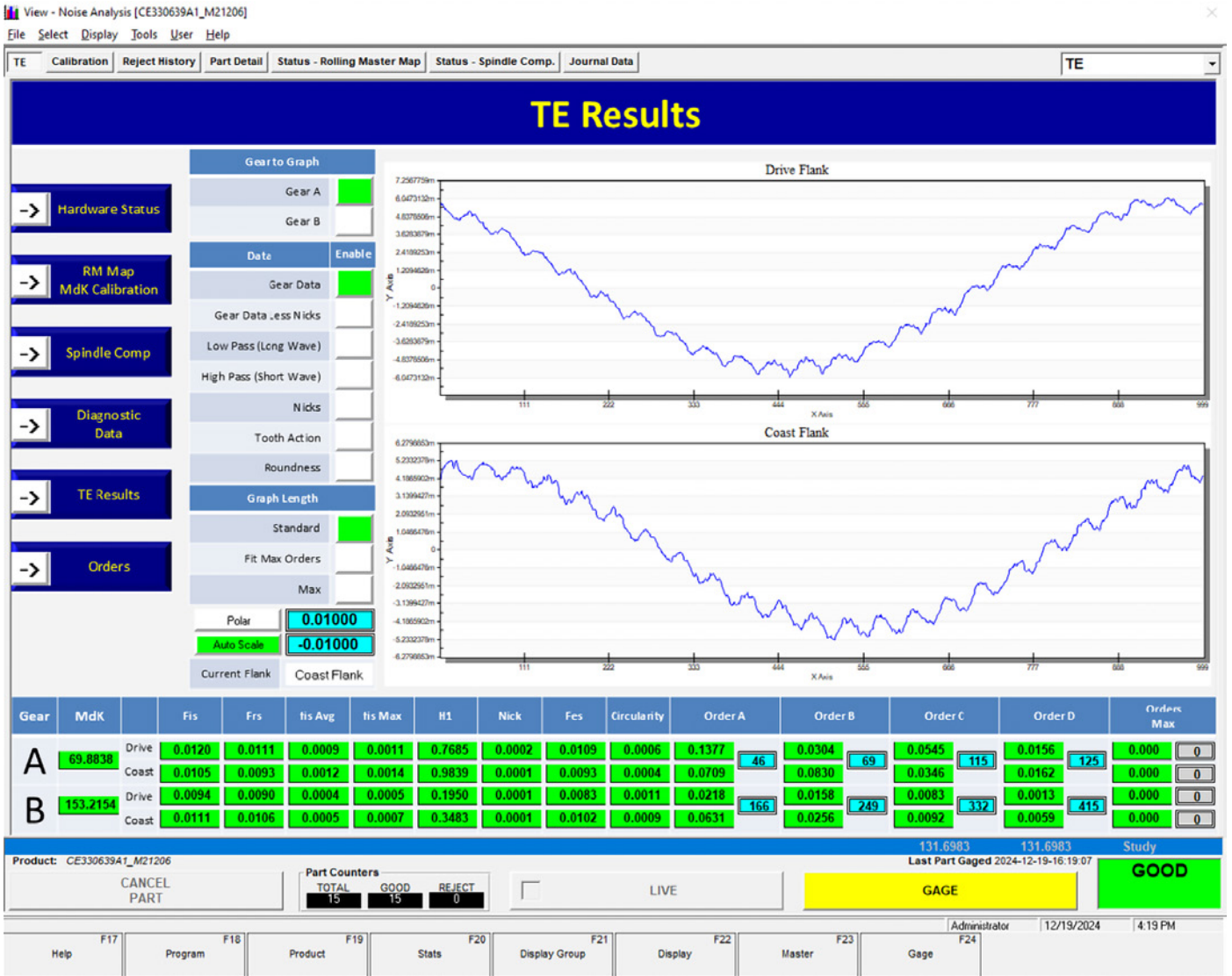
Gleason's Intra SFTX Single-Flank Testing System with Twin Spindle for single or compound external gears. (All images: Gleason Corporation)

Gear inspection and noise analysis are essential for ensuring quality and efficiency in modern gear manufacturing. Increasingly stringent requirements on dimensional tolerances—often in the micron range—and noise, vibration, and harshness (NVH) performance necessitate advanced measurement and evaluation methods.

Recent developments in gear metrology include the integration of single-flank testing (SFT) technologies into broader measurement portfolios. Over the past two decades, multiple SFT system variants have been developed, with

ongoing advancements focusing on expanded functionality, improved measurement resolution, and higher throughput in production environments.

SFT is widely used for both in-process and end-of-line inspection in high-volume gear manufacturing. The production environment presents challenges such as tight tolerances, process variability, and increasing NVH constraints. SFT methods address these by enabling continuous quality monitoring and providing real-time feedback on transmission behavior, supporting process control and optimization.



High-precision static and dynamic transmission error (TE) analysis.

SFT Technology

SFT systems have two independent onboard systems operating in concert with each other. transmission error (TE) measurement and torsional acceleration (TA) analysis.

The concept of TE measurement is to capture, with rotary encoders, the rotational geometrical deviations between two gears relative to an ideal rotation. The TA measures the change in rotational speed over time (dynamics), often used to analyze gear meshing impacts and their noise behavior. TE represents the cause (real geometrical deviations), while TA shows the effect of such a TE at higher speeds and loads.

This TE technique is better suited to measure and detect lower-order errors such as: single-flank total composite action, single-flank tooth-tooth action, single-flank runout, single-flank circularity, and single-flank concentricity.

TA is to use a method of rotational synchronous time signals, with data collected from torsional accelerometers, to focus on NVH-related issues in the measured component. These errors can be time domain-based errors like nicks or

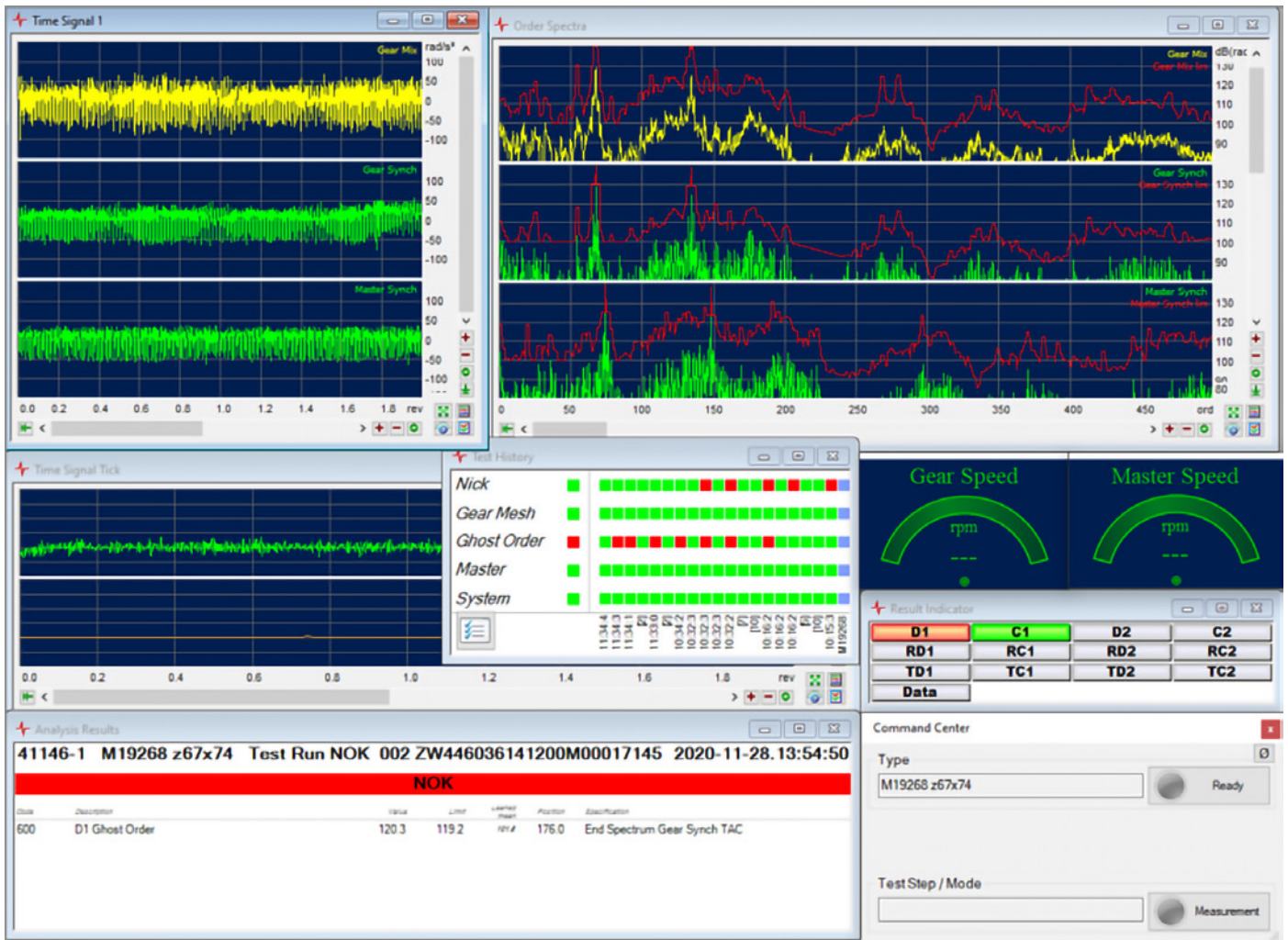
gear modulation due to runout and circularity, and they can be order domain-based errors like gear mesh energies, side bands, and ghost orders. These order domain errors can occur on a sub-micron level.

How Single-Flank Technology Works



The Intra SFT Series by Gleason is designed to measure a wide range of drivetrain components.

Unlike double-flank inspection, where a component and master gear are engaged in tight mesh, single-flank testing



Torsional acceleration (TA) testing.

uses a fixed operating center distance to ensure an appropriate amount of backlash is achieved in the system. This allows the tailored-designed master gear to roll with the component and provide results in the tangential plane, i.e., profile/involute errors, pitch errors, and total index errors. Under light load conditions, the onboard measurement systems will collect vibrational and angular irregularities during rotation, process, and display the result. Depending on the outcome of the part, a list of failure modes will provide important information for an engineer to review in the event that a machine correction is to be made. An additional benefit to single-flank inspection is the ability to measure the true accumulated pitch index, F_p , of the gear and understand how it may impact future sound quality.

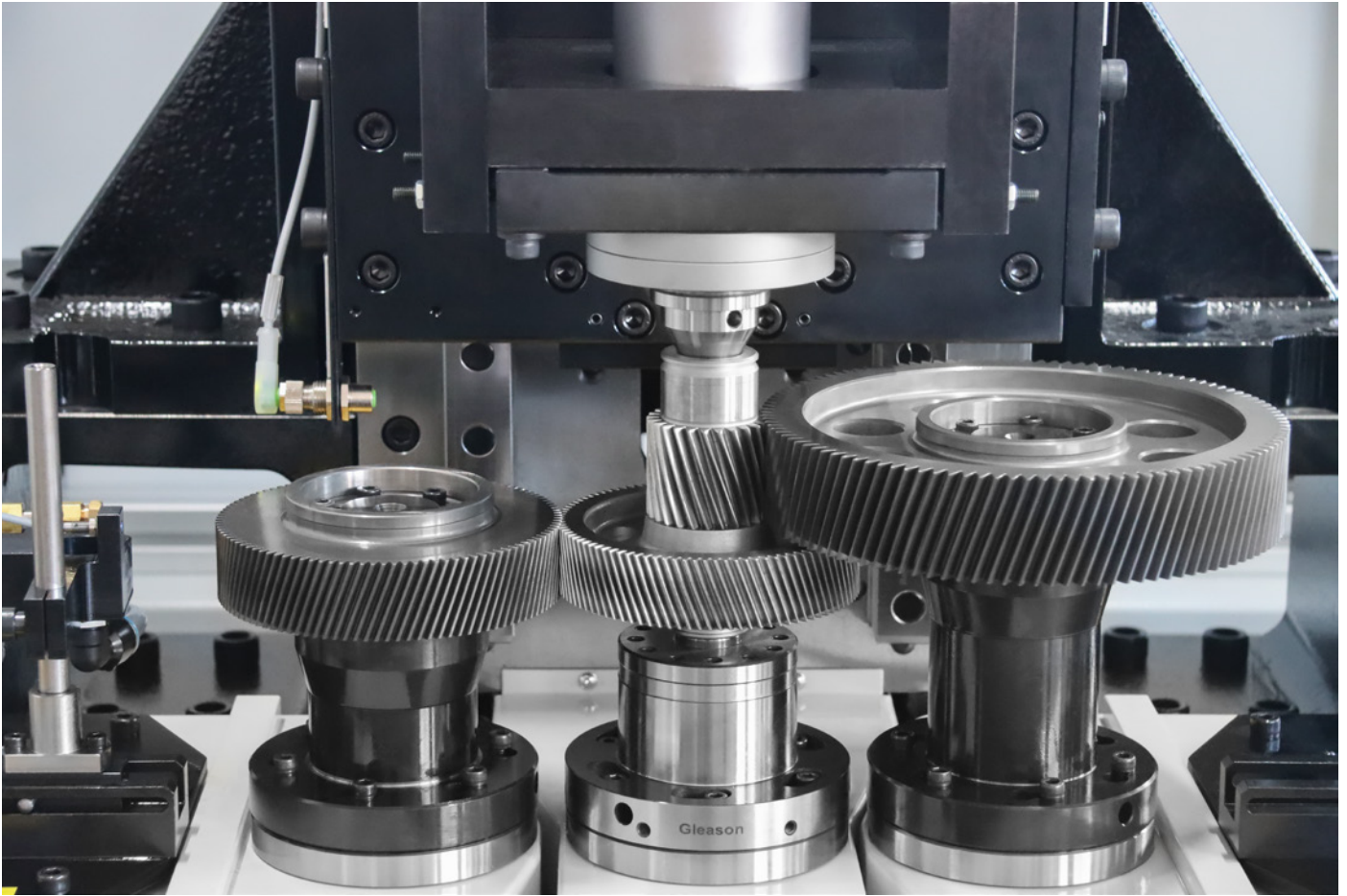
The systems are equipped with high-precision instrumentation to ensure measurement accuracy and repeatability. Each machine incorporates precision spindles and application-specific master gears to support a range of gear configurations, including those used in electric vehicle drivetrains. Measurement of TE and TA is performed within a short cycle time, typically ≤ 35 seconds, enabling efficient evaluation of both quasi-static and dynamic gear behavior in production environments.

Challenges of Gear Alignment

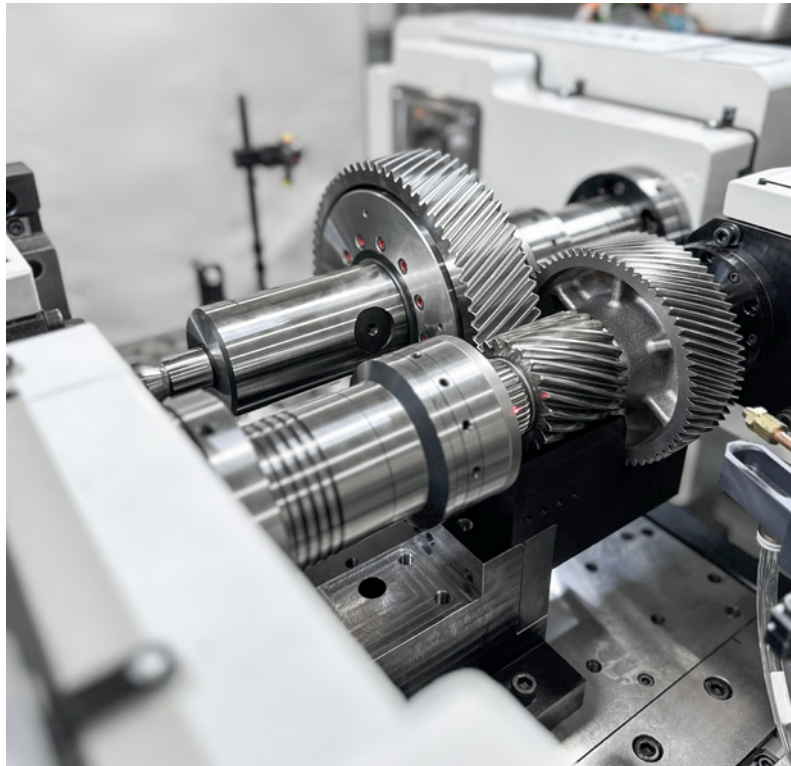
SFT systems provide insightful data to the transmission designers as well as the final test and vehicle assembly departments, but the challenges of gear alignment remain largely unsolved. The SFTA system specializes in measuring match-set parallel-axis gear pairs without the use of a master gear. The SFTA system is integrated with an 8-Axis CNC-controlled pitch and angle function that can automatically adjust testing parameters with up to four degrees of offset face width. The machine is designed with a zero-point center distance function that allows for compatibility with almost all traditional, hybrid, and EV gearbox configurations.

SFT for Quiet Vehicle Cabins

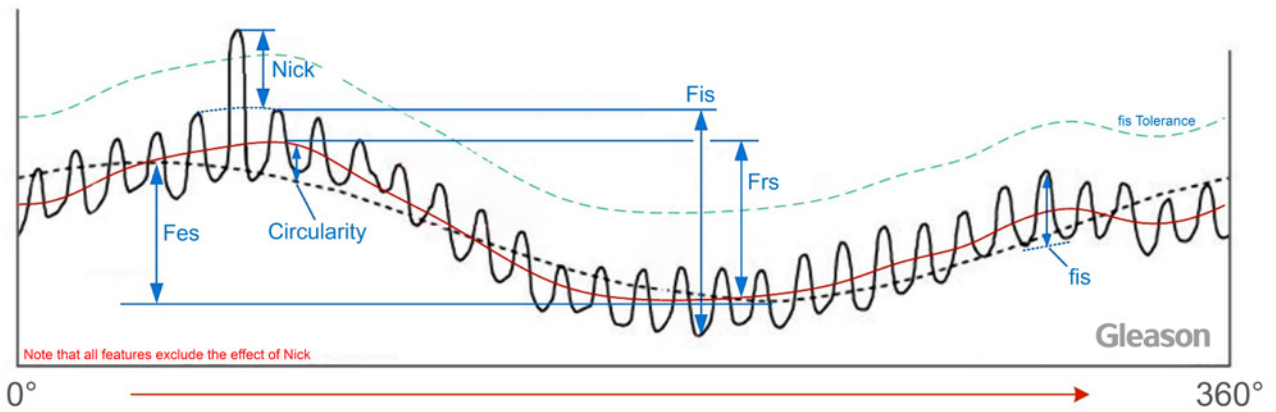
Today's vehicles require high torque gears and ultra-quiet interior cabins. Vehicle OEM's are routinely optimizing gear microgeometry to ensure both performance and gear noise reduction. In our expert experience, we see that even with the most optimized designs, noise can find its way into the gear systems through the manufacturing processes. SFT provides a means to detect and quantify these deviations under conditions representative of functional operation. By correlating transmission error and torsional response with NVH-relevant charac-



Gleason's Intra SFTX with integrated axial alignment option delivers precise and repeatable measurement results for complex coaxial gearboxes with compound gears.



Using Gleason's Intra SFTA for detection of axial alignment challenges and direct component-to-component NVH testing.



Real-time process control in early transmission design phases, providing a base for microgeometry development.

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All Gleason Intra SFT Single Flank Testing Systems can be fully automated and seamlessly integrated into any manufacturing environment.

teristics, SFT enables identification of manufacturing-induced noise sources. Integration of SFT data into statistical process control (SPC) systems supports continuous monitoring and helps maintain consistent quality levels throughout production.

Conclusion

SFT provides a functional approach to gear evaluation by linking geometrical deviations with dynamic system response under operating conditions. Through the combined analysis of transmission error and torsional acceleration, SFT enables identification of both quasi-static deviations and NVH-relevant excitation mechanisms, supporting a more comprehensive understanding of gear performance.

In high-volume production environments, this capability allows earlier detection of manufacturing-induced deviations and facilitates closed-loop process control when integrated with statistical quality systems. As requirements for noise

performance and efficiency continue to increase—particularly in electrified drivetrains—the importance of such functional measurement methods is expected to grow.

As an established supplier of gear manufacturing and metrology systems, Gleason contributes to the development and industrial implementation of SFT technology, true to its “Design-Manufacture-Measure” philosophy. By integrating SFT within a broader portfolio that includes design tools, manufacturing equipment, and inspection systems, a consistent link can be established between design intent, production processes, and measured performance. This system-level approach supports improved correlation between geometry, function, and NVH behavior across the entire gear development and production chain.

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The Edge of Efficiency

Atlanta Gear Works receives grinding wheel assist from Weiler Abrasives

Matthew Jaster, Director, Editorial Content

Atlanta Gear Works saw a 30 percent efficiency boost and 50 percent fewer interruptions (eliminated wheel adjustments) with Weiler's grinding wheel. (Images: Weiler Abrasives)

Machines in paper/pulp applications are among the longest and most complex continuous manufacturing machines in the world—some stretch more than 300 yards. Maintaining precise speed ratios across dozens of shop machines is critical for operational success—even the slightest speed mismatch can cause the paper web to break, wrinkle, or stretch unevenly. Gearboxes (combined with variable speed drives) make this coordination possible.

This has become a specialty market for engineers at Atlanta Gear Works (AGW), a critical rotating equipment design, engineer, manufacture, and repair company headquartered in Dawsonville, Georgia, less than an hour north of Atlanta. The engineers tasked with rebuilding and repurposing printing equipment after failure are on a huge time crunch the second a gearbox goes down.

“Paper mills are one of Atlanta Gear Works most important types of customers,” said Dennis Brown, strategic sales leader, Weiler Abrasives Group. “When paper mills go down due to a gearbox failure, AGW will come up with a maintenance/service plan 24/7. This can only be accomplished if they have the

necessary tooling in shop, ready to go. It's important to have everything they need in the shop the minute a service call comes through.”

With downtime costing thousands per minute, AGW's engineers work around-the-clock to rebuild critical gearboxes and restore operations. Response time, however, depends on having the right, customized grinding wheel available immediately.

In the past, some suppliers have offered grinding wheels with inconsistent performance during emergency maintenance and unrealistic lead times for custom orders. As a result, Atlanta Gear Works turned to Weiler Abrasives to get the grinding wheels they sorely needed within a reasonable timeframe.

Meeting and Exceeding Expectations

The longer the paper mill is down, the more costly the maintenance work required. AGW prides itself as an organization that not only reviews the overall root cause of gearbox failure, but also the condition of all internal components. All

these factors must pass quality control measures before assembly.

In the past, grinding wheel delivery for AGW took 16 weeks to process. Weiler Abrasives delivered their wheels in weeks instead of months, customized and matching the exact specifications for AGW's gearbox needs. On-site analysis and collaboration led to a custom-designed grinding program fit specifically to the exact applications.

After the change in grinding wheels, Atlanta Gear Works saw a 30 percent efficiency boost (8 hours saved per part) and 50 percent fewer interruptions (eliminated wheel adjustments). Brown credits similar engineering philosophies between Weiler and Atlanta Gear Works as critical to the collaboration.

Potential swarf build up was a concern with the new tooling. Weiler worked with AGW's engineering team to ensure the swarf would not clog the drains or flood the floor. The size of the chips coming off the machine were no different from previous setups with the new grinding wheel.

Another challenge was making sure grinding burn (discoloration, cracking, or



Feedback from the AGW engineering team provided the information Weiler Abrasives needed to provide a new grinding wheel for the application.

tempering caused by excessive heat) was prevented. The Weiler team formulated a wheel that reduced the risk for burning while maximizing form holding.

“This is where the experience of the machine tool operators really comes into play and they can provide instant feedback on our tooling recommendations,” Brown added.

Bond Technology Advantages

Cutting grains used in bonded abrasive gear grinding wheels include aluminum oxide, silicon carbide, zirconia alumina and ceramic alumina. Typically, grains are based on the materials being cut, the buildup of heat and the costs. Some

grains are much more aggressive and provide faster cutting combined with just the right bonding technology.

“The reason our technology works so effectively is because we were able to have as little bond on the wheels as possible and the most grain to cut and remove material,” Brown added. “If you have the right bond system, you’ll have a positive impact on the wheel’s lifespan as well as its cutting rate.”

Harder bonds typically have a longer lifespan and are better for softer materials, while softer bonds have a shorter lifespan but shed grains more quickly, providing a faster cut.

Weiler Abrasives’ V59 bond technology, for example, ensures exceptional results and addresses customers’ unique needs with flexibility and precision. The advanced formulation of V59 bond technology provides superior grain retention, improving wheel life and grinding efficiency. Dynamic porosity lowers grinding temperatures through increased coolant efficiency and greatly reduces part surface damage from heat distortion while aiding in material removal rates — allowing for a reduction in grinding cycle times. The extended wheel life delivered with V59 bond technology also improves profile retention and reduces dressing frequency.

The right grain combination generally results in a better surface finish.

Shortening Lead Times and Optimizing Performance

In 2024, Weiler Abrasives launched an express program cutting lead times for gear

grinding wheels from months down to days. The program was designed to help gear manufacturers in industries such as automotive, energy and aerospace improve quality, increase consistency and deliver on time to their customers. The priority was on-time delivery, an area where many vendors had struggled to keep up with demand.

With a sizable stock inventory of over 120-wheel blank sizes and specifications at Weiler Abrasives’ North American headquarters in Pennsylvania, custom wheels can be produced within weeks. Available sizes range from as small as 6 inches up to 24 inches in diameter and from 1/2 inch to 9 and 1/2 inches thick.

The state-of-the-art wheel profiling cell allows for wheel speed testing to ANSI B7.1 safety standards, which is 1.5 times the maximum operating speed labeled on the wheels, ensuring the ultimate safety of the product for the consumer. Elevating industry standards, Weiler’s premium manufacturing quality of precision grinding wheels feature tighter dimensional and imbalance tolerances, resulting in less vibration and very little dressing required when they are mounted on a customer’s machine.

“The flexibility of our wheels is perfect for a customer like AGW where they may work on a damaged gearbox, a complete rebuild and a regrind all in the same week. High-demand situations in paper mills require custom designs and we were able to provide a much more consistent delivery schedule.”

Brown believes the collaboration between both companies will grow in the coming years.

“Performance was a huge factor in this partnership,” Brown said. “The goal was to reduce cycle times and lower the onsite tooling inventory to free up valuable space. Cycle time went from 24 hours to 18 and we increased grinding wheel life in the process. This was a win-win for both organizations. We met the needs of our valued partner and learned some unique benefits of our own tooling technology in the process.”

weilerabrasives.com

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The advanced formulation of V59 bond technology provides superior grain retention, improving wheel life and grinding efficiency.

A Quarterly Check-In on the MPMA Emerging Technology Committees

Mary Ellen Doran, VP, Emerging Technology, MPMA



2025 MPMA SRN participants visit Clemson University International Center for Automotive Research. (Image: MPMA)

MPMA has five emerging technology committees, each focused on a sector reshaping the gear and bearing industry. Across robotics, air mobility, electric vehicles, industrial connectivity, and additive manufacturing, the committees are studying technologies before they fully arrive, building expert networks, and translating what is happening at the frontier into intelligence that members can use. Here is where each stands as we head into the second quarter of 2026.

Air Mobility/eVTOL Committee: New in 2026, this committee has already held two meetings and is growing with each one. We may be able to announce a chairperson soon. The committee is examining which drivetrain types are used across eVTOL platforms and how gears and bearings are incorporated. With these aircraft moving rapidly from concept to flight testing and early certification, the central questions are straightforward: where do gear and bearing manufacturers fit into this supply chain, and how can MPMA facilitate collaboration? We hope to bring speakers from this space to the webinar audience later this year.

Electric Vehicle Technology Committee: The EV committee started the year strong. The standards development arm of MPMA announced that its electric vehicle information sheet will be available later this year—a significant achievement after only two years of work. We look forward to discussing the implications when the document is released.

At our first meeting of the year, we discussed the current landscape. Events in the Middle East have again drawn attention to the fuels that power vehicles globally, prompting a thoughtful conversation about whether countries will pursue alternative fuels or energy sources for mobility. We are exploring bringing in a speaker from the petrochemical sector. Members are also interested in copper and mining as EV production grows and the U.S. pivots toward hybrids. More to come.

3D Printing Committee: The 3D printing committee continues to track where additive manufacturing is crossing from

prototype capability to production readiness and where real barriers remain. Specific programming for the coming months is being finalized. What stays constant is the committee's core premise: precision manufacturers who already operate under tight tolerances and demanding qualification processes are well positioned to engage with additive technology—not as a replacement for traditional manufacturing, but as an expansion of what is possible.

AI/IIoT Committee: This committee remains focused on cybersecurity. The May emerging technology webinar will feature Derrick Phillips, a CMMC expert, addressing the 2026 updates to the Cybersecurity Maturity Model Certification framework and the use of artificial intelligence within a CMMC-compliant environment. The committee also supported the March webinar featuring Pankaj Prasad, founder and CEO of Airwave, who presented “Demystifying AI and Real-World Applications for Field Technicians.” This webinar is available on demand on the MPMA website.

Robotics Committee: The Robotics Committee helped secure strong speakers for the MPMA Strategic Networking and Leadership Forum, June 2–4 in Indianapolis. OnRobot, a global leader in end-of-arm tooling and collaborative application solutions, will present. Steven Sikorski will deliver the second part of that session. Steven runs his own consulting firm, helping manufacturers take full advantage of automation and robotics. He previously served as a factory manager at Standard Bots and understands what it takes to move a robot from prototype to mass production. The committee is tailoring the presentation for a gear and bearing audience. Check out the full SNL program—I hear there may be a special guest.

A lot is happening across all five committees; you should get involved. Join a committee, attend a live event, or watch a webinar on demand. To participate, contact Mary Ellen Doran, VP of Emerging Technology, at doran@motionpower.org.

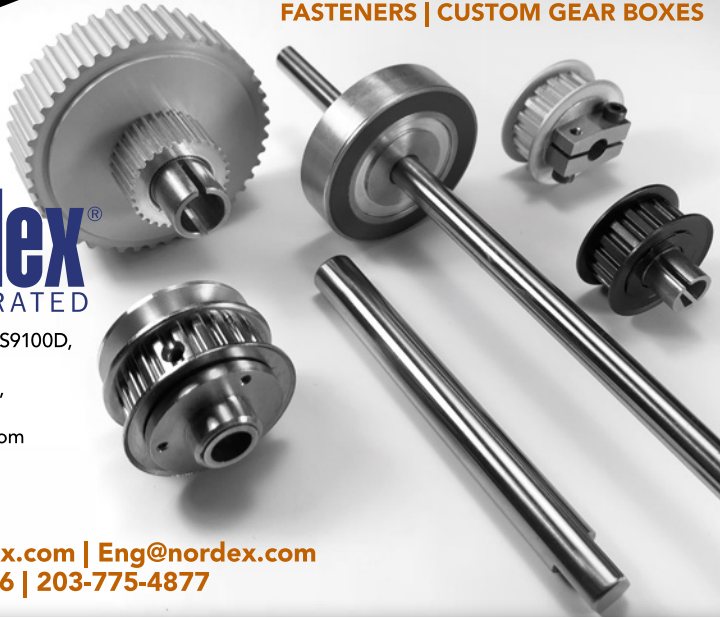


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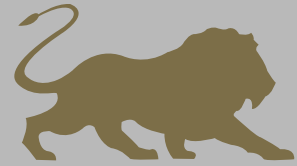


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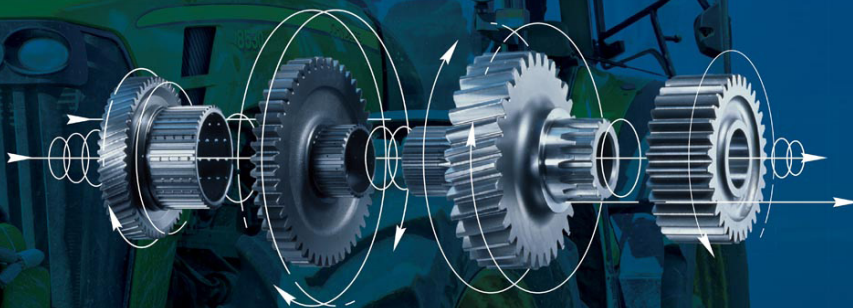
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When Is It Time to Start a New Standards Project?

Philip Olson, Director, MPMA Technical Services

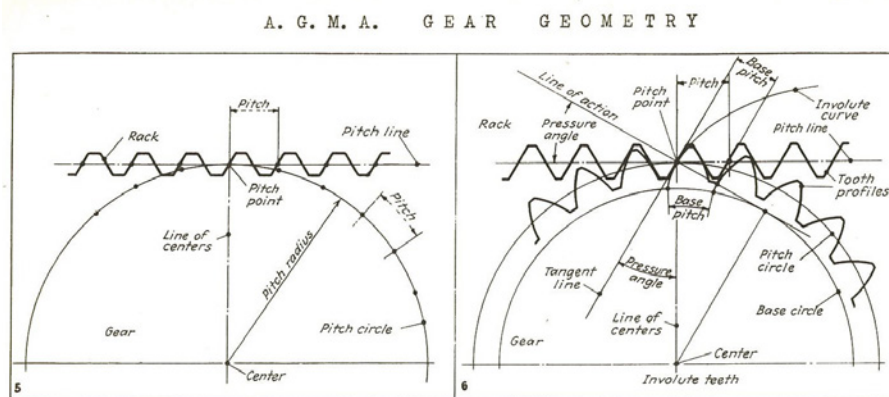
Deciding to launch a new standards project is not a decision taken lightly here at the Motion Power Manufacturers Alliance (MPMA). If things go according to plan, a new project can take four years to reach publication over roughly 24 two-hour-long working group meetings. This is a significant commitment of time from both volunteers and staff. Additional time outside of meetings is often needed for reviewing drafts, responding to comments, and preparing materials, so careful thought goes into every new initiative before work begins.

Standards vs. Information Sheets

AGMA and ABMA publications fall into two categories. Standards provide requirements, specifications, definitions, and terminology that help ensure materials, products, and processes are fit for their purpose. Information Sheets cover topics that are still being tested or have not yet reached full industry consensus—including recommendations that are not yet ready to carry the weight of a formal standard. Because of this, most completely new projects begin life as an Information Sheet, allowing the industry to explore a subject before committing to standardized requirements.

What Triggers a New Project?

A new project may be warranted for several reasons. Sometimes, a common practice already exists in the field, and the standard or information sheet is simply about writing it down so that everyone is working from the same playbook. Other times, competing definitions or methods create confusion, and establishing an agreed-upon standard helps align the industry. In the case of information sheets, there can be significant value in capturing the institutional knowledge and practical recommendations



Figs. 5 and 6—Some basic gear elements

A figure from “Gear Geometry—Terms and Definitions” adopted by the AGMA as a recommended practice in April 1936. (Image: MPMA)

that longtime members have developed through years of experience in the field. Projects also arise when new technology or emerging consensus makes a revision to an existing standard necessary. In all cases, a standard establishes a baseline that companies can build upon—and go above and beyond—as they see fit.

How the Process Begins

New projects originate within MPMA’s committee structure. Committees are asked to think at a high level before recommending a project, considering questions such as: Has this subject already been addressed in an existing publication, and if so, why is a new document needed? Are there enough qualified volunteers to carry the work forward? Who is the target audience of the published document? And at a high level, what’s the scope of the project? To help answer these questions, MPMA has sometimes discussed potential projects across multiple meetings or surveyed the membership to gauge interest and help define scope.

A critical factor in evaluating any new project is ensuring a diverse mix of perspectives from manufacturers, users, and general interest, to make sure no single

group drives the outcome. This balance of viewpoints leads to broader buy-in when the final document is published.

From Committee Approval to Working Group

Once a committee recommends a project, it requires approval from the Technical Division Executive Committee (TDEC) before a working group is formally established. The working group then digs into the details: designating a project leader, finalizing the title and scope, identifying any existing documents that may reference or be affected by the new document or revision, confirming the roster of participants—including subject matter experts who may not already be on the committee—and setting a realistic timeline. A final TDEC approval closes the loop before active development begins.

The standards that shape our industry are only as strong as the people who write them. Bring your expertise to the table and help build the documents that will guide the industry for years to come. Contact us to find out how to get involved: tech@motionpower.org



Design Principles of Bevel Gears: Rationale for Zero Sum Profile Shifts and Generating Gear Choices

Dr.-Ing. Igor Zarębski

Bevel gears are typically designed with a zero sum of profile shifts, meaning that the amount of pinion profile shift is equal and opposed in sign to that of the wheel (Ref. 1). This design constraint stands in contrast to cylindrical gears, which often feature independently adjusted profile shifts to optimize performance parameters such as load capacity and center distance. Despite this apparent limitation, the practice of maintaining a zero sum of profile shifts in bevel gears is well-founded. In the following sections, this article will demonstrate why such an approach is both practical and beneficial for bevel gear design.

In bevel gear technology, the planar generating gear serves as the counterpart to the generating rack used in cylindrical gears. However, in practical applications, conical generating gears are often employed instead. This practice is also well-founded, and its rationale will be illustrated through a detailed example.

Bevel Gear Generation

Figure 1 shows an example of a bevel gearset with the number of teeth $z_1 = 9$ and $z_2 = 13$, a shaft angle $\Sigma = 90$ degrees, a tooth height coefficient $h = 0.8$, a pressure angle $\alpha = 22.5$ degrees, and

profile shift coefficients $x_1 = 0.2$ and $x_2 = -0.2$. The pitch cones, drawn in black, have angles $\delta_1 = 34.695$ degrees and $\delta_2 = 55.305$ degrees (Ref. 2) and roll on each other without sliding.

If profile shift coefficients of $x_1 = 0.7$ and $x_2 = 0.7$ are introduced, the shaft angle Σ must be increased to achieve proper meshing. However, since this angle is fixed, it must first be preliminarily reduced so that after increasing it by applying two positive profile shifts, it ultimately reaches the specified value of 90 degrees. As a result, the pitch cone angles decrease and will no longer be in contact. Using the proprietary bevel gear calculation software at Oktoida, the pitch cone angles for these gearings with double positive profile shifts were calculated to be $\delta_1 = 31.534$ degrees and $\delta_2 = 49.267$ degrees, and are illustrated in pink in Figure 1. Additionally, tooth thickness must be adjusted to enable proper meshing, since those defined on the decreased pitch cones no longer apply due to the lack of rolling contact between these cones.

Figure 2 illustrates the original pinion, with a profile shift coefficient of $x_1 = 0.2$, meshing with its planar generating gear (depicted in black). It also shows the pinion with a reduced pitch cone angle and a profile shift coefficient of $x_1 = 0.7$, along with its planar generating gear (depicted in pink). Note that in the latter case, the rolling radius r_1 has decreased while the generating gear radius r_0 remains

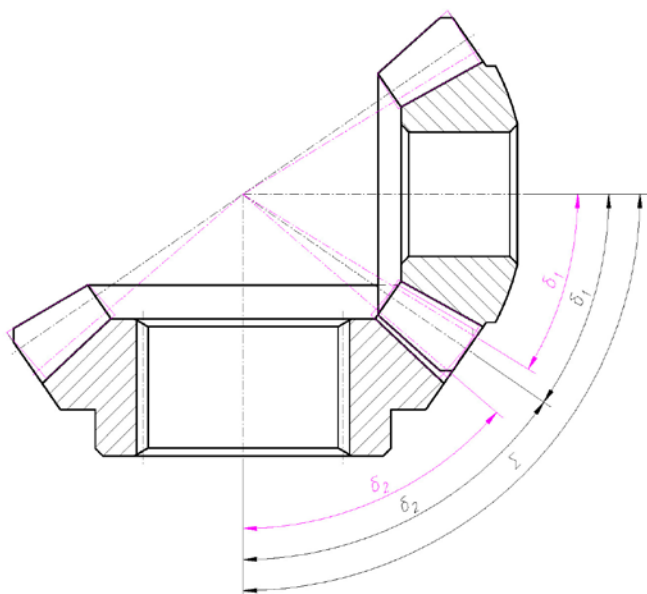


Figure 1—Bevel gearset—axial section.

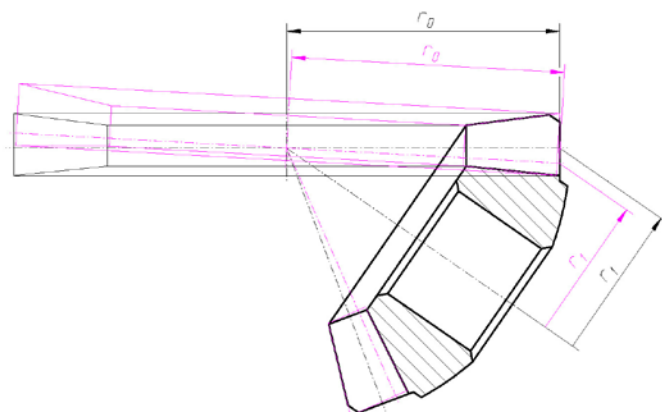


Figure 2—Pinion with a planar generating gear—axial section.

unchanged, resulting in a change in the generating ratio $i = r_1/r_0$. This effect is even clearer in Figure 5, where, in the shown kinematic setup of the generating process, only the value of this generating ratio has changed. Consequently, due to the change in the pitch cone angle, the generating motion is modified, causing changes in the generated profile angle (Ref. 1).

Using the same software, the octoid geometry of the original gear tooth flank was calculated in the form of a point cloud with corresponding normal vectors. This cloud extends from the heel (R_e) to the toe (R_i) and from the outer cone (δ_a) to the start of the generated profile at the root (δ_{gf}) and will serve as the baseline (zero geometry) for comparisons with geometries obtained through subsequent modifications. Next, in the same manner, the tooth flank geometry of the gear with a reduced pitch cone angle was determined. A comparison of these geometries is presented in Figure 3.

Subsequently, the function fitting the tooth flank geometry from the same software was used, yielding a pressure angle value of $\alpha = 31.910$ degrees. The original geometry with zero sum of profile shifts and a modified pressure angle corresponds to the geometry with a double positive profile shift, as shown in Figure 4. It should be noted that, in the original case, both during gear generation and its operation in the transmission, the rolling cone is identical to the pitch cone; therefore, in both instances, the term “pressure angle” can be applied.

Figure 2 shows a planar generating gear; however, in industrial practice, conical gears are often used, such as the one shown in Figure 5. Figure 6 illustrates the effect of using such a conical gear—a crowning on the tooth profile is created.

The use of a conical generating gear causes a slight deviation of the pressure angle, since it is measured relative to the pitch cone of the generating gear rather than its plane of rotation. Therefore, Figure 7 shows the tooth geometry with the appropriate roll ratio correction and adjusted tooth thickness applied.

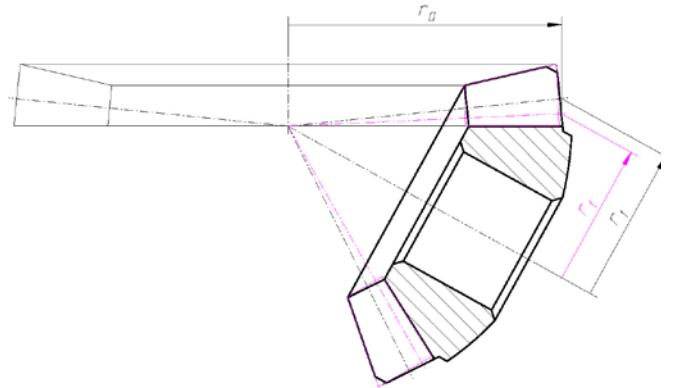


Figure 5—Pinion with a conical generating gear—axial section.

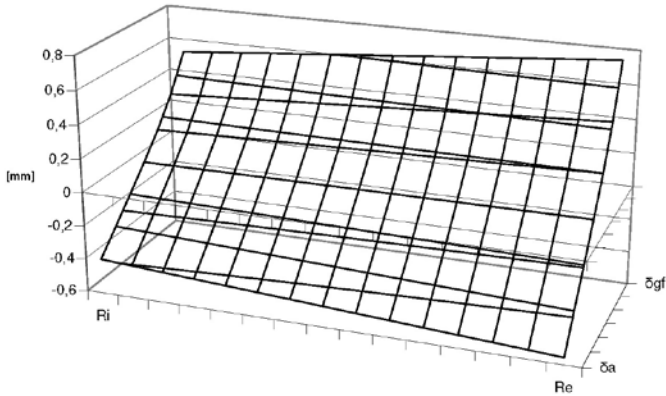


Figure 3—Tooth flank geometry—original vs. reduced pitch cone angle.

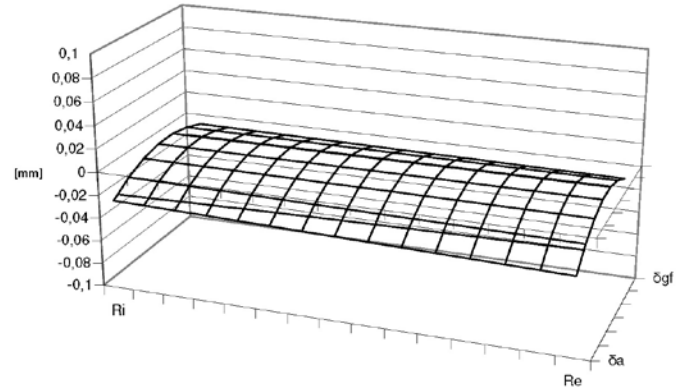


Figure 6—Tooth flank geometry—original vs. conical generating gear.

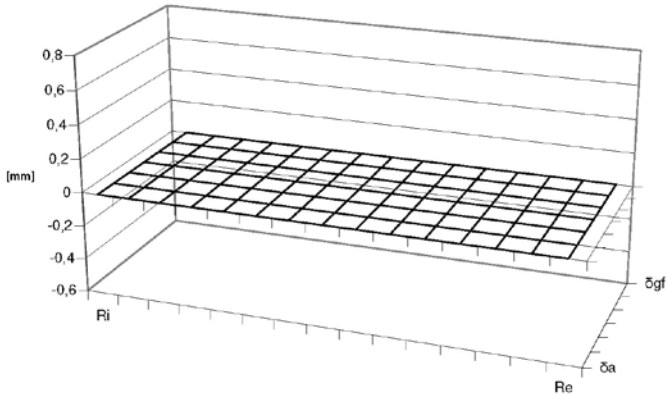


Figure 4—Tooth flank geometry—original with enlarged pressure angle vs. reduced pitch cone angle.

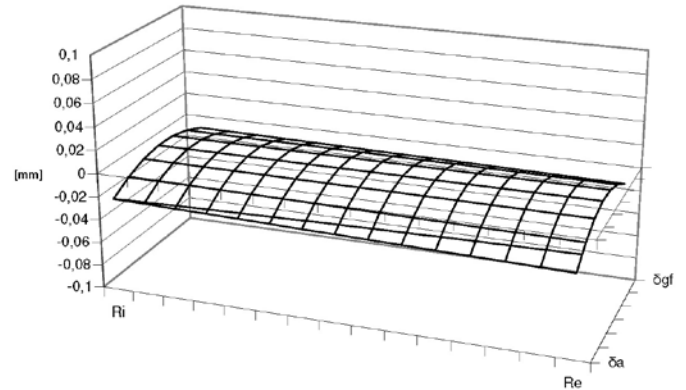


Figure 7—Tooth flank geometry—original vs. conical generating gear with corrected pressure angle.

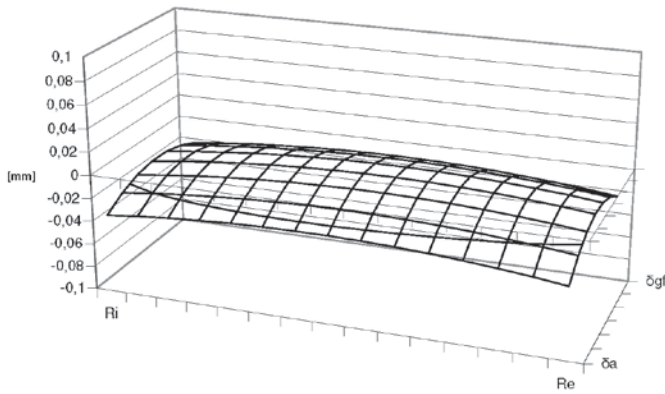


Figure 8—Tooth flank geometry—original vs. conical generating gear with corrected pressure angle and lead crowning.

In the final step of the flank topography development, lead crowning was applied, and the effect is shown in Figure 8. The resulting tooth geometry is of the ease-off type, which counteracts the concentration of stresses at a single location on the tooth surface, which may result from the displacement of mating gears from their nominal mounting dimensions due to housing deflection under load, as well as from elastic deformations of the gears themselves under operational forces.



Conclusion

The performed calculations for bevel gear transmissions confirm that the original geometry with zero sum of profile shifts and a modified pressure angle corresponds to the geometry with a double positive profile shift. This implies that the use of independent profile shifts, which entails providing additional parameters and complicating as well as increasing the amount of required calculations, is not warranted.

If tools with no fixed pitch are used for gear cutting (typical for bevel gears), nominal parameters can be used to describe the generating gear, so the standard set of parameters with a zero sum of profile shifts is correct and sufficient.

If tools with a fixed pitch are used (typical for cylindrical gears), the gearing description is performed using the generating rack parameters, and the use of independent profile shifts is warranted.

The use of a conical generating gear brings benefits in the form of tooth profile crowning. The resulting modification is well proven in industrial practice, is based on the gear's roll angle, and ensures backward compatibility with older designs. Therefore, its replacement with other types of modifications should be preceded by appropriate theoretical and industrial studies.



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non-circular gears, skew-axis and face gears, as well as gear tools—hobs, shaper cutters, and milling cutters.

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Conjugate Bevel and Hypoid Gears

Dr. Hermann J. Stadtfeld

The following chapter is from *Gear Technology Solutions (The Gleason Works, 2025)* by Dr. Hermann Stadtfeld. This is the second of four excerpts provided to Gear Technology readers to preview the book's insights into bevel gear theory, design, and manufacturing.

Why are Today's Hypoids Perfect Crossed-Axes Gear Pairs?

In 1924, Ernest Wildhaber, a well-known gear scientist, invented hypoid gearing. Compared to spiral bevel gears, hypoid gears provide an offset that allows lowering of the body of rear-wheel-drive vehicles by 50 mm or more. This is possible because the propeller shaft between the engine/transmission and the driving axle is not positioned at the center of the drive axle but is lowered by the offset amount (Figure 1). This allows the vehicle designer to lower the floor of the vehicle and subsequently the entire body by the same amount. Lowering the center of gravity of a passenger car by 50 mm reduces the inertia responsible for sideways rolling by more than 10 percent, which provides better vehicle handling and more active safety. The lower body also reduces the CV coefficient for air resistance, providing higher gas mileage. Less than five years after the invention of hypoid gearing, all large automotive manufacturers around the world had converted their passenger cars and trucks to hypoid drive axles with a lower vehicle body.

Ernest Wildhaber emigrated from Switzerland to the USA in 1919 and was hired by The Gleason Works as a gear theoretician. Wildhaber received 279 patents, many of which changed the world of gearing. The cylindrical gear tooth profile that is today called Wildhaber-Novikov gearing was invented by Ernest Wildhaber in 1926. Mikhail Novikov, a Russian scientist with no access to Western publications, invented the same tooth profile independent of Wildhaber in 1956. The contributions of both scientists are

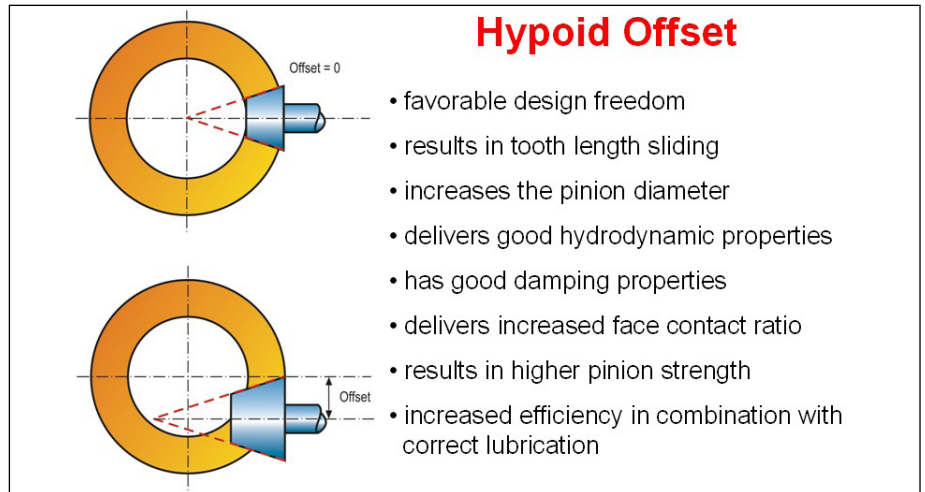


Figure 1—Features of pinion offset.

honored today by calling this system Wildhaber-Novikov gears.

Ernest Wildhaber is the father of modern gear theory. His pioneering contributions have been invaluable for the development of today's gear calculation and manufacturing processes.

News about Hypoid Gears?

This chapter discusses and analyzes whether hypoid gearsets, designed and manufactured today, are based on a precise theory or on approximation. As an opening statement, it can be affirmed that hypoid gearsets with a non-generated gear member and parallel depth teeth have a mathematically exact base geometry (refer to Figure 12). Also, hypoids with tapered depth teeth, which use helical motion during pinion generation, have this mathematically exact base geometry if the ring gear is non-generated.

A generalized law of gearing was interpreted by Errichello and Stadtfeld (Ref. 1) and reads: "Conjugate gears transmit uniform rotary motion from

one shaft to another by means of gear teeth. The common normal to the profiles of these teeth, at all points of contact, must pass through a fixed-point P in the common connecting line that intersects the two shaft axes and is normal to the pitch element."

The topics of this chapter are structured accordingly in:

- The three fundamental laws of gearing
- Perfect conjugacy
- Real-world applications
- Transmission design
- Heat treatment, lapping and grinding

The Three Fundamental Laws of Gearing

The first fundamental law of gearing $n_g \cdot V_\Sigma = 0$, also implies $|N_1 \times R_1| = i \cdot |N_2 \times R_2|$, where i is the constant transmission ratio. The three cases in Figure 2 visualize the problem of a non-constant ratio and are noncompliant with the first gearing law because of a ratio change from case to case. This problem led Leonard Euler to discover the involute tooth profile. A

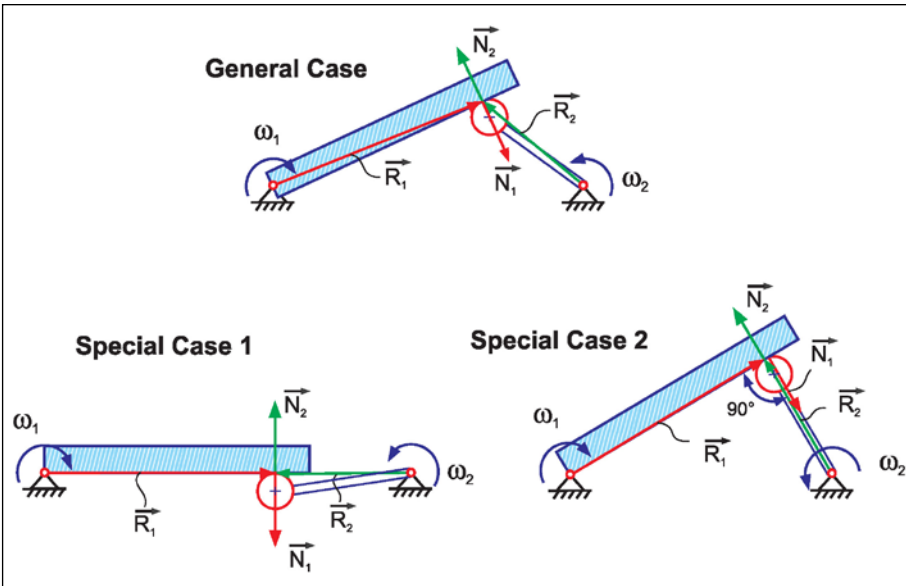


Figure 2—Three general cases of motion transmission with a bar and a crank.

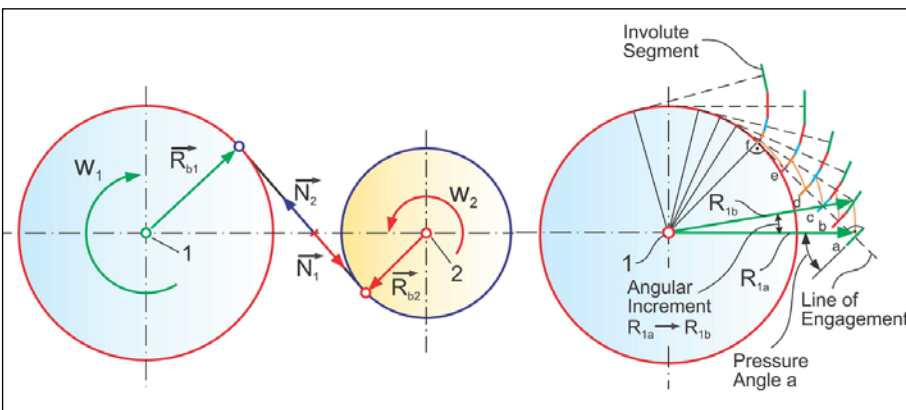


Figure 3—Line of action between base circles (left) and subsequent involute development.

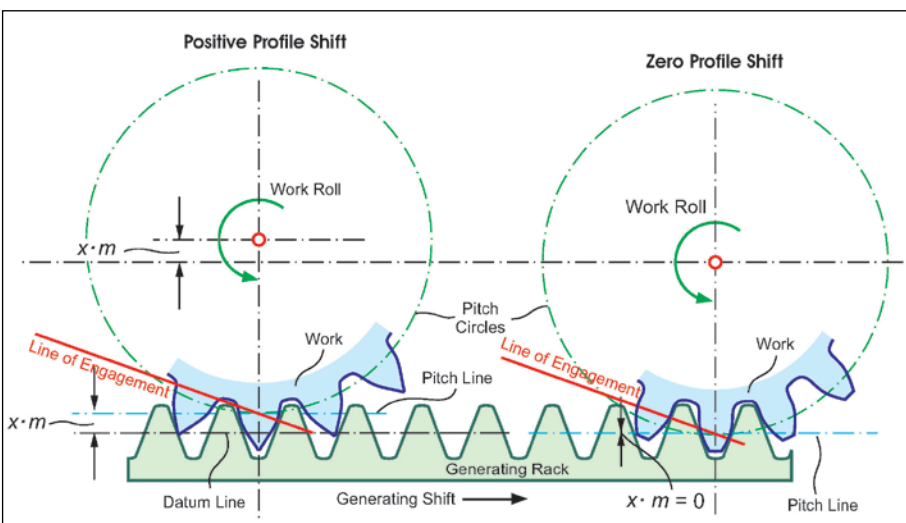


Figure 4—Generating a rack with a straight profile forming involute profiles.

simplistic mathematical approach teaches that the effective radius vector R remains unchanged while the contacting point between two mating flanks moves from R_{b2} to R_{b1} as shown to the right in Figure 3 (movement along the line of action).

The line of action in parallel axes cylindrical gearing is straight, connecting the two base circles. If the surface normal vectors N_1 and N_2 are within the line of action, then the vector product $|N_i \times R_i|$ remains constant during a complete mesh cycle. The consequent application of this principle leads to the construction of an involute, as shown to the right in Figure 3.

The line that forms the tooth surface elements while traveling from position “a” to “f” along the line of engagement (line of action) is always perpendicular to the line of action. This principle implies that a tool, simply with straight cutting edges as shown in Figure 4, can be used to form the complex involute profile. Figure 4 also demonstrates the principle of profile shift, while maintaining the first fundamental law of gearing.

The second fundamental law of gearing, which was proposed in 2017 (Ref. 2), $p_{ln} \times V_m + n_g = 0$ (Ref. 1), is a redundant relationship to the first gearing law and it is limited to cylindrical gears with parallel axes and straight bevel gears without hypoid offset.

A third fundamental gearing law is proposed in Ref. 2 in two different notations. The first notation covers only the special case of ratio = 1:

$$\varphi_{b,g} = \varphi_{b,p} = \varphi_{b,op}$$

The above notation applies only for cases with equal base pitch diameters between pinion and gear because the circular pitch and not the angular pitch has to be equal between pinion, gear, and the operating base pitch. The second notation:

$$p_{b,g} = p_{b,p} = p_{b,op}$$

is consistent with the requirement of equal circular pitch, which makes this notation more relevant. However, it does not add additional substance to the first law of gearing. As a conclusion, it can be stated that the first law of gearing is sufficient and applies without restrictions to all kinds of gearing.

Perfect Conjugacy in Straight Bevel Gearsets

Bevel gears with intersecting axes are the topic of a series of three papers published between October 2014 and January 2015 (Ref. 2). A straight bevel gearset with skew teeth was modeled, and a sample was manufactured. This publication addressed two points: the design of a gearset with a low tooth count and the solution for perfect conjugacy, which was successfully achieved. Also, Coniflex straight bevel gears used since the 1940s can achieve perfect conjugacy when the machine root angle is equal to the pitch angle of the manufactured gear (generated on the pitch line). This principle applies to any tooth count combination.

Straight bevel gears, such as Coniflex, have tapered depth teeth, where the pitch cones roll on each other, and the pitch apices of the pinion and gear match the crossing point of the axes. In the standard case, the face and root cone apices also match the crossing point. In such a standard Coniflex design, the base elements are also cones with cone apices that match the crossing point of the axes. The involute development in Figure 3 can be applied to an infinite number of normal sections along the face width of a straight bevel gear, which allows an involute development like that for cylindrical gears. The conical base elements of both members can be connected with a straight line (the line of action) in each section along the face width, whereas the plurality of all lines of action forms a plane (the plane of action).

This principle is shown in Figure 5. The two cones in Figure 5 are base cones of a straight bevel or a spiral bevel gearset. In the right two graphics, the view is directed such that the plane of action appears as a line that is tangential to the two cones enveloping surfaces. The left side graphic in Figure 5 shows the plane of action three-dimensionally and how it connects the two base elements.

The plane of action cannot be extended beyond its tangential contacting line with the base elements, as shown in Figure 5. The plane of action only exists where tooth engagement

is possible, and it is different than the generating gear plane (more specifically explained below).

There is, however, one difference from the true involute of cylindrical gears. The rotation of the pinion and gear does not occur in the normal plane but in the transverse plane. Because of this difference, the flank profile of straight bevel gears (and all other bevel gear types) is called *Octoide*. The Octoide is the analog function of an involute, and it provides bevel gears with the same advantages as an involute provides to cylindrical gears. Those advantages are constant ratio, center distance insensitivity, and ease of manufacturing.

Like cylindrical gears, bevel gears also have a trapezoidal generating profile. The straight rack of cylindrical gears becomes a ring, as shown in Figure 6. It is required to establish certain conditions to make the ring rack the generating gear for a pinion and a ring gear that will mesh perfectly together with zero transmission error and line contact identical to cylindrical gears. Those conditions are postulated in the kinematic coupling requirements:

1. The flank surfaces of the generating gears of the two mating bevel gears are congruent (same shape but mirror images, as given in the example of Figure 6)

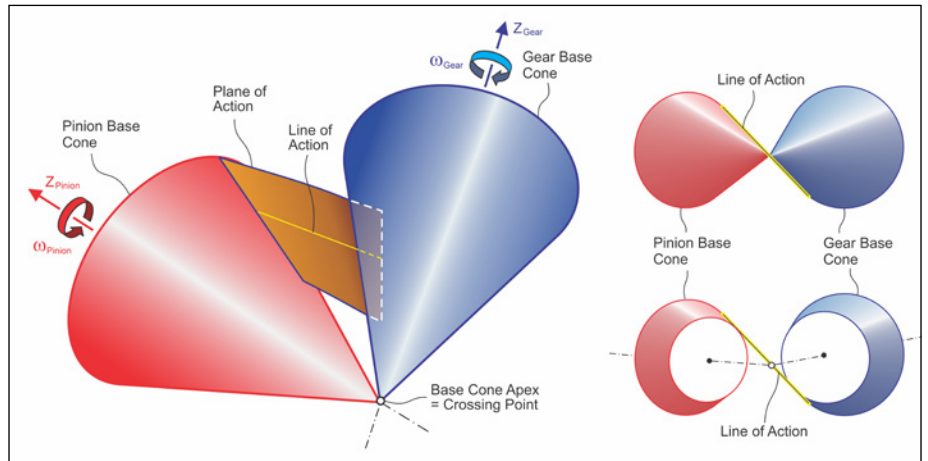


Figure 5—Conical base elements and plane of engagement.

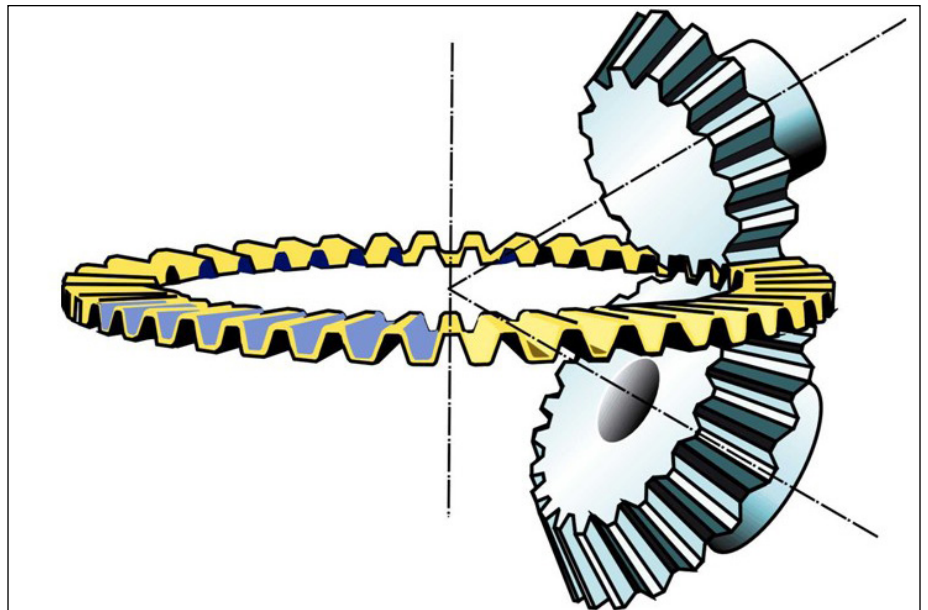


Figure 6—Ring-shaped generating rack with trapezoidal profile.

2. The generating gears of the two mating bevel gears require identical axes of rotation (the top and bottom of the generating gear in Figure 6 form the same generating gear, which rotates in both cases around the same axis and therefore satisfies condition 2)
3. The surface of engagement of pinion and ring gear must be identical to the surface of engagement between pinion and generating gear, and to the one between ring gear and generating gear (without detailed knowledge of the surfaces of engagement,

the global condition in Figure 6 seems to satisfy this requirement)

The generating gear principle must be understood as the ultimate vehicle to form the teeth of two mating gears. The first fundamental law of gearing is fully executed by choosing trapezoidal profiles and by applying the kinematic coupling requirements. Gears are designed and manufactured to mesh with each other. What better way to manufacture them than by way of a generating gear? The generating gear is represented by the manufacturing machine; it forms the teeth of

the gear (at the bottom in Figure 6) while meshing with this gear perfectly. If the pinion is manufactured with the same generating gear but on the opposite side (at the top in Figure 6) and if the generating gear is imagined infinitely thin, then the result is a pinion that perfectly meshes with the gear having zero motion error. It is also given in such a case that line contact between the pinion and gear flank surfaces exists along the entire face width.

Coniflex Pro designed straight bevel gears are manufactured with peripheral cutters, where the tangent to the cutter tip circle is aligned with the root line of the tapered tooth, and the blade profile is aligned with the profile on one side of a generating gear tooth (Figure 6). With this process, it is required that, first, e.g., all left flanks are machined. In a second step, the cutter changes its orientation such that the blade profile aligns now with the second side of a generating gear tooth, and e.g., all right flanks are machined. This way, the generating roll, which is a rotation around the generating gear axis, is repeated for each slot twice. This kinematic condition satisfies the requirement from Figure 6 and fulfills the kinematic coupling conditions. Coniflex is the fastest straight bevel gear manufacturing process, although each slot is addressed twice to generate both flanks.

An example straight bevel gearset computer model is shown in Figure 7. The solid model in Figure 7 has been generated by using standard Gleason basic settings, based on the generating gear approach, and by applying a standard Coniflex Plus cutter head as used on Phoenix bevel gear manufacturing machines. The Coniflex straight bevel gear calculation for conjugate contact must be conducted with a dish angle of zero degrees and no root angle correction ($\Delta\text{Gamma}_M = 0$). The dish angle is creating the length crowning, and the profile crowning is commonly generated with a ΔGamma_M (machine root angle correction). With a dish angle of zero degrees and a ΔGamma_M of zero degrees, flank lead lines are straight lines, and the profile is a true Octoide (involute equivalent).

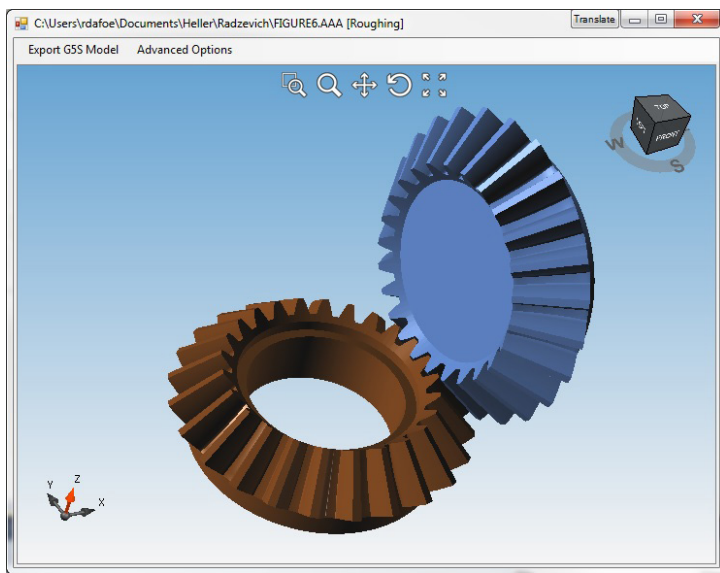


Figure 7—Solid model computer graphic of a perfectly conjugate straight bevel gearset.

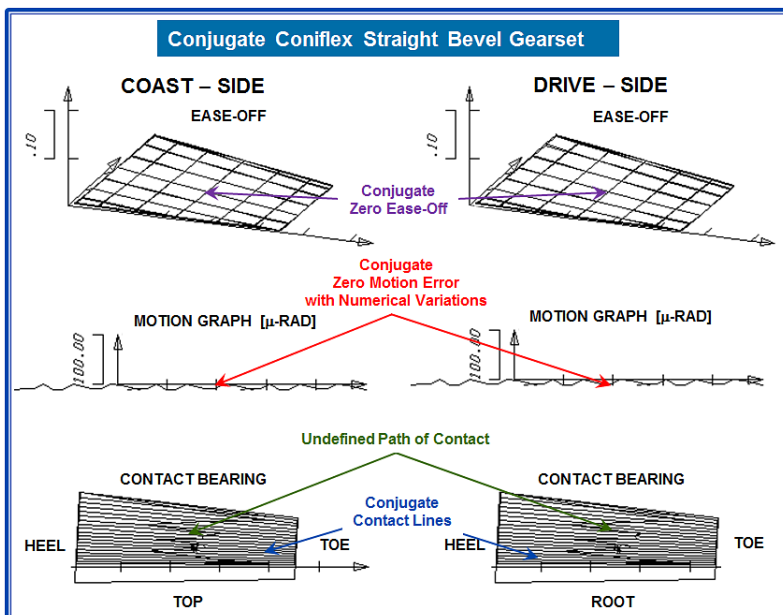


Figure 8—Tooth contact analysis of the perfectly conjugate straight bevel gearset.

A contact analysis of the gearset in Figure 7 is shown in Figure 8. The top of the figure shows the Ease-Offs of the left and right flanks (called the coast and drive side in the graphic). The center of the figure shows the motion transmission errors of the pinion and gear flank pairs. The two bottom graphics are the representation of the tooth contact pattern. The contact pattern graphics are axial projections of the flank surfaces and the contact lines in the same plane where a two-dimensional part print would show the tooth area.

The contact analysis in Figure 8 confirms the full line contact in each roll position (lower graphics) as well as the zero motion error (only numerical static) in the center graphic, which makes this example a perfectly conjugate straight bevel gearset. In the lower graphic, the path of contact was calculated as a zig-zag line, which indicates an undefined contact path. This means that due to the conjugacy, every point along each contact line is a path of contact point which makes the analysis program pick random points.

The Ease-Off base plane (top graphics in Figure 8) defines the conjugate state of a flank surface pair. Because the Ease-Off graph of the calculated flank pairs matches the presentation plane (base plane) precisely, that is proof that a conjugate and precisely rolling gearset was the input of this contact analysis calculation.

The above experiment, creating a conjugate straight bevel gearset, is strictly academic. Conjugacy is the basis of all gearsets manufactured in high volume on dedicated manufacturing machines. A conjugate bevel gearset cannot be used for power transmission because manufacturing tolerances and load-affected deflections, as well as material expansions and deformations under high operating temperatures, will result in edge contact and high load concentrations. The load concentrations already start with a moderate load and cause material damage and considerable noise emission. Although conjugacy is used as a reference for each design, predetermined amounts of length and profile crowning are applied. The right amount of crowning

makes a gearset quiet and gives it the required load-carrying capacity. The crowning is shown in the Ease-Off graphics with the conjugate reference always being present as the Ease-Off base plane. Several Ease-Off examples of a gearset with length and profile crowning are shown in the proceedings of this chapter.

Perfect Conjugacy in Hypoid Gearsets

It begins to become more problematic for hypoid gears. Frequently, the pitch elements of crossed axes hypoid gears are drawn as cones. Even though the face cones of hypoid gears and pinions are machined conically, the pitch elements are hyperboloids.

Ernest Wildhaber and Arthur Stewart described their invention of hypoid gearing in 1926 (Ref. 3). Boris Shtipelman published in 1978 the relationships and derivations required

to understand hypoid gears and their hyperbolic pitch elements (Ref. 4). Figure 9 offers a graphical interpretation of the hyperbolic pitch elements and their generator. The pitch surface generator is a line that winds on the surface of a cylinder beginning at the crossing point of the axes, equal to the first contact point of the pinion and gear pitch surfaces. The pitch surface generator is developed by the connecting line between the pinion and gear pitch surfaces ($n_{op}-n_{og}$), by shifting the connecting line along the pinion and gear axes. The connecting line ($n_{op}-n_{og}$) is normal to the pitch elements. Point P is one point of the pitch surface generator. If the division of the vector products of the distances between the axes and point P and their respective axis direction equals the ratio i of the hypoid gearset, then one point of the pitch surface generator is found with:

$$\{(n_{op} - P) \times Z_a\} / \{(P - n_{og}) \times Z_b\} = i$$

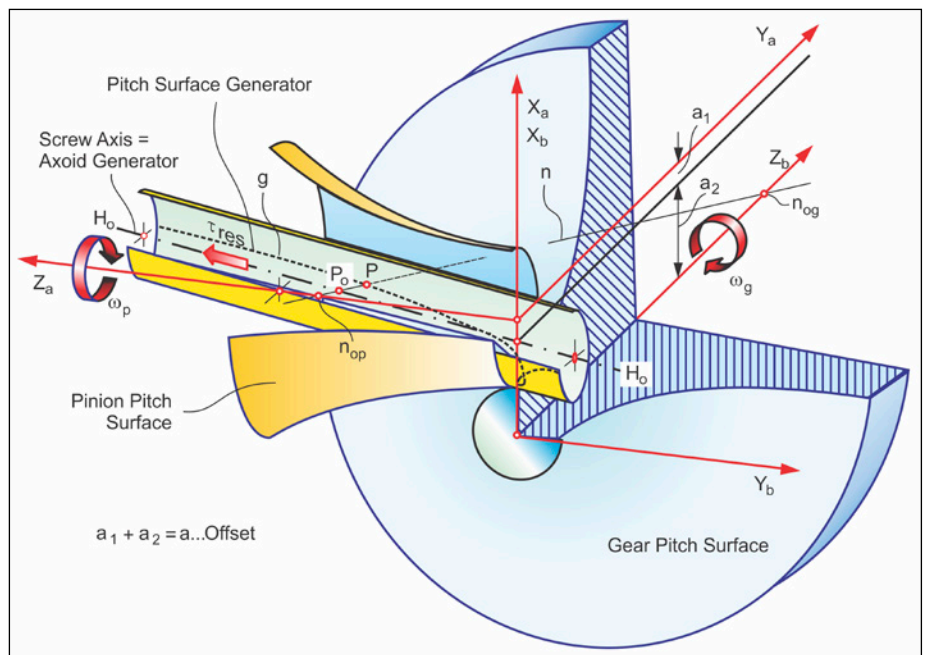


Figure 9—The correct pinion and gear pitch surfaces.

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Although the pitch elements are hyperbolic and not conical, it is possible to use conical faces for the blanks of pinion and gear. If point P in Figure 9 was chosen at the center of the face width, then line $(n_{op}-n_{og})$ can be used as a normal vector to define the face angle of a blank with straight face cones if the hypoid set was manufactured by

face hobbing, which implies parallel depth teeth.

Straight face cones will merely influence the top root clearance of the gearset in the range of 30 to 60 microns. Using straight face cones will not change the form of the pitch surface, nor will it influence the base surface (and root surface). Those functional

surfaces are given by kinematical relationships and must be considered when thinking about the shape of the surface of action. No plane of action can exist between two hyperbolic base elements. The correct surface of action is curved and warped, as shown in Figure 10.

The conclusion is that the first fundamental law of gearing:

$$n_g \cdot V_{\Sigma} = 0$$

is well-suited to govern the relationship of hypoid gears and can be employed to develop a conjugate relationship between two hypoid members. This will be further explained and demonstrated in the following section.

Conjugacy Between Meshing Flanks

The term conjugate is used in mathematics for two or more surfaces that contact each other along a line. Since the 1970s, the term conjugate has also been employed in gear technology literature to define the “exact” gear pair that presents a triple plurality of line contact between two gear flanks during the meshing process (Ref. 5):

1. The flanks contact along a line (contact line), which is only limited by the boundaries of the teeth, i.e., the working area
2. The line contact between the flanks exists within the entire area of engagement in every mesh position
3. Line contact is maintained in the entire area of engagement if the pinion and ring gear are rotated by angular increments, where:

$$\frac{\text{(angular pinion increment)}}{\text{(angular ring gear increment)}} = \text{(transmission ratio)}$$

The Ease-Off is a three-dimensional graphic of the flank deviations from a conjugate pair. It is calculated by the transformation of a pinion flank “into” the gear coordinate system according to the first gearing law, resulting in a virtual gear flank that is conjugate to the actual pinion flank. This conjugate gear flank will then be compared to the present gear flank, where all differences in arc length are plotted point by point in ordinate direction into the Ease-Off graphic.

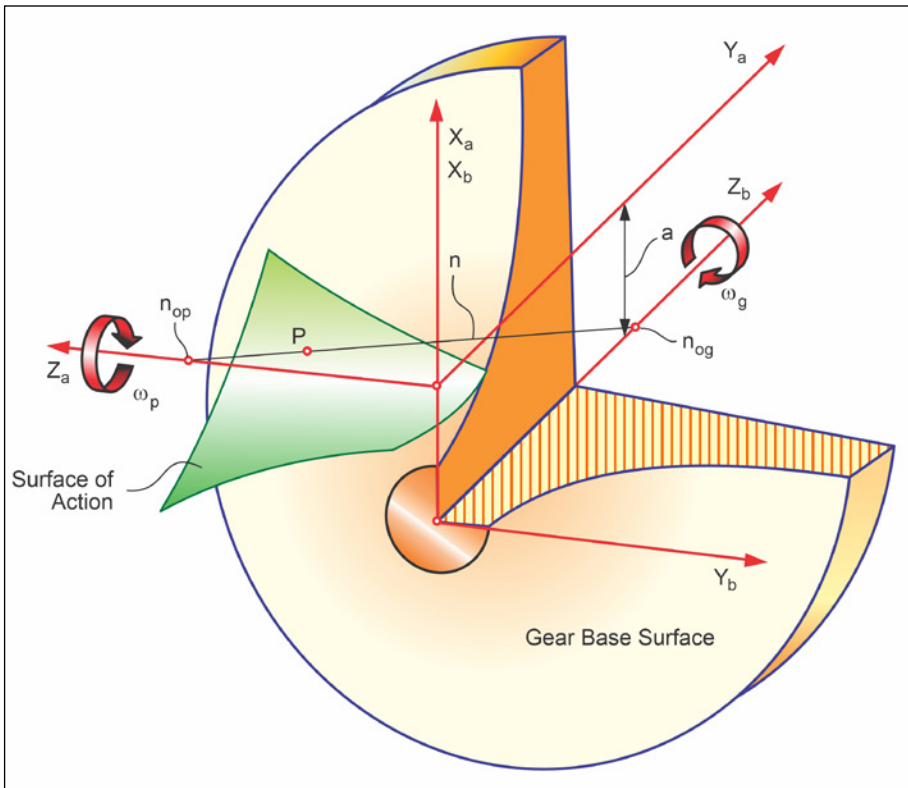


Figure 10—Surface of action connecting the gear and pinion base surfaces.

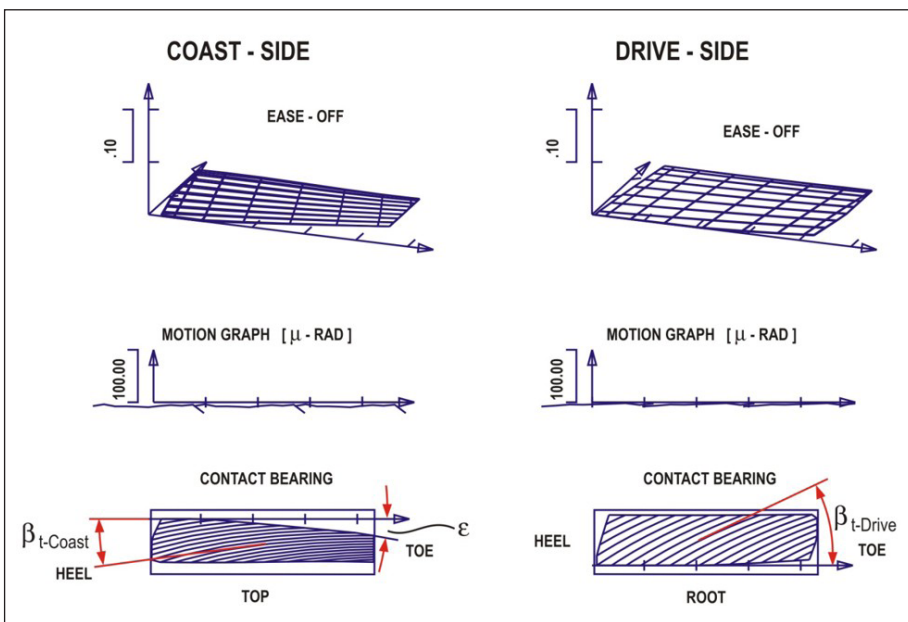


Figure 11—Ease-offs, motion graphs, and contact lines of a real conjugate hypoid gearset.

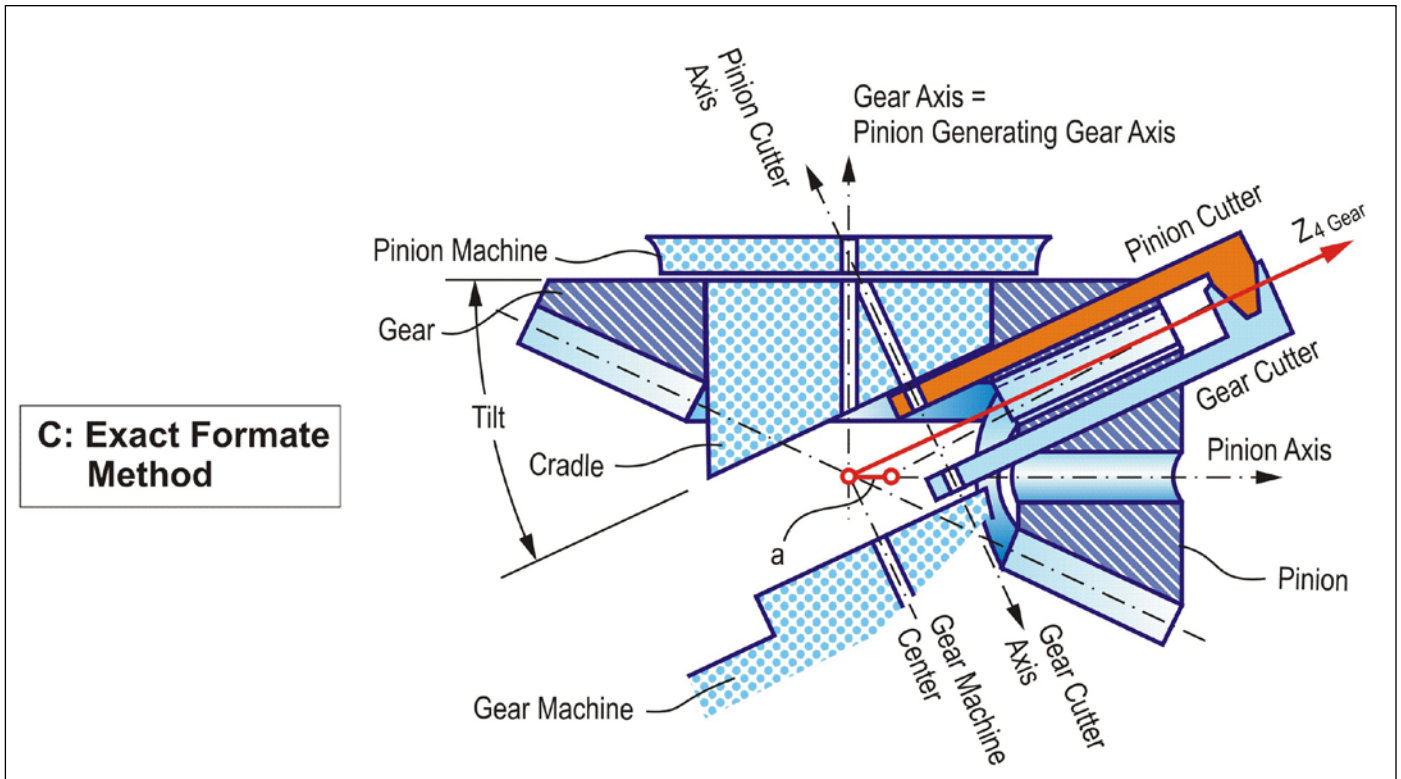


Figure 12—Generating a perfect conjugate hypoid pair.

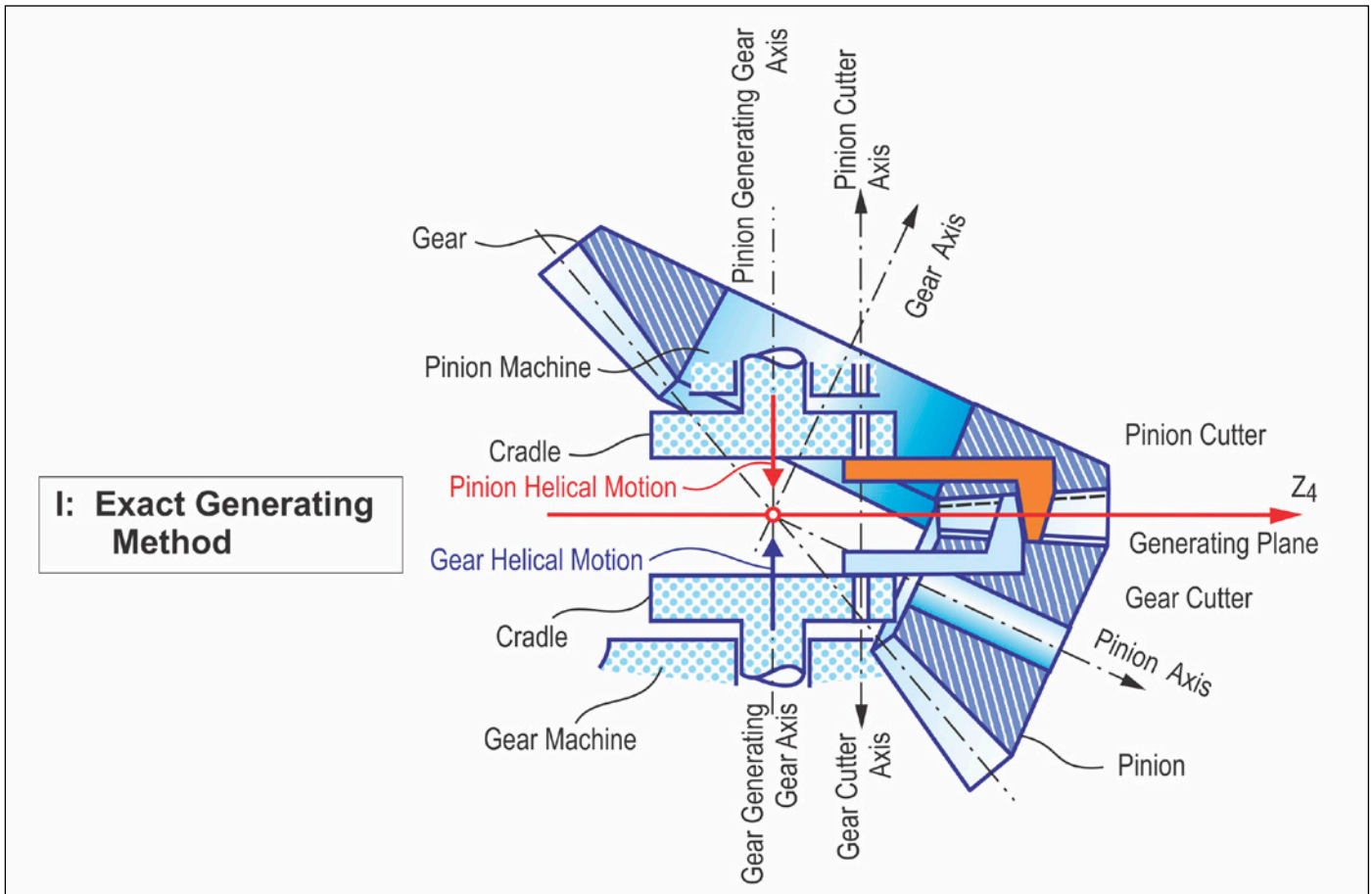


Figure 13—Generating a conjugate tapered depth bevel gearset.

If both mating bevel gears have conjugate manufacturing data, then the Ease-Off graphic has no deviations in the ordinate direction. Also, if the pinion flanks and the gear flanks have spiral-angle and pressure-angle errors of equal amounts, the Ease-Off graphic will not show any deviation. Although the individual gears are considered incorrect in this case, they will roll conjugate with each other, which subsequently leads to an Ease-Off without any ordinate values. Figure 11 shows the analysis results of a typical conjugate hypoid gearset. The Ease-Off graphics have zero crowning magnitudes in the ordinate direction. The motion graph has, next to some numerical entrance and exit variation, zero motion error. The contact bearings show line contact within the entire working area. The coast side contact ends at a toe root undercut (section ϵ).

Each spiral bevel gearset with uniform tooth depth has a conjugate base design. This applies to all face-hobbed and some face-milled gearsets. Hypoid gearsets can only be conjugate with a non-generated gear that meshes with a generated pinion. For the calculation and manufacturing process, the hyperbolic pitch elements are calculated for the gear first. Then a suitable blade profile (gear cutter in Figure 12) is chosen and positioned in a face cutter head. The cutter head is

positioned to create the desired spiral angle. With this procedure, a non-generated gear can be created by computer simulation, and it can be manufactured with a bevel gear cutting machine (Ref. 6).

A pinion cutter (see Figure 12) is positioned in a mathematical model or in a bevel gear cutting machine such that it represents one tooth of the non-generated gear by rotating around its axis. An additional simultaneous rotation around the pinion generating gear axis results in this pinion cutter becoming the generating gear of a conjugate pinion. If the pinion is positioned with the same offset “a” that was used to determine the pitch surfaces (Figure 9), then the cutter rotation around the pinion generating gear axis will form a pinion that is perfectly conjugate to the non-generated gear. The tooth contact analysis in Figure 11 has been obtained from such a non-generated hypoid gearset and therefore shows perfect conjugacy.

More complicated is the generation of a conjugate bevel or hypoid gearset with tapered depth teeth (see Figure 13). If the generating gear axes have identical axes of rotation that are perpendicular to the pitch line, the rotating cutter heads and their blades will not follow the root line of a tapered depth tooth. Tilting the cutter head to follow the root line would violate

the first kinematic coupling requirement for teeth that are congruent to the slots of the mating member. The following solution was developed in the 1940s (Ref. 7). If the cutting edges are adjusted in the cutting machine such that the tooth reference profile and depth are matched at midface, and if an axial motion of the cradle is introduced that guides the blades along the tapered root line while the generating roll progresses along the face width, then the requirements of congruent teeth and slots are fulfilled with the result of perfect conjugacy. However, in the case of hypoids, the gear must be non-generated, and the pinion must be generated with helical motion to achieve conjugacy.

The process configuration and kinematics in Figure 13 are called *duplex completing*. Today, all face-milled and ground spiral bevel and hypoid gears are manufactured with the duplex completing process. The axial cradle movement in this process is called *helical motion* and was first introduced with mechanical bevel gear machines in the late 1940s. The helical motion of the days of mechanical machines required an additional change gearbox which actuated a cam that moved the sliding base during the generation process.

Today’s CNC-controlled Phoenix free form machines have the helical motion capability automatically through their interpolated axes movement.

Why is Conjugacy not Desirable for Real World Applications?

In 1926, Ernest Wildhaber (Refs. 3, 8) was the first to propose applying surface crowning on hypoid gears. Wildhaber acknowledged that the slightest deviations in the gear housing and in the building position, as well as deflections affected by load and heat, will cause edge contact with peak stress levels of a multiple of the allowable values the gearset had been designed for. The conjugate gearset used for the TCA in Figure 11 was repeated with realistic displacement values of 50 μm offset, 50 μm pinion cone, and 30’ of shaft angle change. The results in Figure 14 show warped and tilted Ease-Offs and severe edge contact on the

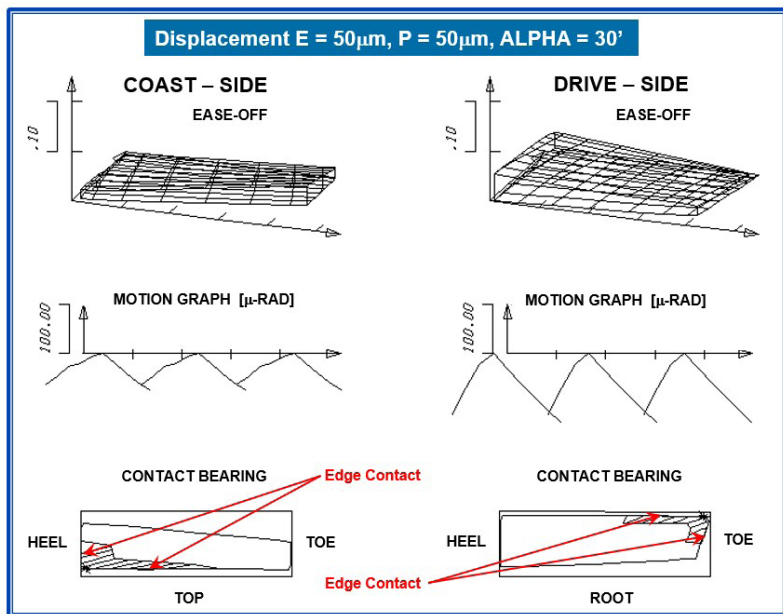


Figure 14—TCA of conjugate hypoid set from Figure 11 with displacements.

heel and top. This edge contact will cause noisy operation, followed by pitting and tooth fracture.

The theoretically conjugate hypoid set will depart from fulfilling any of the fundamental gearing laws in case of the smallest gearbox inaccuracies or deflections. As mentioned above, already small deflections at moderate loads lead to load concentrations on the edges of conjugate flank pairs and can cause material damage and considerable noise emission. As such, the conjugate gear pair is not suitable for any task in power transmissions.

The introduction of 80 μm length crowning and 15 μm profile crowning to the conjugate hypoid design delivers the analysis results shown in Figure 15. The crowning makes the gearset insensitive to expected inaccuracies in the gear housing and load, and heat-affected deflections. Applying the same amounts of shaft displacements as those used for the TCA of the conjugate hypoid set in Figure 14 moves the mean point slightly out of the initial position (see Figure 16), but a large contact area within the tooth boundaries is still maintained.

It was demonstrated that the hypoid gearset with length and profile crowning in Figure 15 was developed based on a conjugate design. The first and third fundamental gearing laws, mentioned in this chapter, apply to the hypoid set in Figure 15 at the mean point roll position, if the load is zero. The first and third fundamental gearing laws will apply in the area of contact as the load increases and the Hertzian contact spreads in the contact line direction as well as in the path of contact direction. This ideal condition can only be achieved with correct amounts of crowning, adjusted to the operating displacements. It is interesting to mention that a hypoid gearset with crowning will fulfill the first and third fundamental gearing law even in the case of gearbox inaccuracies.

Transmission Orientations

Hypoid gearsets are used as final drive gears in cars and trucks. Hypoid gears are not used as simple reducers, but their purpose is to redirect rotation and torque

by a certain angle, commonly 90° . In case of hypoids, the second purpose of lowering the center of gravity of a vehicle body has become very important in the automotive and truck industry. The redirection of rotation and torque has to be done at the driving axle of a vehicle. The engine orientation of vehicles with a rear wheel drive is longitudinal. Because engines of cars and trucks are commonly in the front, a longitudinally oriented propeller shaft transmits the engine rotation to the rear drive axle, as shown in Figure 17. The transmission, which is located between the engine and the propeller shaft, needs to have a gear shaft orientation identical to the direction of the engine crankshaft. The hypoid gearset redirects rotation and

torque and provides the final reduction at the drive axle. The advantage of this concept is the lower torque in the complex shift or automatic transmission, and the high torque only at the ring gear at the drive axle.

Is Lapping an Attempt to Make Hypoid Gears Conjugate?

Lapping, like grinding, is a hard finishing process. In grinding the same profile and length crowning applied in the soft cutting process is created. Grinding re-establishes the original surface function after the heat treatment. In lapping material is only removed in the tooth contact area. This not only establishes a good rolling condition, but it also makes

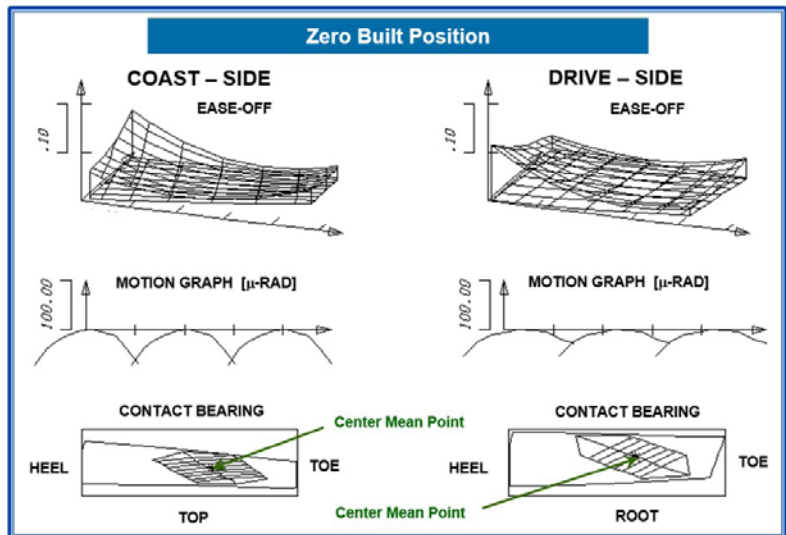


Figure 15—TCA of the hypoid set from Figure 11 without any displacements.

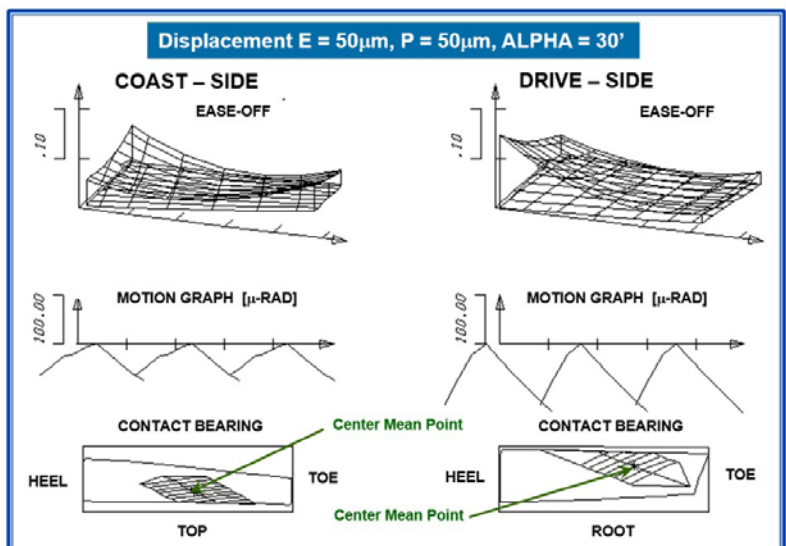


Figure 16—TCA of hypoid set from Figure 11 with added crowning and shaft displacement.

the flank surfaces more conjugate in the area where the tooth contact patterns are located.

Lapping and grinding are hard-finishing operations. The soft-manufactured bevel and hypoid gearsets must be heat-treated, which in the most common case begins with a case carburizing of standard gear steels such as AISI 8620 or 16MnCr5. To give the low-carbon steel a surface hardness in the 60 HRC range, a layer of carbon enrichment below the surface of 0.8 to 1.5 mm depth is placed by a diffusion process. After the carburizing and quenching in oil, an additional tempering takes place. The result is a surface hardness that is commonly close to 60HRC and a core hardness in the

30HRC range. Case hardening provides an ideal transition between surface and core hardness that makes gears on the surface hard and wear resistant, and in the core ductile. This makes shock loads and certain small plastic deformations tolerable without failure of the gearset. One major side effect of the heat treatment process is the distortion of the gears that is caused by carburizing, the recrystallization of the steel, and the quenching. To make a gearset after heat treatment suitable for power transmissions, for example, in cars and trucks, a hard-finishing operation is required. The hard-finishing operation eliminates the heat treatment distortions hereby providing the flank surfaces with the correct geometry from before

the heat treatment. In addition, hard finishing improves the surface finish to a low roughness and waviness, which enhances the hydrodynamic lubrication and reduces noise. Grinding and skiving are the preferred hard-finishing methods, creating a defined surface form that duplicates the original designed surfaces in the single micron range.

In case of face hobbled bevel and hypoid gearsets, grinding is not possible, because of the epicyclical flank lead function. Skiving can generate epicyclical lead functions but is not yet accepted for the high production volumes in the automotive and truck industry. This leaves only the lapping process for the hard-finishing of face-hobbed angular gearsets. However, the face hobbled surface texture and the relative sliding between the flanks of hypoid gears make lapping an ideal alternative. Lapping can remove the surface scale left from heat-treatment, and it re-matches two mating members by removing some runout and flank form distortions. Lapping can reduce the transmission error in many cases due to the fact that the major material removal is in the center region of the teeth, where the tooth contact under light load is expected. In order for the lapping to work well, more crowning than required in the hard-finished gearset is used in the gearset design for the soft cutting. Lapping removes about 30 percent of this crowning, such that the length and profile crowning are just right after the lapping. Soft cutting of parts that are lapped after heat treatment considers a stock allowance of .03 mm in the pinion and 0.01 mm in the gear. If grinding is the hard finishing process (for face-milled gearsets) then the design crowning is identical to the desired crowning after hard finishing. Between soft cutting and grinding, a uniform stock allowance of 0.10 mm to 0.15 mm is applied to the pinion and gear flanks.

Summary

Conjugacy between the members of straight bevel, spiral bevel, and hypoid gears was only the first step and goes back more than 100 years. Quickly, the early scientists and engineers found out that conjugacy only gives us an impor-

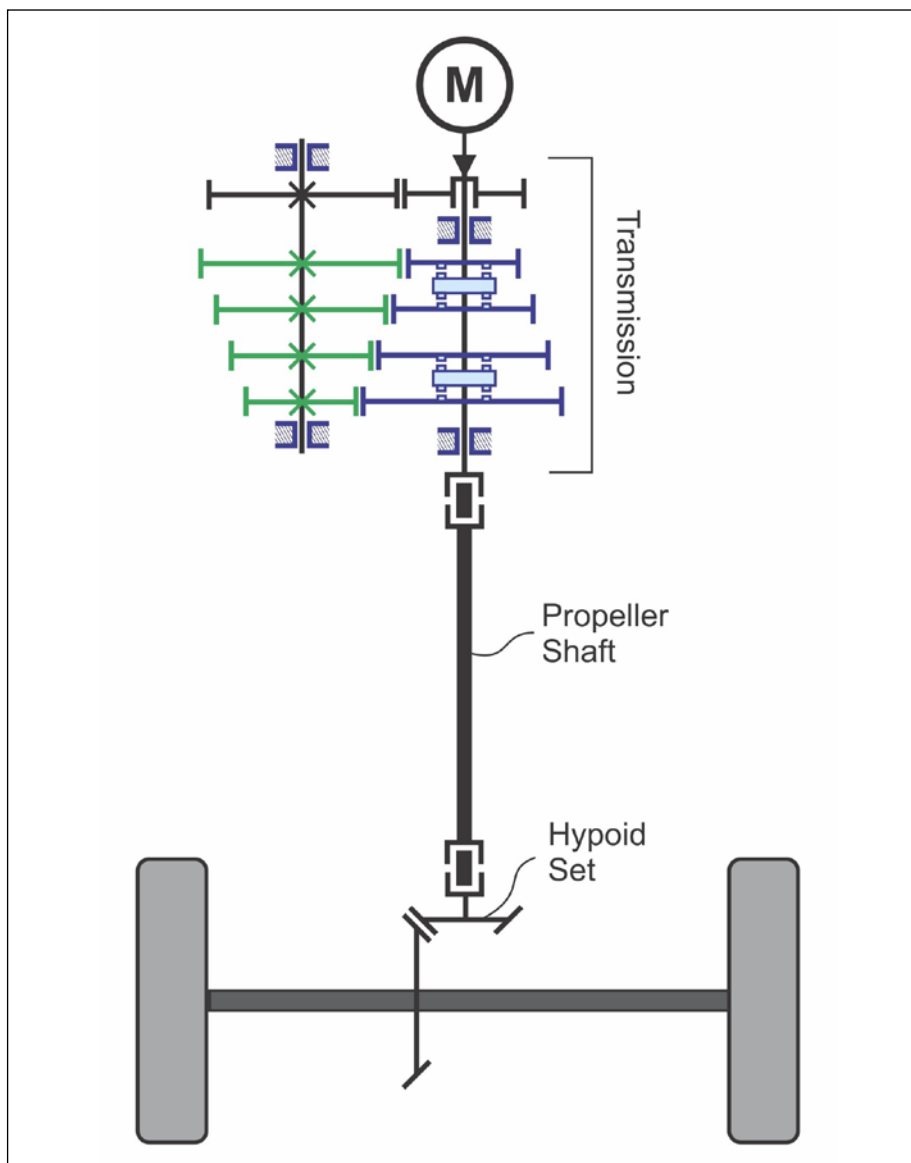


Figure 17—Hypoid gearset location in vehicles with rear wheel drive.

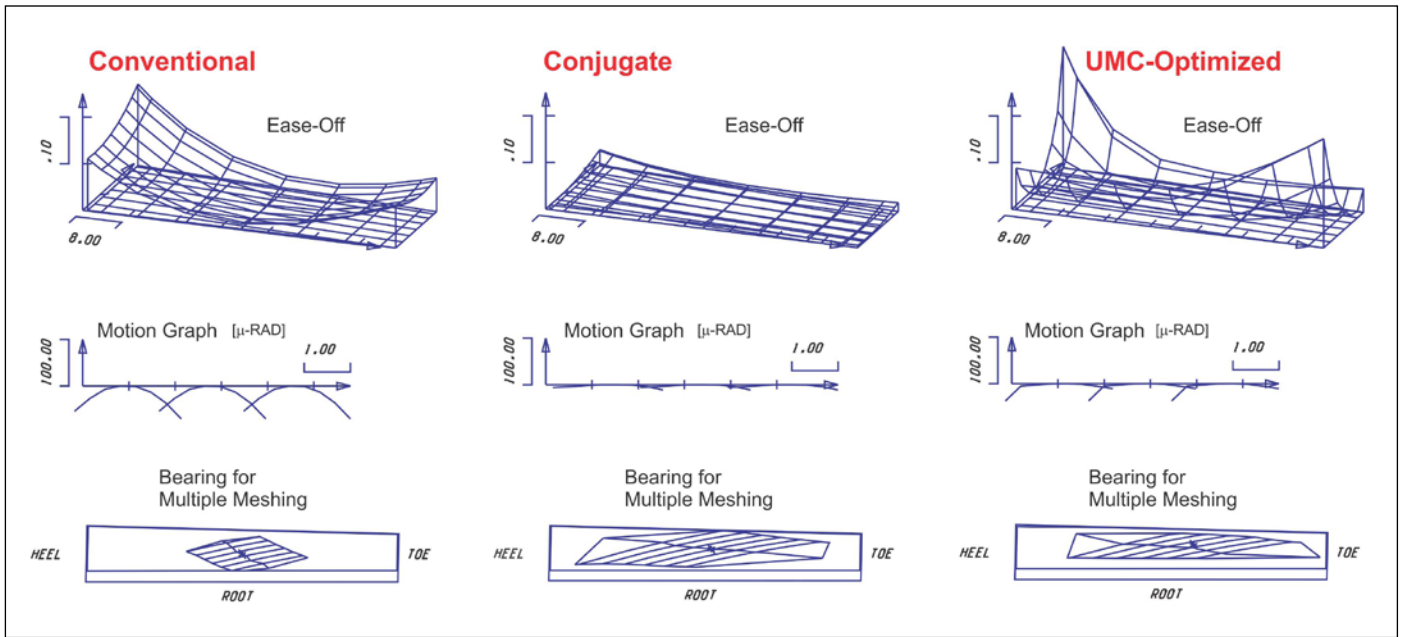
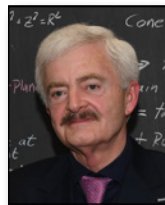


Figure 18—From conventional crowning via conjugate to UMC-optimized.

tant basis, but not a solution for power transmissions. Angular gearsets under load experience deflections that move them away from their theoretical position by half a millimeter or more. Well-designed and manufactured bevel and hypoid gearsets today can live up to those requirements and still maintain a power density that is four times higher than it was 50 years ago. Transmission errors of 50 to 150 microradian that were normal in the 1970s are in today's high-power-density gearsets only between 5 and 15 microradian. All this was achieved by

converting a global length and profile crowning (Figure 18, left) first back to conjugacy (Figure 18, center) and then into a UMC-optimized selective crowning, which is limited to particular regions of the teeth, as shown in the right graphic in Figure 18. Notably, the flank center of the UMC-optimized Ease-Off is conjugate, and the transmission error is next to zero. In lapping, similar effects as in grinding are achieved by utilizing low-inertia spindles with rotational compliance and high-speed torque control (SmartLap).

The dream of conjugate angular gearsets turned out to be a false objective. Gear scientists, gear engineers, and gear manufacturers worked very successfully for many decades on finding the optimal flank forms and the optimal non-conjugate flank surface interaction. The conjugate tooth design today is considered simple compared to sophisticated higher-order surface modulation. There is still room for improvement, but this cannot be achieved by going back to antiquated conjugate designs.



Dr. Hermann J. Stadtfeld is the Vice President of Bevel Gear Technology and R&D at the Gleason Corporation and Professor of the Technical University of Ilmenau, Germany.

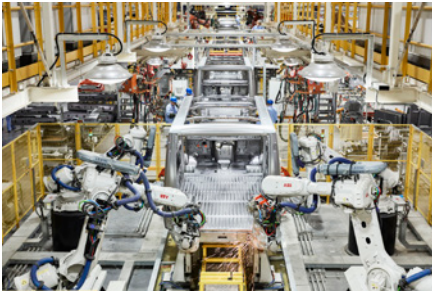
Gear Technology Solutions continues and completes his 2019 work, *Practical Gear Engineering*. Recently awarded a patent for MicroForm, the innovation marks his 70th patented invention.

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ABB Robotics

CITES SURVEY SHOWING RENEWED CONFIDENCE IN EV PRODUCTION



Automotive manufacturers worldwide are showing growing confidence in their ability to build electric vehicles efficiently and at scale, according to ABB Robotics' latest Automotive Manufacturing Outlook Survey, as EV production becomes a more established and predictable manufacturing discipline.

"This year's survey presents a more positive picture of EV manufacturing than we have seen in previous years," said Joerg Reger, managing director of ABB Robotics Automotive Business Line. "Key indicators such as manufacturing time, cost and integration show that EV production is increasingly becoming a known quantity. This is supported by sustained investment in automation, such as ABB Robotics' delivering more autonomous and versatile robotics (AVRTM), capable of creating a leap in productivity and flexibility by combining key skills to autonomously plan and independently perform diverse, complex tasks in real time."

The global survey, conducted in partnership with Automotive Manufacturing Solutions, shows that manufacturers in all major regions expect EV output to rise in 2026 compared with 2025, signaling continued commitment to electrification at the manufacturing level despite uneven consumer demand in some markets.

Confidence has also improved around the practical delivery of EV programs. Fifty-one percent of respondents say EVs and their key components are now easier to manufacture than a year ago, compared with just eight percent who believe they have become harder to build. This suggests that EV assembly processes are becoming faster, more stable and less

disruptive as experience grows, supported by developments in automation.

Cost trends reinforce this picture. More than four in ten respondents (41 percent) report that EV manufacturing costs have decreased over the past 12 months, while a further 39 percent say costs have remained stable. Only 21 percent report rising costs, pointing to improving efficiency as EV platforms and supply chains mature.

However, the survey also highlights a measured, demand-led approach to powertrain strategy. While EV production is expected to continue increasing, manufacturers predict even stronger growth in hybrid powertrain manufacturing over the same period. This indicates that many producers view hybrid technologies as an important stepping stone, enabling them to balance electrification ambitions with real-world customer demand and operational flexibility.

"Manufacturers are no longer asking whether they can build EVs—they are focused on how to build them efficiently, profitably and alongside other powertrains," added Reger. "Investment in robotics, automation and flexible manufacturing is a key driver behind this growing confidence, helping producers scale EV output while remaining responsive to changing market conditions."

As EV manufacturing continues to evolve, the survey findings point to an industry that is steadily converting ambition into operational confidence, underpinned by automation-led approaches to efficiency, flexibility and long-term competitiveness.

go.abb/robotics

Affolter Group

EXPANDS CAPACITY, POSITIONS FOR GROWTH IN ROBOTICS AND HIGH-PRECISION MARKETS

Affolter Group is investing in a major expansion and renovation of its headquarters in Valbirse (Grand Chasseral, canton of Bern, Switzerland). Construction has been under way since 2024 at the company's site on Grand-Rue 74 and will continue through 2027. The project will add 2,750 m² of new space, increasing the

company's total footprint to 10,500 m², while also fully modernizing existing production and office facilities originally built between 1993 and 1999.



This long-term investment reflects Affolter Group's commitment to sustainable growth, expanded production capacity, and an enhanced working environment for employees, customers and partners.

"This expansion is a strategic step to support our long-term growth and ensure we can meet rising demand with the highest Swiss quality standards," says Mikael Affolter, head of sales at Affolter Group. "At the same time, it strengthens our ability to serve forward-looking industries—especially robotics—where precision gearing is essential for the next generation of motion systems."

Through the combination of expanded infrastructure, automation-ready technologies and deep expertise in high-precision gear hobbing, Affolter Group is preparing for the next stage of its development. The company expects continued global growth in precision markets, particularly in robotics, where micro-gearing and Swiss precision engineering will remain essential.

affoltergroup.ch

SMW Autoblok

APPOINTS NEW NATIONAL SALES MANAGER

SMW Autoblok Corp. appointed Brandon Mathis as national sales manager. Mathis brings more than 16 years of experience in the machine tool and manufacturing technology industry, including nine years in sales leadership.

"Brandon's experience and deep industry knowledge make him the ideal person to lead our sales initiatives in the United States," President and CEO Larry Robbins said. "We know that his efforts

will bring value to our customers, and we're thrilled to have him on the team."



Brandon Mathis

Mathis will be responsible for national sales strategy and focus on expanding customer engagement, strengthening partnerships with OEMs, distributors and end users, and advancing SMW Autoblok's full portfolio of workholding and automation solutions across the United States.

Prior to joining SMW Autoblok, he held sales leadership roles at Ellison Technologies. He holds a Bachelor of Business Administration in Management from the University of Houston and is a Certified Manufacturing Technology Sales Engineer (CMTSE).

smwautoblok.com/us/en

Star SU

ALIGNS GLOBAL GEAR TOOL STRATEGY WITH DUAL ROLE FOR RICK YAN

Star SU, the marketing, sales and service affiliate of Star Cutter Company, announces the expansion of Rick Yan's role. Yan, currently general manager of Star SU Tools and Machines in Shanghai, China, now also will serve as gear tools product manager for all domestic and international locations.

In this dual role will, Yan will serve Star SU customers by leveraging his solution-driven technical expertise and global market perspective to strengthen product strategy, application support and customer success across the company's gear tool portfolio.

Yan has served as general manager of Star SU China since 2016, overseeing

three business units: Gear Tools, Carbide Materials, Round Tools and the sales, marketing and reconditioning business. Under his leadership, Star SU China has supported automotive, industrial gearbox, robotics, wind powers and precision gear manufacturers with high-precision gear cutting tools, while providing guidance to optimize quality, manufacturing processes and overall production costs.



Rick Yan

"Rick's outstanding success in growing Star SU Machines and Tools in Shanghai is a great asset to our clients worldwide," said Andreas Blind, president at Star SU. "We are pleased to expand his role and benefit from his insights as we continue to enhance the value we deliver across all Star Cutter brands."

In his new role as Gear Tool Product Manager for Star SU, Yan is responsible for product strategy, market research, product development, pricing, technical support and collaboration with sales, marketing, engineering and production to drive innovation, application excellence and customer-focused solutions.

Yan holds a bachelor's degree in mechanical engineering from Changzhou University.

star-su.com

Nidec and Wenzel

HOST GEAR UP FOR PRECISION OPEN HOUSE

Nidec Machine Tool America is pleased to announce a joint Open House with Wenzel America this June, bringing together manufacturing leaders for two

days of technical presentations, live demonstrations, and industry networking. The Gear Up for Precision Open House will spotlight Nidec's latest advancements in gear manufacturing and its expanding portfolio of advanced manufacturing technologies, paired with live demonstrations of Wenzel's high-precision metrology and CT scanning solutions.



This joint Open House highlights the critical synergy between high-performance machining and precision measurement. Attendees will see firsthand how Nidec's production workflows are complemented by Wenzel's inspection and validation technologies, helping manufacturers achieve higher throughput and tighter tolerances.

Throughout the two-day event, live demonstrations will feature Nidec's latest equipment alongside Wenzel's metrology and CT scanning systems. These demonstrations will show how integrated measurement data can validate production results and accelerate process optimization.

Expert-led technical sessions will offer insights into current industry trends while addressing the specific challenges of modern manufacturing environments.

Attendees will also have the opportunity to connect with representatives from several industry partners, including Takisawa, Federal Broach, and Gear Research Technologies, to discuss application-specific solutions and emerging technologies.

Beyond the technical program, the Open House will provide ample opportunities for networking with industry peers and subject-matter experts to discuss the future of smart manufacturing. The event will also feature catering and entertainment, creating a productive environment for professional exchange.

The Joint Open House takes place June 9–10, 2026, at Nidec Machine Tool America, 46992 Liberty Dr., Wixom, MI 48393 and Wenzel America, 28700 Beck Rd., Wixom, MI 48393.

wenzelamerica.com/event/gear-up-for-precision-open-house

geartechnology.com

JUNE 9-10

Gear Up for Precision Open House



This joint Open House (Wixom, MI) highlights the critical synergy between high-performance machining and precision measurement. Attendees will see firsthand how Nidec's production workflows are complemented by Wenzel's inspection and validation technologies, helping manufacturers achieve higher throughput and tighter tolerances. Throughout the two-day event, live demonstrations will feature Nidec's latest equipment alongside Wenzel's metrology and CT scanning systems. These demonstrations will show how integrated measurement data can validate production results and accelerate process optimization.

geartechnology.com/events/gear-up-for-precision-open-house

JUNE 9-11

Fabtech Canada 2026



Fabtech Canada (Toronto) is the country's premier event for the metal forming, fabricating, welding, and finishing industries. With live exhibits and hands-on demonstrations, it's a vital platform for networking, innovation, and staying ahead in Canada's advanced manufacturing landscape. Exhibitors include Hexagon, Epicor, Wintriss ISB, IKO Thompson Bearings Canada, ABB, Yaskawa and more.

geartechnology.com/events/fabtech-canada

JUNE 15-18

Reliable Plant 2026

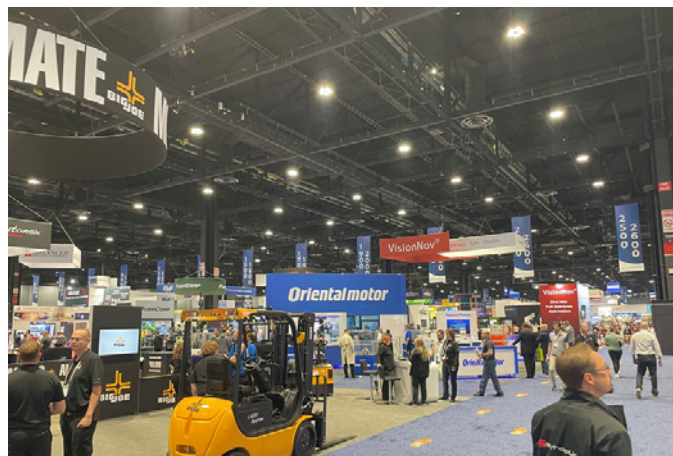


This event (Reno, NV) offers attendees learning sessions and case studies on the latest industrial lubrication and oil analysis technologies. The comprehensive conference schedule covers every facet of the machinery lubrication industry and includes workshops on topics such as employee performance, lubrication fundamentals, condition-based maintenance and planning. Reliable Plant attendees come to the conference to connect with suppliers and service providers who can help them achieve bottom-line results in maintenance, reliability, and operations. From technicians and planners to management and leadership, you will be able to meet and influence entire buying teams at Reliable Plant.

geartechnology.com/events/reliable-plant-2026

JUNE 22-25

Automate 2026



Automate (Chicago) is North America's largest robotics and automation event with more than 1,000 exhibitors and 50,000-plus registrants. Topics include robotic automation, vision systems for quality control and inspection, motion control systems, AI and machine learning applications, collaborative robots, and industrial robots. Critical for understanding automation trends and includes comprehensive educational conference with 200-plus sessions. A new development at the 2026 show is a dedicated Humanoid Robot Pavilion, sponsored by NVIDIA. The pavilion will spotlight a range of humanoid robots and offer live demonstrations.

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Constructive Failure

Aaron Fagan, Senior Editor

In a developing zebrafish heart, cyclic loading fractures the extracellular matrix in locations governed by geometry and strain, not material defects.

In gear engineering, fracture is public enemy number one. Think of all the highly particular ways we case-harden, shot-peen, and obsess over root fillet radii to keep cracks from ever nucleating. The entire discipline of failure analysis rests on a simple premise: breaking is bad. Biology, it turns out, has faithfully exploited fracture as a manufacturing tool, and the details suggest to me, as a thought experiment at least, gear engineers might benefit from paying attention. A recent *Quanta* article (“Break It to Make It: How Fracturing Sculptures Tissues and Organs,” by Clare Watson, February 27, 2026) reports on a growing body of research, compiled in a February 2026 review in *Development*, showing that developing animal tissues deliberately fracture themselves to build functional structures. The most directly relevant case for tribologists involves African elephant skin. Elephants don’t shed dead skin cells, so their epidermis thickens continuously. As it grows, it bends around microscopic bumps in the underlying dermis until it cracks, generating an intricate network of channels across the skin surface. These microfractures are less “damage” and more “functional topography.” The channel network retains water when elephants bathe or spray themselves, dramatically improving evaporative cooling. In other words, biological tissue uses controlled fracture to generate a surface texture optimized for fluid retention.

That should sound familiar. Laser surface texturing of gear flanks is an active area of tribological research, with micro-dimples and grooves acting as lubricant reservoirs, hydrodynamic pressure generators, and debris traps. Results have shown meaningful reductions in friction and wear, particularly under boundary and mixed lubrication. But machining micro-texture into hardened gear surfaces is expensive and difficult to scale. The elephant offers a different model: rather than imposing texture from the outside, its skin grows the texture through fracture driven by internal geometry. Additive manufacturing may eventually make a similar approach feasible, building subsurface features designed to guide beneficial crack patterns during post-processing. This raises a practical question for surface engineers: Could controlled microcracking during heat

treatment or surface processing be harnessed to create beneficial lubricant-retaining topography, rather than rejected as a defect? We already accept that shot peening introduces beneficial damage in the form of compressive residual stress. The step from “controlled plastic deformation is useful” to “controlled microfracture patterning is useful” may be smaller than we assume.

Biology also challenges a deeper assumption in gear design. Traditional practice is overwhelmingly focused on crack prevention: keep stresses below the endurance limit, eliminate inclusions, maximize surface hardness, and ensure fracture never initiates. This makes sense for components where any crack is a runaway failure. But biology operates on a fundamentally different principle, not preventing fracture, but steering it. In a developing mouse embryo, pressurized fluid preferentially ruptures weaker cell-to-cell bonds while stronger junctions stay intact, and the resulting cavity defines the animal’s body axis. In a developing zebrafish heart, cyclic loading fractures the structural matrix lining the heart wall, and the crack locations are governed by geometry and strain distribution rather than material defects.

That echoes aerospace fatigue philosophy, where structures are designed to tolerate cracks and inspections manage their growth. As gears push into lighter, thinner-rimmed, higher-performance territory for aerospace and EV applications, pure crack prevention becomes harder to guarantee. A complementary approach that incorporates damage-tolerant thinking, designing tooth geometries and rim sections so that if a crack does initiate, it propagates into a benign arrest zone rather than through the rim, could add a meaningful layer of reliability. We already see early versions of this in split-path and redundant drive architectures. Biological research suggests the principle can operate at the material and geometry level, too.

None of this means we should welcome cracked gear teeth. But the emerging picture from biophysics reframes an old question: instead of only asking how to prevent fracture, it may be worth asking where we’d want fracture to go if it came. For the zebrafish, the heart is breaking on purpose.



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