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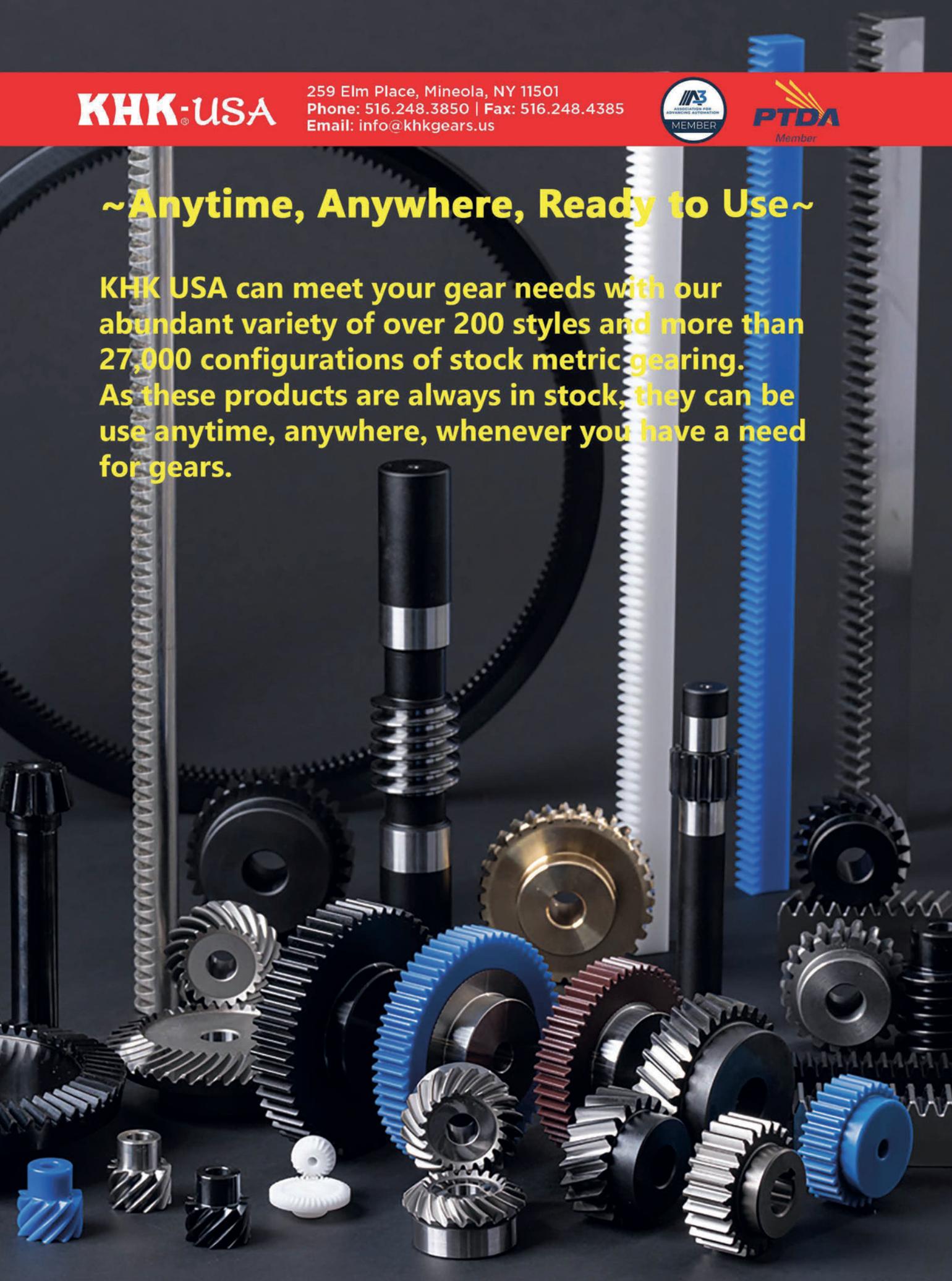
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## PTE REVOLUTIONS

### From Assembly Lines to Algorithms

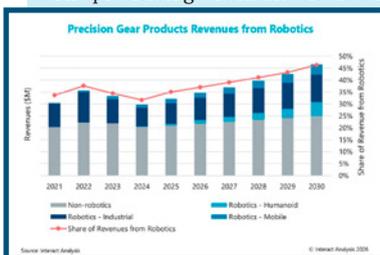


Siemens Digital Industries Software is in the business of solving shop floor challenges across manufacturing. From automotive to packaging, industrial machining to aerospace, the company builds systems with AI and digital tools to enhance efficiency, sustainability and quality control. Matt Jaster, director, editorial content at MPMA, spoke with Raul Garg, vice president industrial machinery, Siemens Digital Industries Software, on the role AI will play in industrial machining, particularly for small to medium-sized manufacturers.

[powertransmission.com/from-assembly-lines-to-algorithms](http://powertransmission.com/from-assembly-lines-to-algorithms)

### Interact Analysis Examines Market Outlook for Gearboxes and Geared Motors

The precision gears market is closely linked to the robotics sector, which contributed 35 percent of global market revenue in 2025, up from 33.6 percent in 2021. By 2030, robotics is projected to account for 46.3 percent of the global precision gear products market. The latest analysis shows sales of precision gear products across industrial robots, mobile robots, and humanoid robots, and indicates the share of revenues from robotics will increase steadily over the coming years.



[powertransmission.com/interact-analysis-examines-market-outlook-for-gearboxes-and-geared-motors](http://powertransmission.com/interact-analysis-examines-market-outlook-for-gearboxes-and-geared-motors)

### Hydraulic Institute Evaluates Cost-Benefit of Motor Rewinding vs. Replacement in Mining Operations

When two critical motors—rated at 18.5 kW (25 hp) and 90 kW (120 hp)—burned out, the maintenance team faced a common decision: rewind or replace. While rewinding is often less expensive upfront, it can result in reduced efficiency.

This Hydraulic Institute case study presents a comparative cost analysis, revealing that motor replacement offers greater long-term value, with a break-even point reached within two years.

[powertransmission.com/hydraulic-institute-evaluates-cost-benefit-of-motor-rewinding-vs-replacement-in-mining-operations](http://powertransmission.com/hydraulic-institute-evaluates-cost-benefit-of-motor-rewinding-vs-replacement-in-mining-operations)



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Michael Goldstein founded *Gear Technology* in 1984 and *Power Transmission Engineering* in 2007, and he served as Publisher and Editor-in-Chief from 1984 through 2019. Michael continues working with both magazines in a consulting role and can be reached via e-mail at [mwg42@hotmail.com](mailto:mwg42@hotmail.com).



Mayr Power Transmission provides brakes for Saueressig's large laminating unit. Photo courtesy of Mayr Power Transmission.

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# Enjoying the View from the Mighty Mac

Matthew Jaster, Director, Editorial Content

My daughter is currently attending Northern Michigan University in Marquette, MI. It's typically a six-and-a-half-hour drive according to the smartphone, but a recent expedition took eight+ hours due to a surprise blizzard coming off Lake Superior.

If you've never crossed the Mackinaw Bridge, I recommend adding it to your bucket list (preferably in spring, summer or fall). The "Mighty Mac" is one of longest suspension bridges in the western hemisphere.

According to the Bridge Authority, 4.5 million vehicles cross the bridge annually. I wonder how many drivers—like myself—spend the 5-mile trek marveling at its engineering swagger. Suspension bridges like the Mighty Mac are designed to accommodate wind, temperature fluctuations and weight. They say the deck at the center span of the bridge can move as much as 35 feet to accommodate huge wind gusts and sub-zero temperatures.

The engineering is quite extraordinary.

The bridge boasts 931,000 tons of concrete. It features 1,016,600 steel bolts and 4,851,700 rivets. There were 85,000 blueprints and 4,000 engineering drawings created during the design process (I complained about the 50-page booklet I needed to help my son build a LEGO castle).

Every time I cross the Mighty Mac, I try to enjoy the scenery, but I'm always thinking more about how a bridge of this size and magnitude opened to traffic way back on November 1, 1957. What did construction look like? How did they reach the finish line?

I think about projects like this all the time.

Whether it's the sheer size of the FCMD components needed for cement production (p.16) or the two-week period Atlanta Gear Works took to rebuild a 145,000 lb. Flender KMS1100 vertical mill drive (p.20), engineering success stories are everywhere.

We've all sat in construction on the freeway complaining about traffic. We roll our eyes when a bridge closes and we're forced to drive ten minutes out of our way. I fondly recall trying to edit books on deadline in Chicago while they built a noisy skyscraper across the street.

I tell myself repeatedly there is a method to all this manufacturing madness. Engineers are building, producing, planning and making our world safe. This country was built on our ability to design, make and provide economic growth.

I was stuck in traffic once on the Mighty Mac. The delay was going to cost me an extra 55 minutes. I had Lake Huron to my right, Lake Michigan to my left and a sunset I could not find the words to describe if you asked me a thousand times. I imagine the workers building the Mackinaw Bridge back in the 1950s did not get much accomplished during sunrise or sunset.

Still, I appreciate every rivet, bolt and blueprint—and I acknowledge all the work needed to get me safely across this engineering marvel each time I cross.

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- Meets military specification MIL-PRF-2105E and API classification GL-5.



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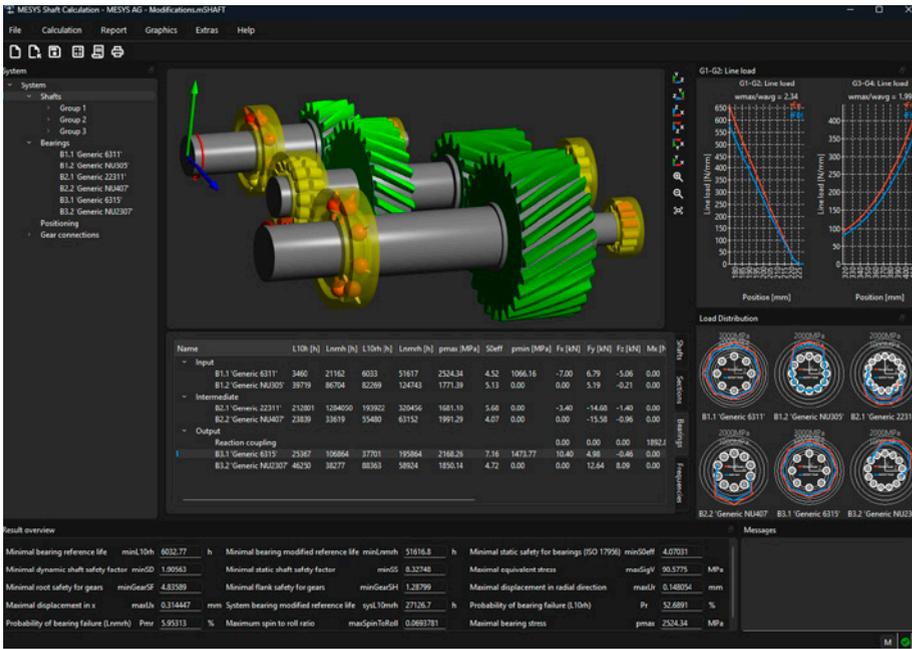
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# MESYS

## Releases Latest Version of Shaft and Rolling Bearing Analysis Software



A new version of the MESYS shaft and rolling bearing analysis software is available. The bearing analysis software allows the calculation of the load distribution within the bearing as well as bearing life according to ISO 16281. It is integrated in a shaft system calculation offering additional capabilities such as modal analysis, strength calculation for shafts and interfaces to gear calculations. Currently the software is used by customers in 32 countries across four continents.

### General Extensions

The bearing databases—including internal geometry from CSC and GMN—are updated. They now include information about the lower shoulder and preloads. The database from HQW/Barden also containing internal geometry is unchanged. Additional encrypted databases containing internal geometry are available from IBC, SLF and GRW, but must be requested from the manufacturer.

Bearing databases with catalog data from NSK and SKF are updated

and a new database from Timken was added.

The lubricant database now supports the definition of viscosities for up to four temperatures. This improves the definition of low or high temperature lubricants.

The appearance of the program can now be adjusted using different styles or font sizes directly in the software instead of configuration files. A dark mode is supported too.

The possibility of defining custom results values was added. This leads to additional possibilities for optimization targets in parameter variations.

### Extensions in the Bearing Calculation

For ball bearings a reduction of clearance due to the lubricant film can optionally be considered. The bearing mass (without cage) is calculated and reported.

For angular contact ball bearings, the lower shoulder can be defined now, before it was set automatically by the software. For four-point bearings optionally contact angles for

both rings can be defined to consider effects of tolerances.

### Extensions in the Shaft Calculation

In the shaft calculation the deflection curves can be shown relative to another part. This allows a better evaluation of clearances between parts as the thermal expansion can be eliminated.

In the 2D-views an option grid and global markers lead to easier estimations of distances.

For cylindrical gear connections additional options for the sizing of profile shift are added and the safety against scuffing is added to result overviews.

The automatic meshing of 3D-FEA based components based on STEP import was improved.

### Extensions in the Cylindrical Gear Calculation

The cylindrical gear pair calculation now also calculates scuffing according to ISO/TS 6336-20/21. In addition to the safety for root and flank strength, the safety for scuffing based on flash and integral temperature is shown.

mesys.ag

# SCHAEFFLER

## Expands OPTIME Portfolio



The Schaeffler OPTIME ecosystem is a condition monitoring and smart lubrication solution. With the FAG OPTIME E-CM (Electrical Condition Monitoring, E-CM), Schaeffler is now expanding its portfolio to include electrical condition monitoring of three-phase motors—such as those commonly used in compressors,

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rotary pumps, fans, blowers, grinding machines and in large quantities in all industrial sectors. Schaeffler is thus taking the next step towards trouble-free production processes.

“Electrical condition monitoring adds an essential perspective to the existing OPTIME ecosystem and enables maintenance teams to detect both mechanical and electrical malfunctions at an early stage,” says Dr. Philipp Jussen, head of Schaeffler Industrial Lifetime Solutions Europe.

The existing OPTIME sensors are specialized in detecting vibrations that indicate premature wear and possible mechanical malfunctions. FAG OPTIME E-CM rounds off the product family by monitoring and evaluating electrical currents and voltage of the electrical drive. “As a result, our customers can now prevent unplanned downtimes in production environments even better,” explains Dr. Philipp Jussen.

For example, FAG OPTIME E-CM enables early detection of insulation faults and damage, cable defects, static and dynamic eccentricity, broken rotor bars, voltage fluctuations, and overcurrents. Customers benefit from improved system transparency, resulting in higher plant availability, proactive maintenance planning, and thus lower costs and personnel expenditure. This is especially true for systems that work in hard-to-reach environments, as the sensors are attached to the cables in the control cabinet.

The technical installation is straightforward for electrical personnel. The system consists of a measuring unit and the sensors for current detection, which are attached to the live cables of the generators in question. Both are in the control cabinets that are easily accessible for maintenance staff.

Either current transformers (split-core) or Rogowski coils (wound coils that are placed around a conductor and record the temporal change of a current flow) may be used as sensors. The distance between the sensor and the measuring unit in the control cabinet can be up to ten meters and is bridged by cable. Additionally, the

three-phase voltage signals of the electrical motor are connected to the main unit.

The measuring unit sends the data obtained by FAG OPTIME E-CM directly and wirelessly via a protected LTE data connection to the Schaeffler Cloud for analysis. In addition to its decades of experience as a manufacturer and developer of rolling bearings, Schaeffler uses modern machine learning technologies and artificial intelligence to find patterns in the data and derive recommendations for maintenance teams.

Maintenance managers receive notifications via their dashboards on the PC or via app when irregularities occur. In addition, the collected data can be used to document and improve existing processes. FAG OPTIME E-CM can be integrated into an existing system or set up as the first OPTIME solution.

With the now even more comprehensive OPTIME ecosystem, complex production environments with many different units can be monitored and maintained easily, efficiently, cost-effectively and reliably. FAG OPTIME E-CM is launching end of February 2026 in Europe and some Asian countries and will gradually be available globally.

[schaeffler.com](https://www.schaeffler.com)

## **RULAND MANUFACTURING Introduces D-Series Six Beam Couplings**

Ruland Manufacturing has introduced its new D-series of six beam couplings, expanding its beam coupling product line to offer one of the most complete selections of standard beam couplings available for precision motion control applications.

D-series beam couplings feature an expanded bore size range up to 1 in (25 mm), angular misalignment capability up to 7 degrees, and an anodized finish for improved corrosion resistance. The six beam design provides higher torsional stiffness compared to single or four beam

couplings while maintaining high misalignment compensation.

Ruland manufactures D-series beam couplings with two sets of three helical cuts with a wide slot, allowing for high axial misalignment. They have the longest size-for-size length in the Ruland beam coupling line, making them ideal for applications with a wide distance between shaft ends.

With the addition of the D-Series, Ruland now offers standard beam coupling solutions suitable for the majority of light- to medium-duty servo and motion control applications. Engineers can select a standard coupling rather than specifying a custom component, simplifying design, qualification, and procurement.

Ruland D-Series beam couplings are carefully manufactured in the USA from meticulously selected 2024-T51 bar stock, using proprietary processes to ensure consistent





autonomous mobile platform, which simplifies material handling and improves operational efficiency.

The booth will feature live demonstrations of several Kuka AMR models, including the KMP 250P, KMP 600P, KMP 1500P and KMP 3000P. These AMRs range in payload from 250 to 3,000 kg, and they fully integrate with the *Kuka.AMR Fleet* software for managing a facility's autonomous vehicles. The display will also include AMRs interacting with a KR Quantec PA palletizing robot, demonstrating the speed, flexibility and efficiency of Kuka's automated palletizing solutions for safer, more efficient material handling.

The KMP 250P is a compact, highly maneuverable AMR designed for flexible deployment. With differential drive technology, the KMP 250P offers excellent maneuverability, and each unit can lift a 250-kg load. The conductive charging station and optional inductive charging solutions ensure continuous operation with minimal interruption.



Kuka's KMP 600P is a compact AMR that can transport up to 600 kg and is particularly suitable for production environments with limited space. It improves storage processes, increases the flexibility of assembly lines and makes material flow more efficient in complex industrial environments. With its differential drive technology, it can move forward and backward in addition to rotating in place and rounding curves with a defined radius.

The KMP 1500P supports transportation and logistics processes with a 60 mm lift stroke, precision positioning and a payload capacity of up to 1.5 tons. Using built-in identification technology and QR

product quality. They are available in bore sizes from 5/32 in. to 1 in. or 4 mm to 25 mm. The D-series is ideal for applications such as encoders, positioning systems, robotics, medical devices, and automation equipment, where accuracy and reliability are critical.

[ruland.com](http://ruland.com)

## KUKA ROBOTICS Showcases AMR Technology at Modex 2026

Kuka Robotics will showcase its broad portfolio of autonomous mobile robots (AMRs) designed for seamless automation integration at Modex 2026, taking place April 13–16 in Atlanta, GA, at the Georgia World Congress Center. Attendees can visit Kuka in Building ABC, Level 1, Booth #B15132 to see live demonstrations of advanced AMR solutions, including the debut of the KMP 250P

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code readers, the AMR can lift and transport a wide range of load carriers, making it easy to integrate into existing production and warehouse environments.

For heavy-duty performance, the KMP 3000P handles payloads of up to 3 tons with millimeter precision. With the same advanced safety provisions as the KMP 1500P, the KMP 3000P is designed to operate safely alongside people while transporting heavy loads using its omnidirectional movement system, which enhances its ability to maneuver into tight spaces, using a “crabwalk” motion for smooth lateral movement. It has a 3D camera on all four sides to aid navigation, avoid obstacles and provide further safety to people working alongside it.

[kuka.com](http://kuka.com)

## STAFFORD Offers Shaft Collars, Couplings and Mounts for Warehouse Automation Systems



A broad line of mechanical components for use such as stops, spacers, shaft connectors, and versatile mounting devices in warehouse automation systems has been introduced by Stafford Manufacturing Corp. Warehouse automation components include several shaft collar designs for positioning, spacing, securing, and limiting motion on

a shaft; rigid couplings for connecting two rotating shafts while allowing for misalignment, vibration absorption, or motion transfer; and motor, bearing, sensor, or bracket mounts. The firm offers over 4,000 standard parts. Suited for use in conveyors, automated guided vehicles (AGVs), robots, and lift tables and sorting systems, Stafford Warehouse Automation Components are available in aluminum, steel, and stainless steel with round-, square-, hex-, and threaded-bores. Popular shaft collar variations include flanged shaft collars, one- and two-piece collars, and quick-adjust shaft collars. Stafford Warehouse Automation Components are priced according to configuration and quantity. Their website provides e-commerce and a CAD library.

[staffordmfg.com](http://staffordmfg.com)

## KOLLMORGEN Advances Linear Motor Safety with SafeMotion Upgrade



Kollmorgen Corporation has released the next update for the *SafeMotion Monitor (SMM)* firmware: *SMM 3.0*. This upgrade expands functional safety support for linear motors and linear axes, helping machine builders implement functional safety in applications ranging from semiconductor manufacturing to battery production and industrial automation that require safety.

Integrated into AKD2G servo drives and the Kollmorgen 2G Motion System, *SMM 3.0* continues to work with all motors that feature

any HIPERFACE DSL rotary-safe feedback system. It also allows the AKD2G drive to now support EnDat 2.2 safe feedback systems to better serve the growing demand for high-performance safety solutions in precision motion control.

The EnDat 2.2 safe protocol, now supported by ADK2G drives and 2G Motion System, delivers dual independent positioning for robust error detection, high-speed serial data transmission for fast cycle times, integrated diagnostics with comprehensive monitoring and flexible encoder support for incremental and absolute feedback drives.

“Linear motors deliver unmatched performance, but implementing functional safety can be challenging,” says Chris Cooper, product management senior director at Kollmorgen. “The newest update for the SafeMotion Monitor (SMM) firmware solves this by bringing EnDat 2.2 safe feedback support to our platform, giving machine builders a complete safety solution that doesn’t sacrifice the speed and precision of linear motors.”

Kollmorgen’s AKM2G and AKMA servomotors also include an EnDat 2.2 safe feedback option, offering even higher performance and accuracy than HIPERFACE DSL for axes where functional safety is required. When combined, machine builders get a complete, integrated motion solution for safety-related applications.

[kollmorgen.com/en-us/solutions/industry/safety](http://kollmorgen.com/en-us/solutions/industry/safety)

## NEUGART Launches a New Performance Class of Precision Gearboxes

Neugart is introducing a new performance class with the new PSNpro, PSFNpro and PSBNpro series. These are based on new gear technologies and the use of new materials in production. The optimized tooth flank quality reduces point load peaks and enables higher torques to be transmitted with the same service life.

The PSNpro, PSFNpro, and PSBNpro series set new standards in dynamic applications. In particular, cycle torque has increased significantly, enabling the pro series to rival and even surpass spur gearboxes. This series is suitable for applications involving frequent changes in load and direction.



Pro gearboxes utilize the advantages of helical teeth to achieve excellent synchronization. Transmission fluctuations between the input and output remain extremely low throughout the rotation of the output shaft. This visibly improves

process quality and minimizes chatter marks in woodworking machines, for example. At the same time, the gearboxes operate at a particularly low noise level, even under high loads. This improves the system's acoustic properties and stabilizes the machine's overall performance.

Another area of development focused on reducing mass inertia, particularly in small frame sizes. Thanks to the consistent implementation of the modular principle, the input stage is now from frame size 064 smaller than the output stage. This reduces the rotating mass, enabling faster acceleration and braking processes, as well as improving control quality in highly dynamic axes.

Neugart offers the usual gear ratios, sizes, and options for the pro series—even a factory-mounted pinion on the output shaft, ideal for pinion-rack drives, is included as standard.

[neugart.com](http://neugart.com)

## EATON Showcases Mobile Power Innovations at 2026 Heavy Duty Aftermarket Week



Eaton recently showcased four new mobile power innovations at the Heavy Duty Aftermarket Week (HDAW) show in Grapevine, TX. The new offerings expand Eaton's already comprehensive vocational and heavy-duty truck portfolio, delivering greater flexibility, reliability and performance for fleets and upfitters.

Champion athletes possess an impressive arsenal.

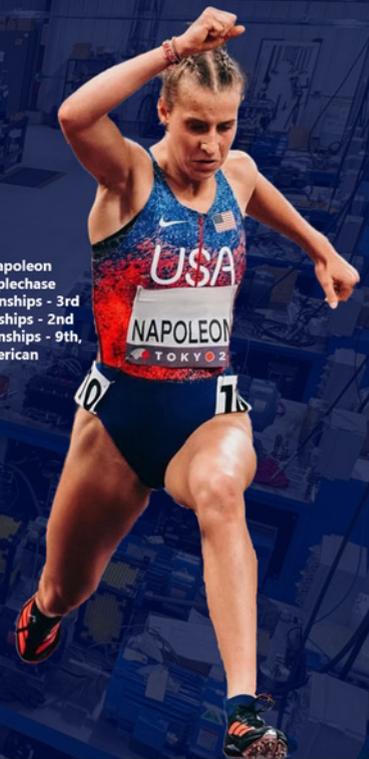


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Eaton introduced the all-new PT 500 Series PTOs, purpose-built for Dodge transmissions, including compatibility with ZF PowerLine 8AP and Torqueflite HD applications. Designed for demanding vocational use, the PT 500 Series features a low-profile hot-shift two-gear PTO design with hydraulic shifting in stationary mode. The PTO mounts laterally on either side of the transmission, giving upfitters installation flexibility.

The PT 500 Series delivers continuous torque up to 380 Nm (280 lb.-ft.) and intermittent torque up to 530 Nm (391 lb.-ft.), with power output reaching 40 kW (54 hp) at 1,000 rpm. An engine-to-PTO ratio of 1:1.21 supports efficient power transfer, while the compact 24 kg (53 lb.) design helps minimize added vehicle weight. For smoother engagement and reduced torque peaks, Eaton will also highlight its optional soft electro-hydraulic soft-start shifting kit, designed specifically for hot-shift PTO applications.

Designed for the next generation of automated transmissions, Eaton's new hot-shift PTO for the Endurant transmission enables smooth clutch-free engagement, even in stop-and-go or continuous-duty environments. By allowing PTO engagement under load, the system improves operational efficiency and helps reduce downtime in demanding applications such as refuse, utility and construction.

"These new products represent Eaton's continued commitment to building smarter, more efficient solutions that meet the evolving needs of the commercial vehicle market," said Brad Gulick, commercial product manager, Eaton's Mobility Group. "Our customers rely on Eaton for performance and durability, and we're excited to bring expanded PTO and hydraulic options to help them do more with less complexity and greater uptime."

[eaton.com/us/en-us/products/transmissions/bezares-mobile-power-solutions.html](https://eaton.com/us/en-us/products/transmissions/bezares-mobile-power-solutions.html)

## ABB Introduces Automation Extended Program Enabling Industrial Innovation with Continuity



ABB has introduced its Automation Extended program, a strategic evolution of its distributed control systems (DCS), designed to help industries modernize without disruption. Building on ABB's long-standing leadership with the world's largest DCS installed base and vision in process automation, Automation Extended outlines how future automation capabilities can be introduced progressively—preserving system integrity while enabling the flexibility, scalability and efficiency needed for the next era of industrial operations.

Industrial operations today face volatile markets, cyber security challenges, regulatory pressures and a rapidly changing workforce. ABB's Automation Extended addresses these realities by enabling innovation with agility and pace without disruption to production, supporting advanced analytics and IoT integration, and simplifying operations for diverse skill levels.

Automation Extended will positively impact the evolution of ABB technologies currently active in the metals industry including ABB

*Ability Manufacturing Operations Management for Metals, ABB Ability Data Analytics Platform for Metals, Advanced Process Control (APC), Advanced Performance Management and ABB Ability Connected Worker technologies.*

Across industries, operators can continue to rely on trusted ABB systems such as *ABB Ability System 800xA, ABB Ability Symphony Plus and ABB Freelance*, while introducing new technologies progressively and without operational interruption. This approach provides a structured, low risk path to modernization, preserving continuity while enabling innovation.

"In industries we serve—many operating large and complex infrastructures that deliver essential resources—our customers rely on modernization without disruption," said Peter Terwiesch, president, ABB's Automation business area. "Automation Extended delivers exactly that: bringing future-ready capabilities into the systems they know and trust, with security and interoperability at the core."

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# Precision Under Pressure

## Optimizing cement plant performance through advanced gearing systems

Matthew Jaster, Director, Editorial Content

*Cement producers are seeking environmentally efficient, innovative and responsible manufacturing techniques to establish a clearer path toward carbon neutrality.*

Mechanical engineering develops the scientific and mathematical principles behind physical machines, but you can't help feeling a little real-world magic taking place in the manufacture of components needed for large, heavy industrial applications. Cement production, for example, relies on gigantic equipment to grind raw materials using rotary kilns, ball mills, vertical mills and crushers.

The challenge in 2026 is to maintain existing plants and provide the production upgrades required for future cement production. Enter FCMD, a Ferry Captain and CMD Gears company, a single-source supplier in the cement industry offering ring gears and pinions, gearboxes/inching drives,

trunnion and ball head mills, pinion bearings out of Babbit Metal, gear/grid couplings and more.

"FCMD provides everything from design and manufacturing to installation and maintenance," said Victor Manoury, sales engineer at FCMD North America. "We focus on high-torque, low-speed applications including custom-made gearboxes, worm gear and planetary gearboxes and kiln gear drives."

### Cement Production Strategies

Cement producers are seeking environmentally efficient, innovative and responsible manufacturing techniques to establish a clearer path toward carbon neutrality. This



“  
Each project adds to our knowledge base, informing the next, refining our designs, and deepening our understanding of how our equipment performs in the field. We don't just manufacture parts; we engineer complete solutions grounded in real-world performance data and customer feedback.

Victor Manoury,  
sales engineer,  
FCMD North America

”

aligns with the sustainability push taking place across heavy industrial sectors including mining, construction, aggregate, off-highway and agriculture.

“This is truly one of the biggest challenges today in cement,” Manoury said. “Reducing energy consumption, decarbonizing plants and finding cleaner and more efficient solutions to produce cement.”

Furthermore, the cement industry is extremely competitive. Manoury said suppliers must be aware of pricing, lead times, service and support, etc. Companies seeking contracts must assume five other suppliers are working on the same open bid.

“Given the larger nature of the products we deal with (high-torque/low-speed applications), naturally buyers turn to worldwide solutions. There's a constant struggle to fight against cheaper, alternative solutions across the globe,” Manoury added. “To stay relevant in these industries, we focus on quality, reliability and added value, rather than price alone. It helps to offer 150+ years of experience as well as a team of dedicated engineers.”

Flexibility—it turns out—is one of the most important aspects of cement production. The success of a component upgrade or a gearbox replacement depends largely on clear and concise communication with the clients. FCMD North America acts as a direct link between the French engineering offices and the U.S. end users, ensuring smooth coordination and quick decision-making.

“If our customer is transparent and shares the date of an outage, for example, we can figure out how to get the equipment up and running as quickly as possible,” Manoury noted.

### Technologies for Cement Applications

With so much experience in cement production, Manoury discussed how CMD knows the customer's specific difficulties and pain points. They developed the Kiln Gear Drive (KGD), a three-degree of freedom system, that allows perfect meshing from the pinion to the ring gear. Customers provided feedback on issues such as pitting and, in extreme cases, tooth rupture, resulting from the complex running behavior of the kiln. The deformation of the kiln shell often altered the girth gear geometry, creating misalignment and accelerated wear.

To address these recurring problems, CMD engineered a completely new solution the “KGD” specifically designed to compensate for kiln movement and maintain optimal gear engagement throughout operation. This unique system includes the gearbox, pinion and ring gear all as one solution. The technology has been around since the late 2000's and fits the cement industry perfectly. By introducing the Bogiflex KGD (Kiln Gear Drive), CMD made the drive system an integral part of kiln performance by enhancing its reliability and performance.

The Bogiflex is a floating and self-aligning gearbox. It follows the movement of the girth gear, and therefore kiln shell, in every direction. It compensates for any kiln deformation or movement and ensures that pinion-girth gear meshing conditions are always constant. The CMD Bogiflex KGD components include standard components and therefore allow commonality of spare parts between several plants. The tuning of the drive reduction ratio is obtained by adjusting the specification of the primary gearbox. Three standard sizes of Bogiflex KGD units exist so far which cover most existing kiln sizes.

Another major technological advancement in cement solutions is the development of FerryNod, a proprietary ferrous alloy created by Ferry Capitain. With a hardness range between 250 BHN and 340 BHN, FerryNod is a ductile iron material designed in full compliance with AGMA 6014/ ISO 6336 specifications.

“Our foundry capabilities enable the production of large-scale components such as ring gears up to 16 meters in diameter, mill heads and trunnions, all cast using FerryNod. Originally developed to meet demand for larger and more robust equipment in the mining industry, this material has proven to deliver exceptional performance under heavy-duty conditions. The name FerryNod reflects its core achievement: surpassing the stress values defined by AGMA standards, offering our customers a solution with superior mechanical properties, shorter lead times, and lower costs compared to conventional cast steel,” Manoury said.



*FCMD's commitment extends far beyond manufacturing and delivery. The company believes true reliability comes from long-term partnership with each cement producer.*

## Live Monitoring, Drop-In Technology and Safety

Live monitoring has become a key focus for cement plants, particularly for maintenance teams striving to enhance safety and prevention. Thanks to advances in digital technologies, it is now possible to monitor an entire plant's equipment in real time directly from a control room. Even the slightest variations in vibration or temperature can be detected instantly, allowing for early intervention that protects equipment integrity and prevents costly unplanned downtime.

As a supplier of drive components for critical cement equipment (kilns and mills) FCMD places special emphasis on monitoring solutions.

“To address these needs, we have developed the Connected Pinion, an innovative system designed to detect misalignment, lubrication disturbances, and abnormal operating conditions that can lead to scuffing, pitting, or even cracks. The Connected Pinion is equipped with embedded temperature sensors located near the active flank of the tooth, providing operators with precise, real-time temperature data. When irregularities are detected, the system emits immediate alerts, allowing for rapid corrective action before any damage occurs,” Manoury said.

In addition, FCMD partners with specialized monitoring experts who provide comprehensive live-monitoring

capabilities for position and temperature, for all drive components- ring gears, gearboxes (planetary, parallel, etc.), and complete drivetrains. These systems integrate alarm signals, predictive analytics, and continuous data collection, ensuring quick diagnostics and expert analysis to determine the right corrective actions and prevent unplanned downtime.

Unlike the mining industry, which often drives innovation through new projects and disruptive technologies, the cement sector focuses primarily on maintaining and upgrading existing equipment. Most investments involve modernizing older systems rather than building entirely new ones. This is where drop-in replacement systems play a crucial role. They allow operators to repair or replace aging components while simultaneously upgrading performance. Thanks to modern manufacturing techniques and advanced heat treatment processes, today's gears offer significantly higher durability and resistance than those produced decades ago.

“As an engineering-driven company specialized in gear systems, FCMD views every retrofit or replacement project as an opportunity to enhance reliability and optimize design. For example, our engineers can redesign a gearbox to serve multiple applications through smart modular design—allowing the same unit to fit two types of equipment. This approach not only reduces spare parts inventory but also improves overall system reliability and efficiency.”

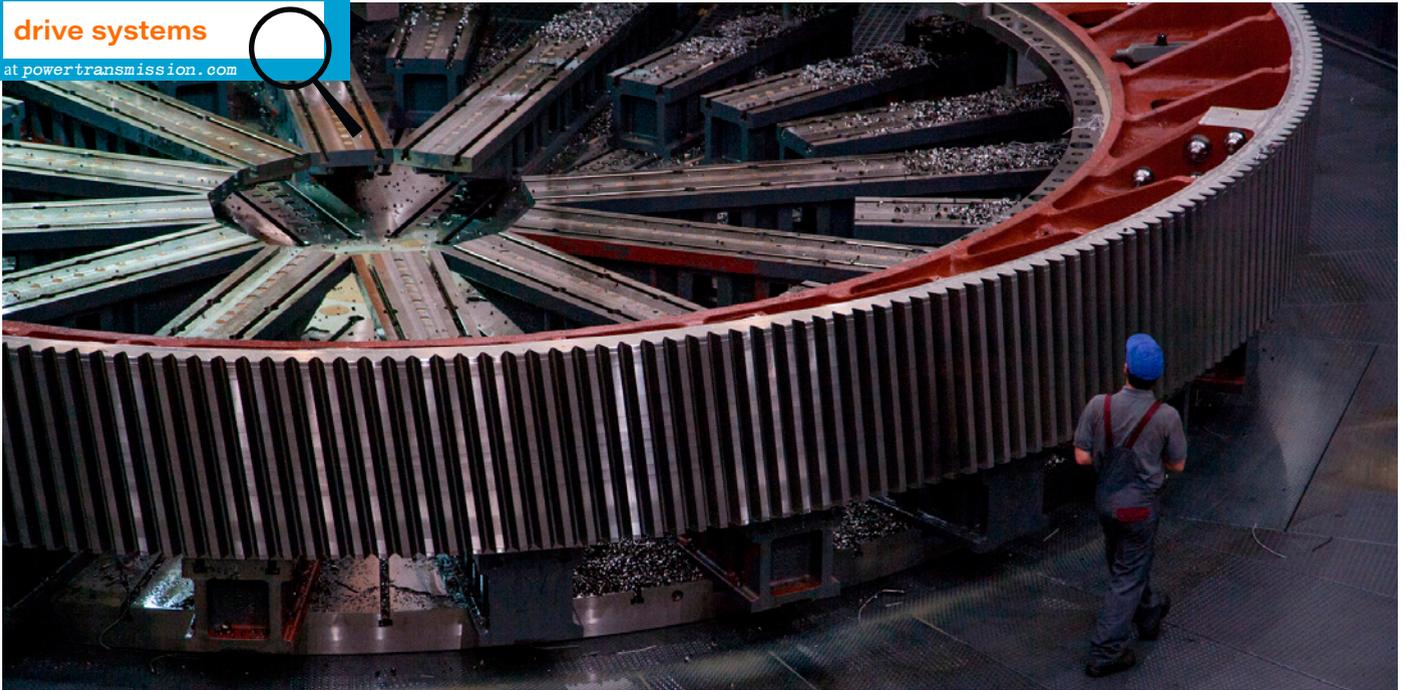
Safety continues to be a focal point in cement production. There's an increase in safety across all the market segments. From torque-limiting couplings that protect not only the equipment but also the maintenance personnel in the factory to hydraulic inching drives systems used to perform maintenance on horizontal mills.

These hydraulic systems are also highly adaptable and can be customized to suit mills of different sizes and configurations. A frozen charge occurs when material solidifies inside the mill, causing an imbalance that can damage the equipment if restarted without proper management. The hydraulic inching drive helps detect frozen charges by rotating the mill slowly and monitoring the resistance or torque feedback during the process before startup.

## Service and Support: The Work Continues

Manoury said FCMA's commitment extends far beyond manufacturing and delivery. The company believes true reliability comes from long-term partnership with each cement producer. “The goal is to ensure continuous technical support, spare-part availability and on-site expertise throughout the full life cycle of every piece of equipment. Each project adds to our knowledge base, informing the next, refining our designs, and deepening our understanding of how our equipment performs in the field. We don't just manufacture parts; we engineer complete solutions grounded in real-world performance data and customer feedback,” Manoury said.

A horizontal mill gearbox will never face the same thermal and mechanical constraints as a kiln drive. That's why every FCMD solution begins with the right



FCMD provides everything from design and manufacturing to installation and maintenance in cement production.

questions: What are the site conditions? How often is the equipment cycled? What temperatures, humidity, and altitude will it operate under? These details matter and they shape every design decision.

### The Evolution of Cement Production

Maintenance is vital in cement production. Manoury said the mechanical drive components that keep a kiln or mill turning operate under extreme conditions—high loads, constant vibration and heat. When those systems stop, production stops. Most cement facilities have at least one outage per year. It is critical to swap the bearings and inspect the gears.

“It’s very easy to get to a point where you’re damaging the equipment in cement applications. Do we see any wear or tear on the tooth surface? Are we using the right amount of lubrication? Is the lubricant the right quality? The plant itself sometimes has stricter MRO policies in place than the provider of the components and equipment. It’s also critical to have the right amount of spare parts on hand at every cement plant,” he added.

They’re putting AI and automation into everything today, so Manoury said he assumes this will eventually take place in these heavy industrial applications as well.

“We’re already seeing automated drones for inspections on cable lines, terrain analysis, etc. I could see that being integrated within the heavy industry too... I mean we touch based on it previously, sensor-embedded gearboxes and pinions will make it possible to continuously monitor temperature, vibration, and torque in real time. These systems will feed data directly into AI-based models capable of predicting failures with remarkable accuracy.”

However, technology alone won’t replace human expertise, it will only enhance it. The interpretation of the data, the understanding of gear contact patterns,

and the ability to connect field observations with design intent will still depend on experienced engineers.

There will come a point in time when complete smart factories will be used in heavy industry. This digital transformation will make cement plants more responsive, more reliable, and ultimately more efficient. In the longer term, true disruption could come from a breakthrough in how cement itself is made.

“Eventually everything in cement plants will be monitored. The core components and processes themselves may not change dramatically—they’ve remained largely the same for decades. What will change is how we operate and maintain them. The industry is moving toward smarter, more connected equipment. We can expect a steady rise in automation, sensors and real-time monitoring systems that provide live insight into performance, wear and efficiency.”

If engineers ever discovered a carbon-free, cost-effective alternative to traditional steel production, Manoury said this would fundamentally reshape the industry.

“Until then, the evolution will focus on making today’s systems smarter, cleaner and more connected.”

*fcmdna.com*

**PTE**

### Additional reading:

Check out these recent *PTE* articles on the benefits of inching drives and a case study on upgrading planetary gearboxes for a ski lift application:

[powertransmission.com/benefits-of-inching-drives](http://powertransmission.com/benefits-of-inching-drives)  
[powertransmission.com/needle-of-the-midday](http://powertransmission.com/needle-of-the-midday)



Atlanta Gear Works brought in a rigger with two 100,000-pound capacity forklifts to remove the gearbox from the trailer (all photos courtesy of Atlanta Gear Works).

# On the Fly Rebuild

## Atlanta Gear Works takes on tight deadline for vertical mill drive project

Matthew Jaster, Director, Editorial Content

The call came into Atlanta Gear Works like any other—a vertical mill drive used for a crusher application in cement needed a gearbox upgrade. The difference this time was the sheer size and scope of the gearbox in question. Similarly-sized gearbox rebuilds could take a month or more to complete, but Atlanta Gear Works had 14 days to complete this rebuild—counting weekends—with a tight schedule leaving no room for error.

“Several accommodations were required at the beginning,” said

Taylor Sims, senior engineer, at Atlanta Gear Works. “Size, weight, tooling, personnel were all critical factors. We needed to ensure we had the lifting capacity and the proper space to disassemble and reassemble the gearbox in the shop.”

### A Logistical Challenge

At the outset, the biggest challenge was the weight of the gearbox. It was the heaviest one Atlanta Gear had ever worked on and required flexibility in the shop.

“We have a 50-ton overhead crane on rails in our main assembly building, but we could only lift individual components for this job,” Sims said. “Getting the gearbox to the shop, off the trailer and into the building was a pretty big undertaking.”

Atlanta Gear Works needed special permitting and custom trucks and trailers just to get the gearbox to the shop. Even with the company’s high-capacity cranes and forklifts, they could not lift the entire 145,000-pound gearbox off the trailer.



“We had seven other gearboxes being assembled and four other gearboxes being torn down. Plus, a machine shop that is making parts daily for everything we need. It took a total team effort.”

Taylor Sims, senior engineer, Atlanta Gear Works

“We brought in a rigger with two 100,000-pound capacity forklifts to remove it from the trailer and into the building. Once the gearbox was inside the building, our equipment was able to move it piece by piece,” Sims said.

Craig Massa, vice president-sales, Atlanta Gear Works, said manpower was another critical challenge. Did they have enough personnel to work on this new rebuild? Would the size of the gearbox interfere with other projects taking place on the shop floor?

“We had seven other gearboxes being assembled and four other gearboxes being torn down,” Sims added. “Plus, a machine shop that is making parts daily for everything we need. It took a total team effort.”

Flender sent an experienced German gearbox technician from Canada who supplied Atlanta Gear Works with tech support and drawings that saved additional time.

Sims said the key to meeting the tight deadline was being prepared during the planning phase.

“Before the gearbox arrived, we formulated an action plan, purchased some special tooling for disassembly and assembly and knew exactly who would be responsible for what on the shop floor,” Sims said.

Luckily, they had history with both the customer and the vertical mill drive. Atlanta Gear Works had detailed engineering notes from looking at the gearbox the year before. This gave the company a headstart on the project.



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*Atlanta Gear Works personnel repair the housing lid bore.*



One of the greatest challenges was the weight of the gearbox itself and required flexibility in the shop to perform the necessary upgrades.



Disassembling the gearbox.

## Increased Repair

After disassembly, they discovered further equipment damage they had not anticipated, all of which required extra work with no additional time allotted.

Sims said damage from a previous build prevented the hydraulic fit from being utilized to remove the table. Before the rebuild could proceed, they had to add the task of configuring a strongback and a hydraulic ram that were powerful enough to remove the table without the hydraulic fit.

Additionally, the output shaft extension side bearing bore was damaged from a bearing spinning in the bore. They repaired the bore by machining out the damaged section and inserting a sleeve. The housing section weighed 30,000 pounds, which they were able to accommodate in a CNC horizontal boring mill. The machine shop's resourcefulness enabled Atlanta to repair the housing to OEM specifications.

One challenge requiring extra hours occurred when the customer supplied an OEM Babbit bearing assembly that was incorrect for the gearbox. Seven of the twelve Babbit pads were missing machining features critical for operation. To remain on schedule, AGW's machine shop worked through the night to machine the pads for installation the next morning.

## All Hands on Deck

Sims said the gearbox rebuild required everyone's assistance across the shop. "Everyone in the company needed to contribute to help reach the finish line."

He added that people on the project were selected from various departments so as not to deplete any one group. Several employees worked extra hours even on weekends.

"Throughout the project, they were resourceful in solving countless unanticipated problems and stayed committed to a job well done even when it required sacrificing personal time to accomplish it," said CEO Jack Conway.

Atlanta Gear Works has invested in machine technology in recent years including four Kapp Niles grinding machines, four CNC Mazak lathes and other machine tools for gear cutting, grinding, checking, inspection, testing, dynamic balancing and more.

Safety was an important aspect with so many moving parts to this project.

"Flender's ideology is like ours. We know how critical it is to keep the environment clean and keep the parts clean during reassembly. We try to follow that kind of thought process," Sims said.

With years of experience working with Flender equipment, Atlanta

Gear Works recently became certified as an official Flender Service Partner. The company underwent a rigorous two-day audit that covered everything from its environmental, health and safety plans to its manufacturing procedures and operations, including data control, training and even the cleanliness of the facility.

"The two companies share similar protocols when it comes to safety, and our experience working with Flender has given us an edge when it comes to updating or refurbishing any of their equipment," Sims said.

The most satisfying element of this project was knowing Atlanta Gear Works has the capabilities and engineering knowledge at their disposal to work on these heavy-duty applications in the future, fast and efficiently.

"It's the confidence in completing a project like this under a strict deadline," Sims said. "This is the biggest one we have done, but I am sure we will be taking on bigger gearbox projects in the future. Knowing we have the right personnel and equipment in place to keep these projects running smoothly certainly helps."

[atlantagear.com](http://atlantagear.com)

**PTE**

# Examining the EV Revolution

## The North American outlook in 2026



Norm Parker, Stellantis

We have all seen the Q4 2025 headlines around electric vehicle (EV) sales and they were not good. Ford recorded a \$19.5B loss in EV pullbacks (Ref. 1). General Motors posted \$6B in EV debt (Ref. 2). Stellantis took a \$26B hit which was compounded by underperforming EV sales and recovery from the previous CEO's disastrous cost-cutting strategy (Ref. 3). Also, notably, was the laundry list of not-long-ago hailed startups that have went bankrupt, often leaving investors, suppliers and employees holding the bag: Bollinger, Canoo, Nikola, ELMS, Lordstown, Fisker, Arrival, Proterra, Volta just to name a few. Many more are on the brink along with dozens of startup suppliers that enticed investors with untold wealth to be gained in the automotive revolution 2.0 (Ref. 6,13,14).

As Cox Automotive recently reported, 2025 posted the best non-EV vehicle sales since pre-COVID and

EV sales came in at 7.8 percent. We were on track for 10 percent for three quarters before the incentives expired at the end of September. "2025 unfolded largely as anticipated, with changes to federal EV incentives reshaping the demand patterns that drove record Q3 sales," (Ref. 8) How did we go from 2021 when CEOs were claiming that millions of sales were just around the corner to 2026, when we are talking about billions of write-downs due to cancelled EV contracts (Ref. 5)?

2021 was before the lion's share of the money was spent. There was still time to correct the course - the ship(s) had not yet sunk. Yet here we are. There is great confusion among my friends and colleagues about how industry leaders were this far off the mark. Even to the non-automotive professional, it was



*EV charging (courtesy of Envato).*

obvious that the wild projections could never be met. Yet the CEOs who are paid Hollywood money to get the answers right, all got it wrong.

A good economy can forgive many sins, superficially. The real damage to people and suppliers, however, will take years to clean up. When a supplier is awarded a contract, there is an agreed volume range. For instance, if the minimum target is 500k parts; the supplier does not just get to say they can make 500k parts. They must, in real time, demonstrate they can make 500k parts. This means that by the time that production starts the location, equipment, material, people, packaging, logistics and initial inventory have all been defined in detail. Now, let's say the 500k orders are not coming in...it's only 50k orders. Almost immediately, workers need to be laid off because the



*Electric car assembly line (courtesy Adobe Stock/Ivan Traimak).*

suppliers must begin repayment of the loans, and the reduced income is not sufficient to sustain the debt. If the volumes stay low; eventually, the manufacturer will issue a volume update, and the supplier can start a claim process for unused equipment, material and related expenses. However, this is often a slow process, and many suppliers cannot ride out the debt long enough to remain solvent. As a result, factories close, people lose jobs, and houses are sold at a loss because people cannot afford to keep them. This is the real side of poor decision making. However, you can rest assured that the people that made those decisions are doing just fine.

The current economy is generally healthy in terms of GDP growth and consumer spending, though stagnating jobs are a moderate concern. The GDP is growing, but jobs are not increasing at the same rate. There is uncertainty regarding tariffs, future EV policy and trade relations which create consumer anxiety for some buyers—potentially putting off new purchases for a year or downsizing purchasing plans (Ref. 10). Additionally, there is concern of China controlling the majority of rare earth minerals that are needed for battery and motor production (Ref. 15).



**Disassembling the battery of an electric vehicle engine (courtesy Adobe Stock/romaset).**

We continue to expect semiconductor shortages as AI data centers have dramatically increased global demand. There is a looming shortage of DRAM (Dynamic Random-Access Memory), on the horizon with an overall increase in memory prices (Ref. 16). There is excitement around the digital transformation of the vehicle cockpit with AI advancements. Sophisticated vehicle interaction and infotainment features are expected to be a focal point over the next several years.

For 2026, U.S. sales for non-EV vehicles are anticipated to be on par with 2025—which was the best post-COVID year to date. The EV market is not as optimistic with Bloomberg predicting an “EV Winter” in 2026 as sales

continue to slide following the loss of buying incentives. The U.S.-based full electric vehicle sales are forecasted to be at least 15 percent lower than 2025—optimistically, around 1 million vehicles for 2026 (Refs. 9,11,12,17).

From an insider and engineering perspective—I view electric vehicles as a great option for predictable commutes and in areas where the charging systems are known and reliable. Several major fueling stations have started picking up chargers such as Loves and Circle K with others joining. This will be a huge move in reducing range anxiety. In terms of engineering complexity—the mechanical complexity is dramatically reduced in an EV. Between an internal combustion engine + automatic transmission—we go from perhaps 3,000 parts to maybe 300 (varies widely depending on the type of box).

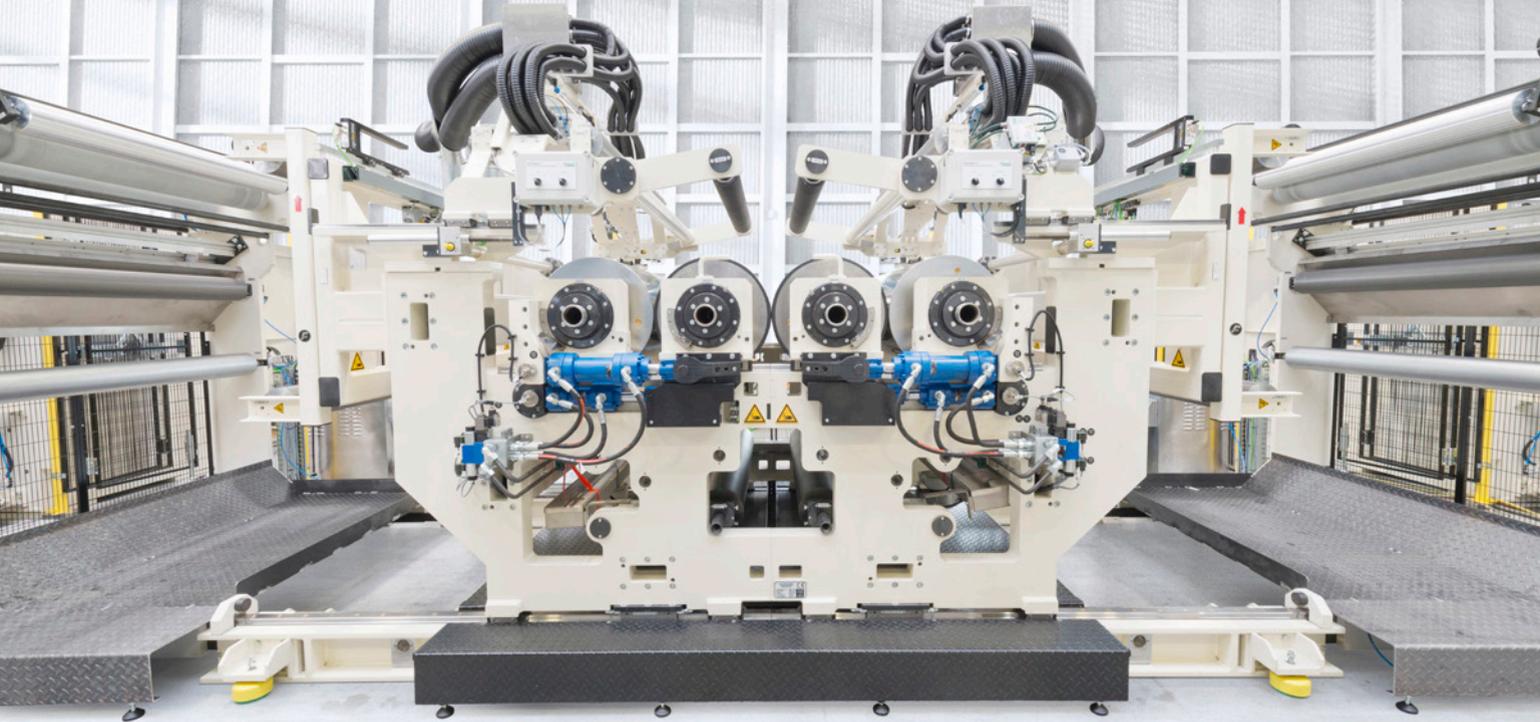
However, the complexity is not truly reduced. It is simply transferred to different components. The battery, PIM, motor, ECU network is amazingly complicated and usually creates the most trouble in EV reliability. This is a slow-moving train, and there are no real deadlines other than the man-made ones which are usually attached to contracts. This market will grow and improve at the pace that people and the market provide. Eventually buying gas vs. electric will not be any more dramatic than deciding if you want a gas or electric chainsaw.

**PTE**

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# Quick-Change Artists



## Printing and embossing manufacturer applies Mayr ROBA Guidestop brakes for custom system solution

*Saueressig has evolved from being a manufacturer of printing and embossing rollers to becoming a highly innovative machine manufacturer with a diverse product range.*

In a large laminating unit by Saueressig Engineering for laminating steel strip on both sides, rubber rollers press a protective PET film onto hot steel strip. Despite cooling, these rubber rollers do wear down and need to be replaced regularly. Four profiled rail brakes by Mayr Power Transmission ensure that the laminating process, which takes place 24 hours a day, only must be interrupted briefly to replace the rollers.

Saueressig began manufacturing printing and embossing rollers for the packaging and printing industry around 70 years ago. Today, the company is a highly innovative mechanical engineering company with a diverse portfolio. As a leading full-range supplier of calendering, embossing and rotary processing systems in standard and special designs, the company supplies a wide range of industries.

The machine solutions include both complete production lines and customized systems for embossing, finishing, coating, smoothing, perforating and calibrating sheet materials such as paper, film or metal sheets. The company offers comprehensive expertise from the initial idea to the final customized solution, including planning and designing mechanics, drive and automation technology,

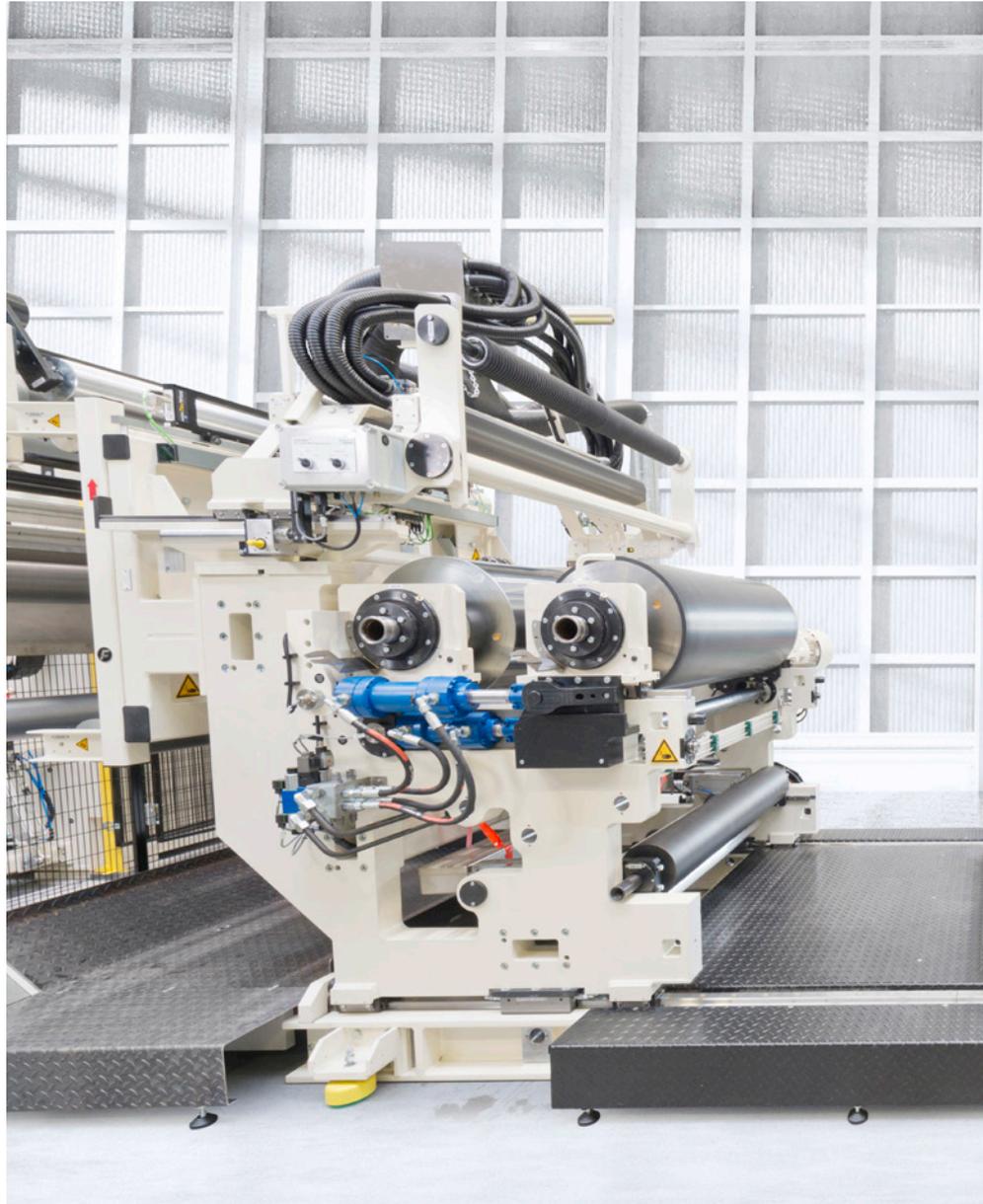
pre-assembly and commissioning in the factory, and final approval at the customer's premises.

One such customized system, no less than six meters long and around four meters wide, coats a steel strip on both sides with a thin protective PET film. Harald Bartsch, head of design/expert advisor at Saueressig Engineering, described the machine's design concept:

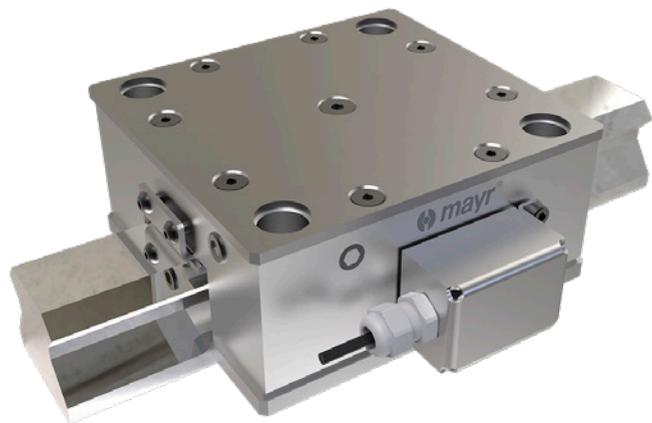
"The complete laminating unit consists of two nearly identical, symmetrically arranged side frames, each with a rubberized laminating roller and a contact cooling roller. For laminating, the steel strip moves vertically between the two laminating rollers through the laminating unit at a conveying speed of up to 250 m/min. The laminating rollers press the film onto the hot steel strip from both sides."

The steel strip's high temperatures of up to 260°C heat up the rubber coating on the laminating rollers. Water-cooled contact rollers dissipate this heat and limit the rubber coating's temperature to a maximum of 90°C. Despite the cooling, the rubber linings of the laminating rollers are subject to wear and must be replaced regularly. "As the laminating process should ideally be running continuously all year round and 24/7 without interruption," explained Bartsch, "the time required to replace the laminating rollers must be kept as short as possible. Therefore, the laminating unit is designed in such a way that the automated roller replacement only takes half an hour."

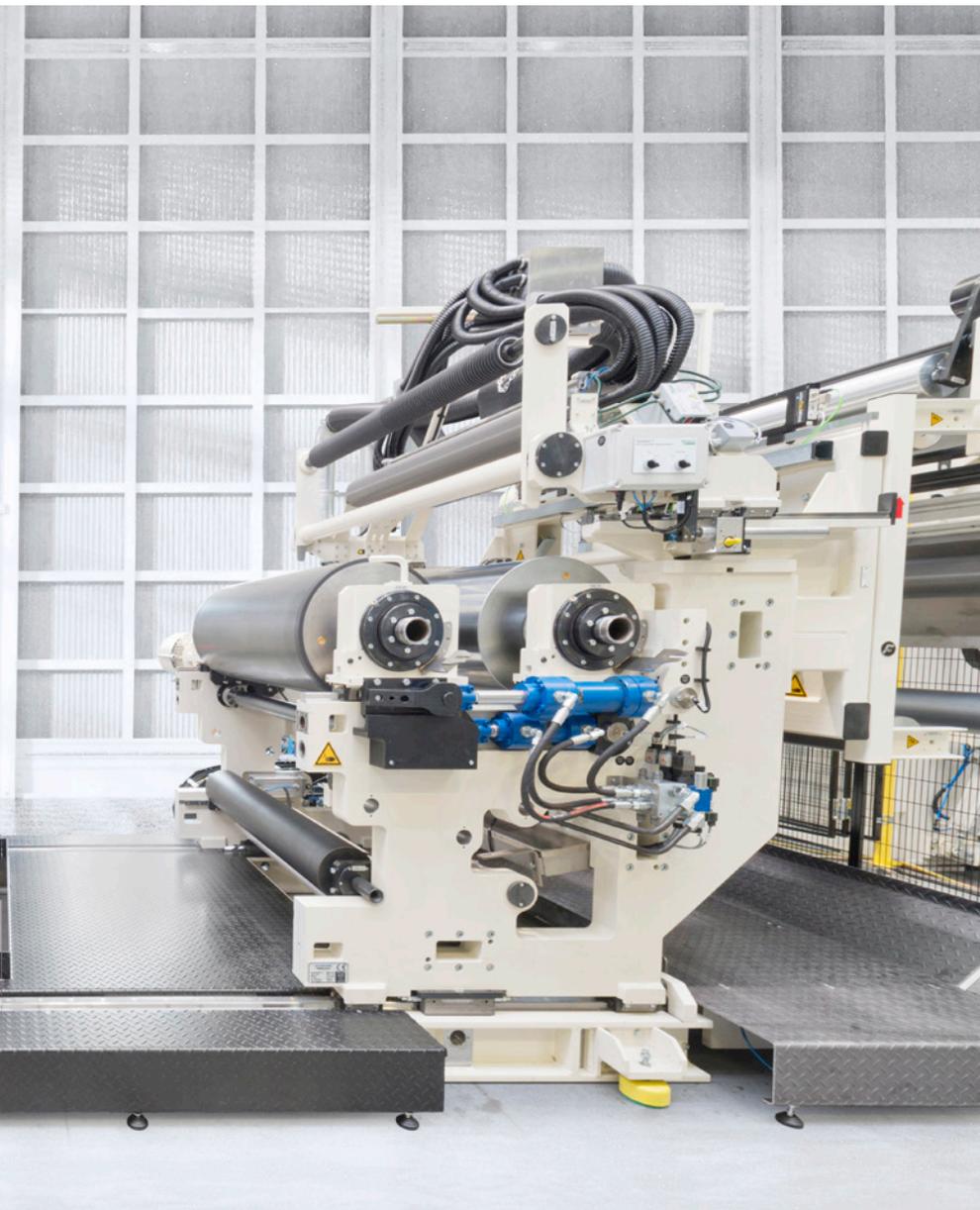
The laminating unit consists of two symmetrically arranged side frames. Both side frames are mounted onto profiled rail guides and can be separated axially to replace the worn laminating rollers. While the coating process is in progress, profiled rail brake of the ROBA Guidestop series by Mayr Power Transmission hold the two system parts in position backlash-free and with high rigidity. To replace the rollers, these safety brakes are



*Saueressig's large laminating unit coats both sides of the steel strip with a protective PET film.*



*Profiled rail brake of the ROBA Guidestop series by Mayr Power Transmission hold the two system parts of a large laminating unit in position backlash-free and with high rigidity.*



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released hydraulically, the two machine halves can be moved apart via rack and pinion gears, and the laminating rollers can be replaced.

The ROBA Guidestop profiled rail brake serves as a reliable safety brake and backlash-free clamping unit. It can brake movements safely and quickly and clamps the axes rigidly and backlash-free. Just like all safety brakes by Mayr Power Transmission, the profiled rail brakes

also work according to the fail-safe principle. This means they are closed in de-energized conditions. The ROBA guidestop brakes use pre-tensioned cup springs to press the brake shoes against the 'waist' of the profiled rail, thus clamping it in place.

The hydraulic brake design used in the Saueressig laminating unit is released using a nominal pressure of 70 bar. This is comparatively

low in relation to the very high holding forces. The brake mechanism is dimensioned for relatively large strokes. As a result, the brake can compensate for production tolerances on the profiled rails without losing braking force. The ROBA Guidestop safety brakes are equipped with two independent brake circuits: This allows for either double holding forces or a redundant design.

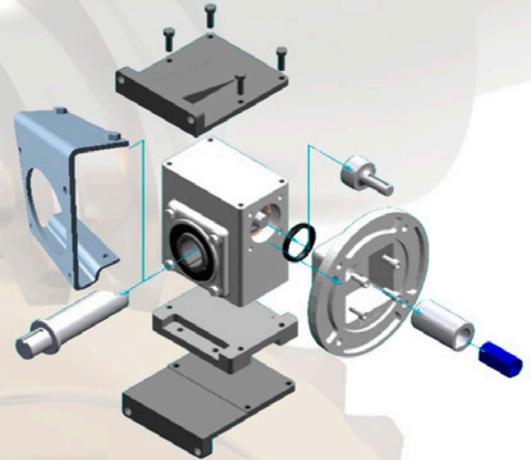
The profiled rail brakes are therefore directly mounted onto the masses which are to be braked or held. This minimizes the risk of hazards, particularly with gravity-loaded axles, as drive elements between the motor and the moving mass, such as spindles, spindle nuts, shaft couplings and gears, do not affect safety. This is different for concepts with motor brakes, as all drive elements must transmit the braking torque to the carriage. Furthermore, every element between the brake and the carriage has a negative effect on rigidity.

ROBA Guidestop safety brakes are therefore considerably more rigid than motor brakes, rod brakes or band brakes, which are often subject to backlash. ROBA Guidestop safety brakes by Mayr Power Transmission are available in pneumatic or electromagnetic versions in addition to the hydraulically opening design. The hydraulically releasing ROBA Guidestop series covers nominal holding forces from 5,000 to 34,000 N with four sizes. The pneumatically releasing version offers the greatest variety of options: Six sizes with nominal holding forces from 700 to 15,000 N are available in the standard product range. Both versions (i.e., pneumatically and hydraulically releasing) are available for all common linear guides. Electromagnetically opening rail brakes do not require any pneumatic or hydraulic equipment. Mayr Power Transmission develops this variant on request, customizing it for the respective application.

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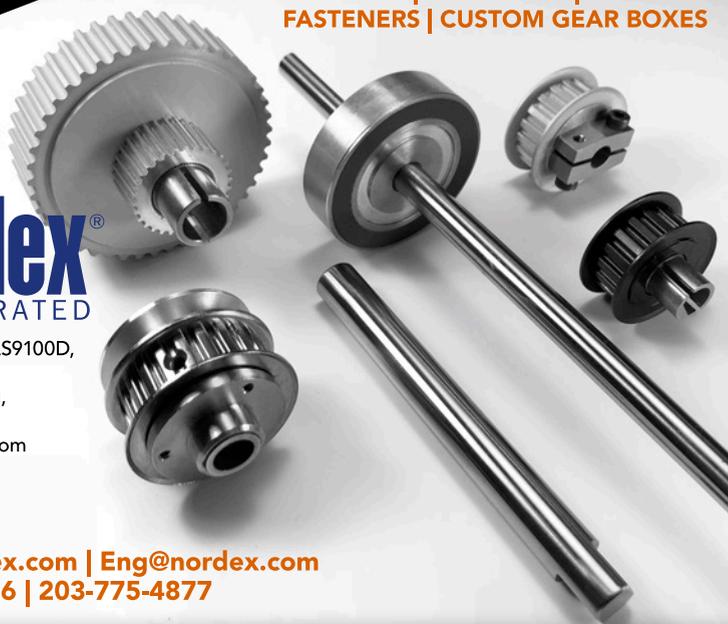
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# How To Replace Oil as a Lubricant in Worm Gearboxes With Grease

Felix Müller, Dr. Manuel Oehler and Dr. Oliver Koch

For worm gearboxes, oils are mainly used in combination with splash lubrication. Consistent lubricants, such as greases, are used less frequently and are used, for example, in gearboxes where it is not possible or difficult to seal the housing (Ref. 1). These applications include positioning gears, but also power gears with high sealing requirements, such as in the food industry. Grease lubrication has, in comparison to oil, a negative thermal effect on the worm, resulting in higher mass temperatures (Ref. 2). However, this effect becomes less relevant in the application of positioning gears, so that the advantages of grease lubrication outweigh the disadvantages in these applications.

At certain operating points, consistent lubricants also offer additional advantages over the more common oil lubrication. For example, in worm gears with low rotational speeds and sliding speeds, friction and wear can be reduced when using grease instead of oil (Ref. 2).

Grease lubrication places different demands on the calculation and design of gearboxes than oil lubrication. This applies to both the housing design and the design of the gearing. In terms of rheological behavior, grease can be described as a non-Newtonian fluid, which means that the viscosity varies with the shear rate. To describe this behavior, there are various models available, such as the power law or the Bingham model. These models assume a solid behavior of the lubricant at low shear rates and viscous behavior at higher shear rates (Ref. 3). In contrast to oil lubrication, there are currently no calculation methods available for predicting friction in grease-lubricated worm gears. Such a physically based calculation method for friction in a grease-lubricated tooth contact enables application-specific gear design and optimization regarding friction reduction.

This work presents the foundation for calculating the friction in the worm gear contact, which is the main difference between calculating the efficiency for gearboxes with oil and grease lubrication. The presented investigation includes the determination of boundary friction as well as the calculation of the film thickness, which is essential for the relationship between boundary friction and fluid friction. The combination of these two friction calculations represents the mixed friction conditions that are present in the tooth contact of worm gears. The calculation methods will be presented exemplarily for one grease.

In addition to those investigations regarding the calculation of the friction, the grease distribution inside the gearbox will be researched by using fluorescent particles. The grease distribution is a key factor for the gearbox design to avoid starvation in the tooth contact. The results will be presented for two different greases, which are different than the one used for the calculation methods. Although one of them is grouped in the same NLGI class as the grease used for the analytical description, according to Ref. 4, the main goal regarding the grease distribution is to avoid dead spaces and to create a good mixing of the grease.

Summarizing this paper answers the question “How to replace oil as a lubricant in worm gearboxes with grease?” with two different approaches. On one hand, an approach for an analytical calculation method is presented, and in addition to that, experimental investigations on the practical design of the gearbox are shown.

## State of the Art

Grease lubrication in worm gearboxes is only little researched so far in contrast to the area of rolling bearings, where grease lubrication is widespread (Ref. 3). Monz showed with an experimental approach the potential for grease lubrication with a wide range of different greases and operating conditions of the worm gear showing upsides compared to oil lubrication in different areas (Ref. 2).

For worm gears, there is no physically based calculation method for friction in the grease-lubricated tooth contact available, which is necessary for application-oriented gearbox design as well as for the optimization concerning friction reduction. Because of this lack of tools to design worm gearboxes for grease lubrication, most gear manufacturers use the design of the gearboxes for oil lubrication and simply fill them with grease. This working method is sufficient to achieve the goal of high sealing requirements, but neglects the potential for optimization.

The calculation methods used for rolling bearings, for example, to determine the rating life according to (Ref. 5), use a simplification to calculate the film thickness for grease lubrication. The calculation of this value for oil lubrication is well researched and broadly used, for example, through the equations by Hamrock and Dowson (Ref. 6). To determine it for

greases, common sense in the practical calculation is to use the properties of the base oil of the grease and calculate the film thickness according to the model for oil lubrication. This method is, around high sum velocities, appropriate because the film thickness of grease converges to that of its base oil with increasing sum velocity (Ref. 7).

Nevertheless, there are approaches to describe the film thickness of grease lubrication in a more detailed way, again with the background of lubrication in rolling bearings. Morales-Espejel et al. present a different way to describe the dynamic viscosity of the grease, in contrast to just using the viscosity of the base oil. They determine an experimental correction factor that is applied to the base oil viscosity and depicts the behavior of the grease in a more precise way. The factor depends on the sum velocity and converges to the viscosity of the base oil with increasing speed, because of the converging behavior of the film thickness from the grease to the oil. This adapted viscosity can later be used in the existing formulas for calculating the film thickness for oil lubrication (Ref. 7).

Another alternative calculation method is presented by Cousseau et al., where the properties of the bleed oil of lubricating greases are used. The film thickness measurements on a ball-on-disk tribometer showed that the behavior of the bleed oil differs from the base oil and is more comparable to the actual grease. Their suggestion for the calculation of grease film thickness is to use the properties, mainly the dynamic viscosity of the bleed oil instead of the base oil, to get a better match to the actual behavior of the grease (Ref. 8).

### Friction in the Tooth Contact

The analytical description of the friction in the tooth contact consists of the description of boundary friction combined with fluid friction. The approach used for determining these two frictions is different from each other, as shown in the existing model for oil lubrication described in Ref. 9.

### Boundary Friction

The boundary friction is calculated by using a characteristic diagram, which is determined with a two-disk test bench for every grease under various operating conditions. The overall setup of the testbench, as well as its functionality and the execution of the test, is described in Ref. 10. The varied parameters to achieve different operating conditions are shown in Table 1. The low sum velocity and the high slide-to-roll ratio SRR (up to 100 percent) can be explained by the conditions in the worm gear contact, as shown in Ref. 9, and these circumstances are modelled with the given parameters on the two-disk testbench. The two discs are analogous to the materials used in worm gears, made of bronze and steel. In a worm gearbox, the worm is usually made of steel, and the worm wheel is made from bronze.

Parameter	Value
Sum velocity	0.2 m/s
Slide-to-roll ratio (SRR)	0 - ±100 %
Temperature	20 °C, 50 °C, 80 °C
Contact pressure	386 MPa, 582 MPa, 802 MPa
Lubricant quantity	0.5 ml
Repetitions	3

Table 1—Parameters two-disc test bench.

During the tests, different coefficients of friction were determined for positive and negative slide-to-roll ratios (SRR). The difference between positive and negative SRR results from the different speed distribution of the two discs. Investigations with positive SRR were made with the steel disc rotating faster, and the values for negative SRR were determined with the bronze disc rotating faster. The primary focus during this investigation is on the values for positive SRR, which means that the steel disc is rotating faster. This condition is the main use case in real worm gear boxes because the worm is rotating faster than the wheel. The used grease is classified according to Ref. 4 into NLGI class 1, and its base oil viscosity amounts to 680 cSt.

During the tests, traction curves are determined for various temperatures and pressures, resulting in a characteristic diagram for the examined grease. As an example, Figure 1 shows the traction curves of the examined grease at 20°C with two investigated contact pressures.

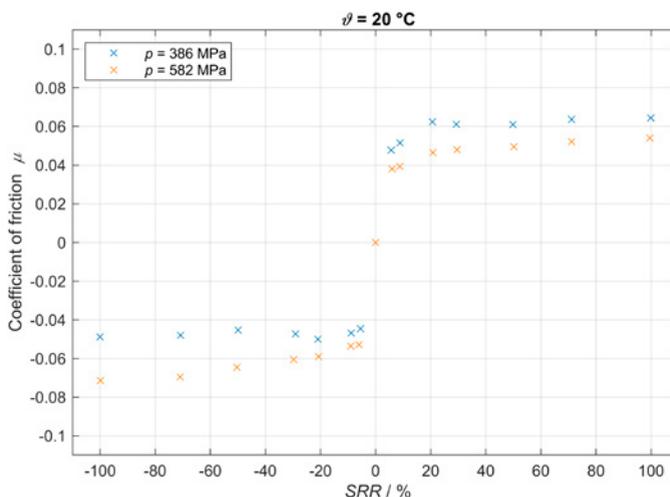


Figure 1—Traction curves for p = 386 MPa and 582 MPa at 20°C.

The traction curves show a temperature and pressure-dependent behavior of the grease regarding the coefficient of friction. There is also a visible difference between the states of positive and negative SRR. The measured coefficients of friction with the bronze disc rotating faster

are higher than those with a faster-rotating steel disc. A possible explanation for this effect is the rolling friction, which always works in the same direction, regardless of the sliding friction. The effect that the coefficient of friction in the area of positive SRR decreases with higher pressure can potentially be explained by a thinning effect on the grease, resulting in lower fluid friction.

### Effect of Preshearing on the Coefficient of Friction

During the experiments on the two-disk test bench, the effect of preshearing on the coefficient of friction was investigated. To research this behavior, the coefficient of friction was measured using two different states of the examined grease. In the first state, the grease was not conditioned beforehand and was directly applied to the two discs. For the second state, the grease was sheared using a kneader for grease according to DIN 2137 (Ref. 11). The kneader used for this investigation is shown in Figure 2.

The determined traction curves for the two different states of the examined grease are shown in Figure 3, this time showing the results of an alternative grease in contrast to Figure 1. In this diagram there is again the difference between the values for positive and negative SRR. But in contrast to that the difference between the normal and the kneaded state of the grease is very small, especially in the area of positive SRR.

### Film Thickness in the Tooth Contact

To determine the share between fluid and boundary friction, the lubricating film thickness is a key indicator. To describe the film thickness of the grease more precisely than the approximation with only the properties of the base oil, both additional methods presented in the state of the art will be investigated in this work. The investigation will take an eye on the applicability of these calculation methods on the examined grease.

### Determination of Lubricant Parameters

Both examined calculation methods require the dynamic viscosity of an oil from the grease, either from the base oil or from the bleed oil. Since these viscosities are not provided by the manufacturer of the lubricant, the viscosities of both oils were measured using a high-pressure viscometer.

### Extraction of the Bleed Oil

Bleed oil refers to the oil in a grease that is “bled” out under load. To determine the properties of this oil, it must first be extracted using a filter method based on the principle in Ref. 12. Therefore, the grease was placed in a filter and then subjected to a static load for a longer period of time. A pleated filter made of cellulose with a retention capacity of 7–9  $\mu\text{m}$  was used and placed in a plastic funnel. The grease was then distributed along the walls of the funnel, and a second funnel was used to apply the load evenly. The load was applied using a disk with a weight of 1 kg, which was placed in the second funnel.



Figure 2—Kneader for grease according to DIN 2137 (Ref. 11).

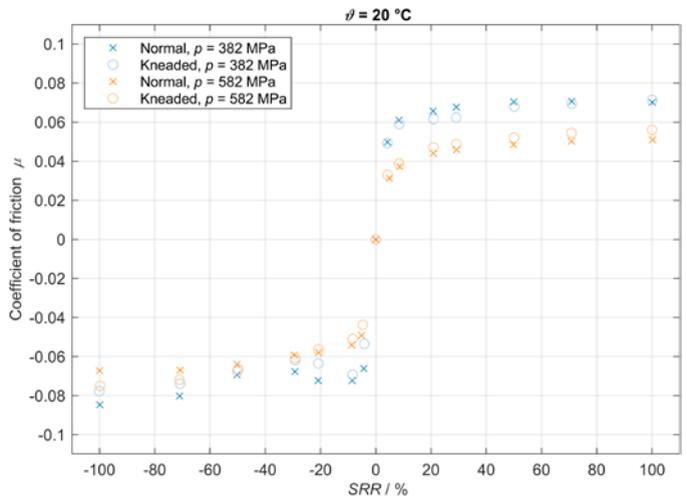


Figure 3—Traction curves for  $p = 386$  MPa and 582 MPa at 20°C with different states of the alternative grease.



Figure 4—Structure for the extraction of the bleed oil.

The entire combination of funnels, grease, and weight was then placed on a beaker to collect the bleed oil. To speed up the extraction process, the entire assembly was then placed in an oven at a constant temperature of 70°C. In this way, approx. 15 ml of bleed oil per funnel assembly could be obtained over a period of 5 days. The structure in the oven is shown in Figure 4.

### Measurements on the High-Pressure Viscometer

The measurements to determine the lubricant parameters were conducted using a high-pressure viscometer. The design of the device and the mode of operation of the viscosity measurement are explained in Ref. 13. The measuring principle of the viscometer is based on a falling body, which sinks downwards due to gravity in a tube filled with fluid, whereby the fluid is tempered and pressurized. During the experiment, the falling time of the body is measured, and the viscosity is determined based on this information. The longer this time is, the slower the body sinks in the fluid and the greater the viscosity. The temperatures assessed were 20°C, 40°C, 60°C, 80°C, and 100°C at ambient pressure, 200 MPa and 400 MPa, respectively. In the evaluation, the viscosity is determined using Equation 1 (Ref. 13):

$$\eta(p, \vartheta) = C(\vartheta) \cdot t \cdot \frac{\rho_{\text{sinker}} - \rho_{\text{fluid}}(p, \vartheta)}{\rho_{\text{sinker}}} \quad (1)$$

where

- $C$  is a correction factor;
- $t$  is the measured time of the falling body;
- $\vartheta$  is the temperature;
- $\eta$  is the dynamic viscosity;
- $p$  is the pressure;
- $\rho$  is the density of the lubricant / falling body.

The resulting dynamic viscosities for the various operating points are shown in Figure 5. The measured

viscosities show a visible difference between the bleed oil and the base oil, indicating that these two lubricants are not identical. This is an expected result and matches the observations regarding bleed oil and base oil present in Ref. 8, where differences between the oils were also found. As an example, the difference between the viscosity of both oils at 400 MPa and 80°C is 31 percent of the viscosity of the base oil. The standard deviation at this point is 0.8 percent for the base oil and 0.7 percent for the bleed oil. This shows that the measured difference results from the lubricant properties and is not an outcome of the measurement principle. Furthermore, it is noticeable that the viscosity of the bleed oil increases more with increasing pressure than that of the base oil, which indicates the pressure viscosity coefficient  $\alpha_p$  of the bleed oil is higher than that of the base oil. Currently, there is no explanation for this behavior, and the effect will be subject to further investigations in the future. It is important to check whether this effect occurs with other lubricants as well.

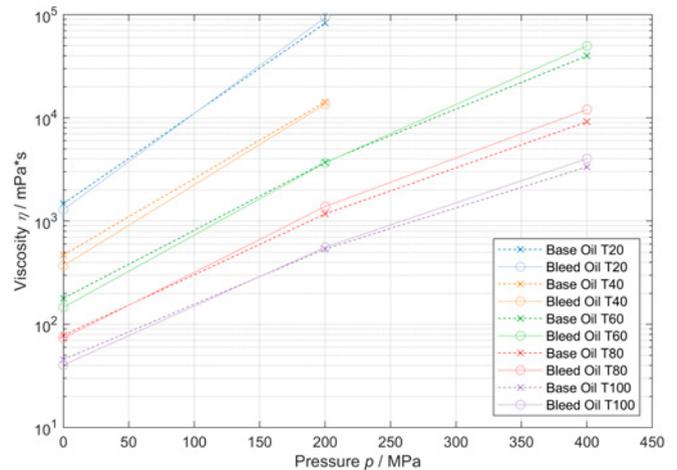


Figure 5—Measured dynamic viscosities for bleed and base oil.

### Determination of Viscosity Parameters

Based on the measured viscosities, there can be specific parameters determined to calculate the dynamic viscosity of a lubricant in dependence on the pressure and the temperature. For this calculation, Equation 2 is used according to Ref. 14:

$$\eta(p, \vartheta) = K \cdot \exp\left[\frac{B}{\vartheta + c}\right] \cdot \exp\left(\frac{p}{a_1 + a_2 \cdot \vartheta + (b_1 + b_2 + \vartheta) \cdot p}\right) \quad (2)$$

where

- $\vartheta$  is the temperature;
- $\eta$  is the dynamic viscosity;
- $p$  is the pressure.

The three parameters  $K$ ,  $B$ , and  $C$  are calculated by Equations 3–5 according to Ref. 15:

$$K = \exp\left[\ln(\eta_{40}) - \frac{\ln(\eta_{100}) - \ln(\eta_{40})}{-\frac{4}{13}}\right] \quad (3)$$

$$B = -\frac{1755}{4} \cdot [\ln(\eta_{100}) - \ln(\eta_{40})] \quad (4)$$

$$C = 95 \quad (5)$$

The remaining four parameters  $a_1$ ,  $a_2$ ,  $b_1$  and  $b_2$  are determined afterwards by nonlinear regression. For this purpose, the measured viscosities as well as the corresponding pressure and temperature are used and the system of equations for the parameters is solved. With the parameters determined in this way, the viscosity can now be determined for the oils under investigation at any pressure and any temperature, which makes it possible to estimate the lubricating gap height for any operating points.

### Film Thickness Measurement

To rate the applicability of the different calculation methods for the examined grease, the film thickness is measured under different operating conditions using a ball-on-disk tribometer. The used device is the high-speed tribometer “EHD-HS” by PCS Instruments, which determines the film thickness using interferometry and enables measurements at speeds of up to 20 m/s. A brief description of the device and the measuring principle can be found in the manufacturer’s brochure (Ref. 16). A total of three temperatures and 31 different speeds at a constant contact pressure were selected for the measurements. The overview of the test parameters is shown in Table 2.

Parameter	Value
Velocity	0.01 m/s to 2 m/s (31 Data points)
Temperature	30 °C, 45 °C, 60 °C
Contact pressure	531 MPa

Table 2—Parameters ball-on-disc tribometer.

As worm gearboxes have very low local sum velocities in contact, the measurements on the tribometer were also primarily conducted at low speeds, with a speed of 0.01 m/s representing the lower limit of the measuring device. This speed is the sum speed, which consists of the sum of the disk speed and the ball speed at the contact point. There is no slip during the tests, which means that the relative speed in the contact is zero. During a measurement, the speed is then successively increased at logarithmic intervals, and a value for the central film thickness is determined at each operating point. The measurement for this is repeated a total of five times, and the result for the film thickness is formed by the mean value from the five measurements. Similar conditions were selected for the temperature as for the tribometer tests on boundary friction to analyze similar operating points. The temperature of 30°C represents the lower limit of the measuring device

in our specific setup, as this value depends on the temperature of the room in which the tribometer is set up. The considered contact pressure of 531 MPa results from the combination of a pressure close to the application and the stress limit of the glass disc of the tribometer, which is 700 MPa. A certain degree of safety was considered here, with which a realistic pressure value in the tooth contact was nevertheless investigated.

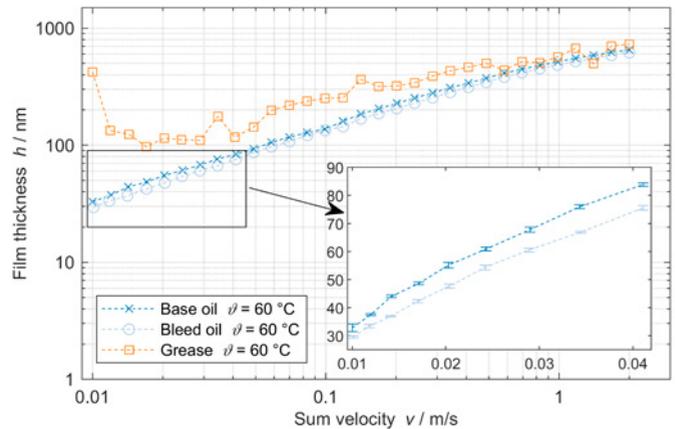


Figure 6—Film thickness measurements for grease and oils.

The results of the film thickness measurement at 60°C are presented in Figure 6. The results show clear differences between the film thickness of the lubricating grease and the corresponding oils. In areas of low speed, the film thickness of the grease is significantly higher than that of the oils, and it converges with increasing sum velocity. In contrast to that, the film thickness of the bleed oil and base oil is fairly similar to each other. The small excerpt shows the film thickness of the bleed oil and base oil in a more detailed view, and with the addition of error bars. These graphs show that the difference between the oils does not come from measurement accuracy and that they have different lubricant properties, like the viscosity measurements.

To further analyze the difference between the lubricant properties of the bleed oil and base oil, Figure 7 shows the calculated central film thickness for both oils according to Equation 6, which will be further explained in the section “Grease Film Thickness.” The needed lubricant parameters were taken from the viscosity measurements shown in the section “Determination of Viscosity Parameters.” The visible results of the calculation show a good match to the experimentally determined values of the film thickness, and the values for bleed oil and base oil are again fairly similar to each other. Furthermore, the calculated film thickness of the bleed oil is lower than that of the base oil, as well as in the experimental results. This difference mainly comes from the lower viscosity at ambient pressure,  $\eta_0$ , which can be seen in the result of the viscosity measurement in Figure 5. The calculated values suggest that the higher pressure viscosity coefficient of the bleed oil does not equalize the lower viscosity at ambient pressure, resulting in a lower calculated value for the film thickness.

## Grease Film Thickness

To compare the two described analytical approaches to the experimental measurements, the film thickness must first be calculated at the chosen operating points. To calculate the central film thickness, the equation for the elliptical point contact, shown in Equation 6, according to Venner (Ref. 17), was used. This approach is based on the equations of Dowson and Higginson (Ref. 18), and the whole calculation is shown in the appendix.

$$H_{cen} = \left[ \left( (1,70 \cdot M^{-1/9} \cdot L^{3/4} \cdot t)^r + (1,96 \cdot M^{-1/9})^r \right)^{s/r} + (47,3 \cdot M^{-2})^s \right]^{1/s} \quad (6)$$

The main equation can be used equally for both approaches because the only difference lies in the calculation of the dynamic viscosity of the lubricant. The dynamic viscosity influences the parameters  $M$ ,  $L$ , and  $H_{cen}$  in Equation 6 because it is used for the calculation of the dimensionless velocity parameter  $U$ , shown in Equation 16, which is needed for the determination of the three mentioned parameters.

The comparison between the measured film thickness at 60°C and the calculated value with both methods is shown in Figure 8. Here, the values described as “Venner bleed oil” were calculated using the viscosity of the bleed oil according to Ref. 8, and the values named “Venner effective viscosity” were calculated using the correction factors introduced in Ref. 7. The calculation for this effective viscosity is shown in Equation 7.

$$\eta_{grease, eff.} = \eta_{0, base oil} \cdot (\cotan(A \cdot \bar{u}))^f \quad (7)$$

The two correction factors  $A$  and  $f$  are determined by using nonlinear regression for the results of the film thickness measurements of the grease at two striking velocities. The first velocity is the lowest measured speed, but higher than 0.0063 m/s, and the second velocity is the speed at which the behavior of the grease matches that of its base oil. Furthermore, the pressure viscosity parameter  $\alpha_p$  needed for the film thickness calculation of the grease is obtained from the highest film thickness measurements, where its behavior is close to that of the base oil (Ref. 7).

The comparison shows overall that the calculation method using the effective viscosity of the grease fits the measured values at this operating point with this exact grease better than the values determined with the bleed oil viscosity. The difference between the two methods is bigger at lower speeds, and the results converge with increasing velocity to each other as well as to the experimental values.

## Grease Distribution

The grease distribution in the gearbox of a worm gear is a key factor for sufficient lubrication of the tooth contact. If the distribution is unfavorable, it is possible that there is not enough lubricating grease in the tooth contact, and the effect of starvation can occur, which leads to increased friction and loss in efficiency. To design the gearbox properly for an optimal grease distribution, it is important to understand the behavior of the grease during operation.

To determine the flow and the distribution of the grease, a gearbox with a transparent lid was used to get a look inside of it during operation. The test bench setup is described in Ref. 19 and shown in Figure 9. The gearbox is designed so that the worm and worm wheel are enclosed close to the contour by the tubular housing parts. The gearbox itself is mounted on a test rig and can be turned into various positions to examine different mounting positions of the worm.

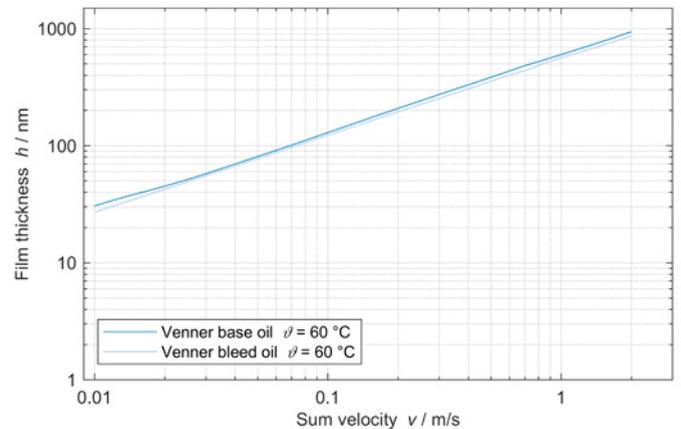


Figure 7—Calculated film thickness for base oil and bleed oil.

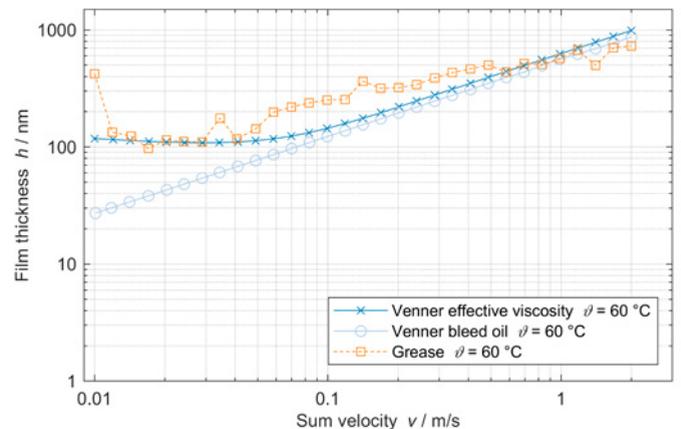


Figure 8—Comparison between measured and calculated film thickness.

During the experimental test, two greases with different consistencies were used, where one is classified as NLGI 1 and the other as NLGI 2 according to Ref. 4. To follow the movement of the grease inside the gearbox and track the intermixing, tracer particles were added to the greases, which can be stimulated to fluoresce by UV radiation. During the test, the drive speed, the location of the worm, the quantity of grease, and the location of application were varied to consider different conditions.

### Results on Grease Distribution

The first test regarding the grease distribution was the experimental determination of the minimal quantity of grease to cover the worm and the worm wheel evenly with lubricant. The result was that the amount is independent of the location of application and grease consistency, because in all tests the approximate amount needed was 20 g. During these tests, it was also visible that the worm wheel functioned as a grease depot, whereas the worm distributed the grease by tearing it out of the tooth gaps. With an increasing amount of grease brought into the gearbox, dead spaces emerged in the gearbox where grease got deposited and was not conducted again by the worm or the worm wheel. An amount of grease sticks to the walls of the gearbox after its contribution and distributes itself poorly. This effect was more distinct with the use of the NLGI 2 grease, the grease with the lower consistency index distributed itself better after a short period of time and did not stick as much on the walls of the gearbox. The amount of grease spun out at a given speed was comparable between the two greases.

Monz already stated in Ref. 2 the effect of a so-called caterpillar as a relubrication mechanism inside the gearbox. This effect occurs when excess lubricant is carried on by the worm wheel and then drifts off at a narrow point. The developing depot grows when a critical amount of grease is exceeded, and a balance is formed between stripping at the beginning of the caterpillar and removal towards the end. The development of this effect is provoked by adding additional grease after the stationary state of lubrication, and in addition to that, the added grease is marked with tracer particles to inspect the intermixing inside the grease caterpillar. Figure 10 shows the emerged grease caterpillar after the test. The investigation on intermixing for the caterpillar is shown in Figure 11. The left picture in Figure 11 shows the behavior of the grease with a lower consistency class, and a good blend between the existing and added grease inside the gearbox is visible. In contrast to that, the grease classified as NLGI 2 in the right picture shows a worse blend of the different markers, resulting in two separate phases of grease. This means that used and fresh grease parts do not intermix as well, and the same grease is carried around in the gearbox all the time. In conclusion, the tested grease classified with the lower consistency had better characteristics regarding the intermixing and overall grease distribution inside the worm gearbox.

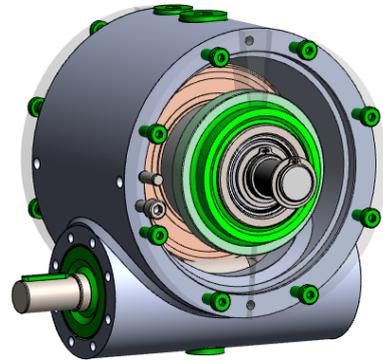
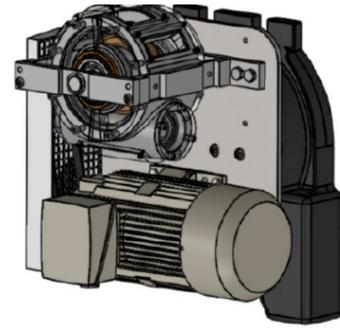


Figure 9—Mounted test bench setup (top) and partly transparent worm gearbox (bottom) (Ref. 19).

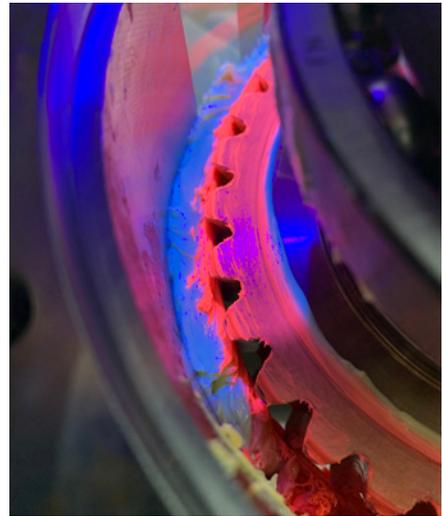


Figure 10—Grease caterpillar after the test.



Figure 11—Intermixing of grease for NLGI 1 (left) and NLGI 2 (right).

The investigations on the intermixing of the grease showed that a significant amount of grease is not transported further into the contact and instead is deposited on the walls of the gearbox and the front side of the worm wheel. To reduce the amount of grease that deposits on the front side of the wheel and the walls of the gearbox, magnetic guide plates were added to the gearbox, which is shown in Figure 12.

The circulating grease is wiped off at these plates and conveyed back towards the tooth contact to ensure sufficient lubrication. The addition of these guide plates led to a ring-shaped grease flow around the toothing of the worm gear, and a larger proportion of the quantity of introduced grease is mixed and thus actively used for lubrication. This works against the effect of bad intermixing, which was shown before.

### Comparative Tests

To compare different locations of the worm, combined with the addition of the guide plates, tests were performed with constant values for the remaining parameters, such as speed and application of the grease. The results of these comparative tests are shown in Table 3.

The comparison between the different locations and greases shows a big difference regarding the grease distribution. With an eye on the location, the results indicate

that the optimal mounting position of the worm gear is with the worm above, followed by a vertical arrangement. The tests with the worm below took the longest time to get into a stable state of grease distribution. In addition to that, the position with the worm above was the only configuration without a dead space in the whole gearbox, which is another benefit over the other mounting positions. Furthermore, the necessary amount of grease to reach the defined condition of lubrication is significantly less when the worm is located above the worm wheel.

### Conclusion

The question “How to replace oil as a lubricant in worm gearboxes with grease” was addressed using two different approaches in this work. The first part included the idea of an analytical method to describe the friction in the tooth contact of a grease-lubricated worm gear. Because of the mixed friction conditions, the combination of boundary friction and fluid friction must be considered in the calculation. The boundary friction was therefore determined using a two-disc test bench with comparable operating conditions to the tooth contact. Furthermore, the calculation of the film thickness was shown, which is a key value to determine the ratio between boundary and fluid friction. In that case, two different approaches for the calculation were presented and compared to experimental results of film thickness measurements on a ball-on-disc tribometer. The results of these investigations showed that for this grease, there is an approach that matches the experimental results better than the other.

In addition to the analytical approach, experiments on the grease distribution inside the gearbox were presented. During these tests, two major experience values emerged from the experiment: the optimal mounting position and the constructional adaptations to the gearbox. In regard to these results, the gearbox for the experimental validation of the analytical model will be designed with a worm position above, and further investigations regarding the use of guide plates will be performed.

To provide an outlook into further investigations regarding grease lubrication in worm gears, the analytical calculation will be expanded further so that the actual fluid friction can also be calculated using grease. With



Figure 12—Guide plate to influence the grease transport.

Mounting position	Grease	Time for stable condition	Caterpillar	Dead Space
Worm below	170 g NLGI 1	6:00 min	Yes	Below worm
Worm below	150 g NLGI 2	7:00 min	Yes	Below worm wheel shaft
Worm above	100 g NLGI 1	4:30 min	Yes	None
Worm vertical	100 g NLGI 1	4:30 min	No	Shaft shoulder, guide plate

Table 3—Results of the comparative tests with guide plates.

this final addition, the efficiency of the worm gearbox can be determined and will then be verified with an efficiency test on an actual test bench.

In conclusion, there is an easy way to replace oil as a lubricant in worm gearboxes with grease by simply changing the lubricant without changes to the design of the gearbox. This simplistic approach seems easy at first thought, but comes at the cost of an unoptimized gearbox. By using an analytical calculation method combined with experimental tests to find an optimized gearbox design for grease lubrication, the efficiency of these gearboxes can be increased in the future.

## Acknowledgement

This work was supported by the German Federal Ministry of Economic Affairs and Climate Action (IGF 22365 N) within the framework of the Forschungsvereinigung Antriebstechnik e.V. (FVA project 962 I).

## Appendix

The following equations show the calculation of the central film thickness for the elliptical point contact, shown in Equation 6, and the necessary parameters according to Venner (Ref. 17). The equation for the central film thickness for the elliptical point contact is again shown in Equation 8.

$$H_{cen} = \left[ \left( (1,70 \cdot M^{-1/9} \cdot L^{3/4} \cdot t)^r + (1,96 \cdot M^{-1/9})^s \right)^{s/r} + (47,3 \cdot M^{-2})^s \right]^{1/s} \quad (8)$$

The dimensionless parameter for the central film thickness  $H_{cen}$  is described by equation (9).

$$H_{cen} = \left( \frac{h_{cen}}{R_x} \right) \cdot (2 \cdot U)^{-0,5} \quad (9)$$

The further parameters in equation (8) are the dimensionless load parameter  $M$

$$M = W \cdot (2 \cdot U)^{-3/4} \quad (10)$$

and the dimensionless material parameter  $L$

$$L = G \cdot (2 \cdot U)^{0,25} \quad (11)$$

and the auxiliary variables  $r$ ,  $s$  and  $t$  calculated from  $M$  and  $L$

$$r = \exp(1 - 6/(L + 8)) \quad (12)$$

$$s = 12 - 10 \cdot \exp(M^{-2}) \quad (13)$$

$$t = 1 - \exp\left(-0,9 \cdot \frac{M^{1/6}}{L^{1/6}}\right) \quad (14)$$

The two dimensionless parameters  $M$  and  $L$  in turn consist of the dimensionless material parameter  $G$

$$G = \alpha_p \cdot E_{red} \quad (15)$$

the dimensionless velocity parameter  $U$

$$U = \frac{\eta_0 \cdot v_\Sigma}{2 \cdot E_{red} \cdot R_x} \quad (16)$$

and the dimensionless load  $W$

$$W = \frac{w}{E_{red} \cdot R_x^2} \quad (17)$$



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## ABB Signs Agreement with Fervo Energy to Deliver Electrification and Motor Control Solutions



ABB has signed an agreement with Fervo Energy to supply advanced motor control solutions for the Cape Station geothermal project in Utah. Scheduled to start delivering reliable, carbon-free power to the grid this year, Cape Station is expected to become the world's largest next-generation geothermal development by installed capacity and represents a major step forward in sustainable energy generation in the United States.

This collaboration brings ABB's expertise in electrification and motor control solutions to maximize production from one of the world's most innovative geothermal projects. Cape Station will see Fervo Energy utilize advanced drilling techniques to drill horizontal wells in geothermal reservoirs, allowing multiple wells from a single well pad. This approach reduces surface footprint, minimizes drilling risks, and unlocks previously inaccessible geothermal resources—expanding the potential for clean, firm energy. Cape Station is scheduled to deliver first power to the grid by late 2026 with plans to add approximately 100 MW by early 2027 and 400 MW thereafter, together providing 500 MW, enough to power approximately 355,000 US homes annually.

“ABB is recognized globally for delivering reliable, high-performance electrification and motor control solutions for critical energy projects,” said Tim Latimer, CEO and Co-Founder, Fervo Energy. “Their proven track record, and ability to advise, develop, and execute at scale made ABB the clear choice again for Cape Station project.”

Under the agreement, ABB will deliver a comprehensive package of medium voltage motor control equipment, including more than 80 drives that will efficiently manage a significant amount of horsepower of critical equipment. ABB's scope of supply also includes medium voltage motors, generators, low voltage motor control centers, and medium voltage switchgear to support multiple aspects of the project, and prefabricated eHouses designed to house the well pad drive systems and associated electrical infrastructure.

“Our strategic partnerships with innovative clean energy producers like Fervo Energy reinforce our commitment to expand the potential of reliable, renewable energy sources with our proven electrification technologies available today,” said Brandon Spencer, president, ABB Motion. “We are excited by Fervo Energy's work and in particular the potential of Cape

Station to contribute to a sustainable energy future.”

Together, ABB and Fervo Energy are combining advanced technology and proven expertise to strengthen grid resilience and support the growing demand for stable, domestic energy sources.

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## IGUS Certifies 238 Chainflex Cables for Dry Cleanrooms



Igus has announced that it is the first supplier to qualify halogen-free chainflex TPE cables for IPA dry cleanroom classes 4 and 5 through the Fraunhofer Institute for Manufacturing Engineering and Automation (IPA). This certification ensures customers in highly automated battery production receive energy supply solutions with a guaranteed service life of up to four years.

In lithium-ion battery manufacturing, production purity is critical. Dust, particles, and moisture can compromise quality and shorten product life. Dry cleanrooms—where relative humidity is typically below one percent or just a few ppm—protect sensitive materials like electrolytes from chemical reactions. However, many machine components fail under such harsh conditions.

“Many components are susceptible to wear and tear due to the dry air, so they have to be replaced within a very short time,” says Kira Weller, product manager e-chains and cleanroom expert at Igus. “To ensure that our cable routing systems meet the requirements of the

dry environment, we are working together with Fraunhofer IPA to develop and certify our motion plastics for use in dry cleanrooms.”

This certification now covers 238 chainflex cables. “These are our high-end TPE cables, which are specially developed and tested for use in the energy chain. The range includes control, bus, motor, robot, servo and measuring system cables, among others,” explains Rainer Rössel, Head of the chainflex Cables division at Iigus. After extensive testing in Iigus’ Cologne lab, the cables earned the two highest IPA dry cleanroom classes, 4 and 5. The certification guarantees low particle emissions under long-term stress and reliable material resistance—key for modern automation in battery production.

“The cooperation with Fraunhofer IPA gives our customers the certainty that our solutions will function reliably even under the strictest conditions,” says Rössel. The halogen-free TPE sheathing ensures maximum purity and durability. Iigus backs all products with a four-year warranty and service life calculation.

These TPE cables are standard catalog items, available from stock in lengths starting at one meter—without cutting fees, small quantity surcharges, or packaging costs.

[igus.com](http://igus.com)

## EATON Announces Plan to Spin off Its Mobility Group

Eaton intends to pursue a separation of its Vehicle and eMobility segments (together, “Mobility Group” or “Mobility”) into an independent, publicly traded company.

Paulo Ruiz, Eaton chief executive officer, said, “The separation of Mobility advances Eaton’s bold new 2030 growth strategy to lead, invest, and execute for growth. Our team will have a sharpened focus on our core Electrical and Aerospace businesses, which are driven by powerful megatrends including in electrification, digitalization and AI, reindustrialization, infrastructure spending and

growth in the aerospace after-market and defense demand. We are confident that Eaton is exceptionally well positioned to capitalize on opportunities to accelerate growth and margin expansion, and to create long term value for our shareholders.”

Ruiz continued, “We are incredibly proud of what our Mobility team has built and believe that now is the right time to separate that business. As an independent company, Mobility will be able to build on its strong foundation as a leading supplier across the globe and have the strategic focus and agility to allocate capital and resources to best serve its customers, pursue independent growth opportunities, and drive innovation.”

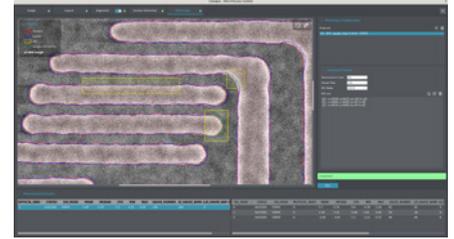


Mobility provides mission-critical and safety-critical engineered solutions responsible for creating, distributing and optimizing power for all types of vehicles and propulsion systems, with a leading position in commercial truck transmissions and clutches in the Americas, as well as high-voltage EV fuses and valve actuation technologies around the world. The business operates as a true innovation partner for OEM customers’ electrification needs, offering deep domain knowledge, proprietary technology and system-level integration.

A separation will allow Mobility more flexibility to pursue near- and long-term growth opportunities, including in markets where it is well positioned with leading technologies serving heavy-, medium- and light-duty trucks, passenger vehicles and off-highway vehicles.

[eaton.com](http://eaton.com)

## SIEMENS Acquires Canopus AI to Bring AI-based Metrology to Semiconductor Manufacturing



Siemens has announced the acquisition of Canopus AI, an innovator in computational and AI-driven metrology solutions, enabling semiconductor manufacturers to achieve new levels of precision and efficiency in wafer and mask inspection processes. This acquisition strengthens Siemens’ position in the semiconductor manufacturing ecosystem and expands its semiconductor design and manufacturing digital thread by integrating additional cutting-edge metrology technologies, enhanced with advanced AI capabilities.

The semiconductor industry faces increasingly complex manufacturing challenges as device geometries continue to shrink and production volumes scale. Massive metrology has become critical to ensuring quality and yield in advanced semiconductor fabrication. Canopus AI’s innovative AI-powered solutions complement Siemens’ existing portfolio, providing semiconductor manufacturers with intelligent inspection and measurement capabilities that drive operational excellence.

“The acquisition of Canopus AI exemplifies Siemens’ commitment to leveraging industrial AI to solve critical challenges in semiconductor manufacturing,” said Tony Hemmelgarn, president and CEO, Siemens Digital Industry Software. “By combining the computational lithography and manufacturing physics simulation capability in our

Calibre portfolio with Canopus-AI's advanced metrology and inspection technologies, we are creating a differentiated, end-to-end EDA digital thread that improves the fidelity of printed wafer patterns, accelerates yield ramp and reduces time-to-volume for advanced nodes. This integration further advances our vision of a comprehensive, high-accuracy, semiconductor manufacturing digital twin, enabling sub-nanometer process control and mask development."

[sw.siemens.com](http://sw.siemens.com)

## ZF AND BMW Sign Agreement for Future-Oriented Drive Technologies



ZF Friedrichshafen AG and the BMW Group have signed a long-term supply agreement in the field of passenger car drive systems. The core of the agreement is the supply and continued development of the proven 8-speed automatic transmission (8HP). The contract, worth several billion euros, runs until the late 2030s. This creates a solid foundation for open-technology and low-emission mobility of the future for both companies.

"Together with BMW, we are sending a strong signal for innovation, efficiency, and sustainability in an industry undergoing dynamic change," says Mathias Miedreich, CEO of ZF. "This agreement highlights the strategic importance of our 8-speed automatic transmission as a key technology for the transformation of drive systems."

As part of the partnership, the 8HP transmission kit will be continuously developed. The aim is to

provide customers with the most powerful and efficient transmission that meets the requirements of future drive concepts.

"The new agreement with BMW shows how important long-term planning horizons are for technological advancements," explains Sebastian Schmitt, Head of ZF's Electrified Drive Technologies division. "It creates clarity and stability for both companies and enables us to align the next generation of the 8HP specifically toward efficiency, performance, and long-term viability."

ZF thus strengthens its position as a system supplier and gains additional planning reliability. Close collaboration in the future will help reduce risks in a rapidly changing market environment and lay the foundation for low emission mobility going forward.

[zf.com](http://zf.com)

## NTN Announces Key Automotive Aftermarket Personnel Changes

NTN Bearing Corporation of America announces a key transition within its Automotive Aftermarket business unit, as longtime NTN veteran John Tyma retires, and Alan Dick joins the team to support continued growth in the heavy-duty aftermarket.

John Tyma retires after 34 years of service with NTN, most recently serving as national account manager for heavy-duty truck markets. Throughout his distinguished career, Tyma built a reputation for expanding NTN's heavy-duty presence through strategic customer partnerships and market development. His experience spans across NTN's industrial, heavy-duty truck, and automotive aftermarket sectors, and he played a pivotal role in securing major national accounts and opening new markets for NTN and its Bower heavy-duty bearings product line.

NTN welcomes Alan Dick, who joins the organization as national sales manager for NTN's heavy-duty aftermarket, filling the role vacated

by Tyma. Dick brings deep leadership experience across the automotive aftermarket, electric vehicle, and component manufacturing markets and was appointed to his new role in November 2025. He holds an MBA from DePaul University's Kellstadt Graduate School of Business and a Master of Science in Economics from Oklahoma State University.



Alan Dick

"John's legacy is one of deep customer commitment, industry and product expertise, and unwavering support for our heavy-duty partners. We are grateful for his decades of service and the strong foundation he leaves behind. At the same time, we are excited to welcome Alan to the team. His strategic mindset, aftermarket experience, and customer-focused approach align perfectly with our vision for long-term growth across the heavy-duty and automotive aftermarket channels," said Charles Harris, vice president, automotive aftermarket.

This transition underscores NTN's continued commitment to delivering best-in-class products, expertise, and customer support across the automotive and heavy-duty aftermarket. The company remains focused on building upon its strong foundation while positioning the team for sustained growth and future success.

[ntnamerica.com](http://ntnamerica.com)

March 17-18

### American Manufacturing Summit 2026

The Generis American Manufacturing Summit (AMS) has a rich history as an exclusive platform for manufacturing leaders—and now in its 12th year, it remains a premier manufacturing summit and one of the top manufacturing events for executives, built for high-level, in-person knowledge exchange and solution exploration. This two-day manufacturing conference (Schaumburg, IL) brings together senior manufacturing, supply chain, and engineering executives, plant and operations leaders, and leading solution providers to share what's working now and what's next in manufacturing. Themes include process optimization, plant performance, talent and innovation.

[powertransmission.com/events/american-manufacturing-summit-2026](http://powertransmission.com/events/american-manufacturing-summit-2026)

March 17-19

### The Bearing Show North America



The Bearing Show is North America's newest exhibition and conference, connecting the evolving needs of bearings end-users with the latest technologies serving, OEM development, maintenance professionals and R&D engineers. Meet visitors from OEM's, machine manufacturers, industrial plants, global distributors and more. Gain insights into emerging trends such as energy efficiency, sustainability, and cost-effective maintenance strategies. The show is co-located with Lubricant Expo North America, a destination for connecting lubricant solution providers with end-user buyers and the entire supply chain. The Lubricant Expo brings together exhibitors and attendees from over 80 countries, covering everything from finished lubricants to formulation ingredients and equipment.

[powertransmission.com/events/the-bearing-show-and-lubricant-expo-north-america-2026](http://powertransmission.com/events/the-bearing-show-and-lubricant-expo-north-america-2026)

April 13-16

### Modex 2026

Modex (Atlanta) is where the manufacturing and supply chain professionals come together for the world's largest supply chain experience. From hands-on product demonstrations to one-on-one meetings and a conference with four keynotes and nearly 200 sessions, Modex 2026 is where they come to see the latest equipment and tech, learn the latest trends, connect with key suppliers and make strategic capital equipment buying decisions for their future operations. Key exhibitors include Beckhoff Automation, Festo, Interroll, Lenze, Misumi, Motion, Nidec Automation, Nord Drivesystems, Regal Rexnord, Siemens and more.

[powertransmission.com/events/modex-2026](http://powertransmission.com/events/modex-2026)

April 23-25

### 2026 MPMA Annual Meeting



In an era defined by economic uncertainty, supply chain disruption, and rapid workforce change, senior manufacturing leaders need more than tactical updates—they need strategic clarity. The 2026 MPMA Annual Meeting held at the Sunseeker Resort in Charlotte Harbor, FL, is designed specifically to deliver that clarity. Hosted by the Motion + Power Manufacturers Alliance (MPMA), this member-only gathering convenes top executives from across the power transmission and motion control industry for high-level dialogue, peer connection, and forward-looking insight.

[powertransmission.com/events/2026-mpma-annual-meeting](http://powertransmission.com/events/2026-mpma-annual-meeting)

May 19-20

### CTI Symposium USA 2026



CTI Symposium USA examines the challenges in automotive powertrain development from passenger cars to heavy-duty vehicles. The program offers the latest solutions in the fields of electric drives, power electronics, battery systems, e-machines, components and the supply chain. Market and consumer research results as well as infrastructure related topics supplement the exchange of expertise. Speakers from Stellantis, Toyota, BorgWarner, General Motors, Ford, ZF and more will be on hand to discuss trends in individual and commercial automotive transportation.

[powertransmission.com/events/cti-symposium-2026-02-04](http://powertransmission.com/events/cti-symposium-2026-02-04)

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# The Gears Behind the Green Machine

Aaron Fagan, Senior Editor

There's a particular irony in watching an electric vehicle glide silently past, promising a cleaner future, while knowing that somewhere in the Democratic Republic of the Congo, massive mining equipment—powered by diesel engines and planetary gearboxes—is extracting the cobalt that makes that quiet drive possible.

Nicolas Niarchos's *The Elements of Power: A Story of War, Technology, and the Dirtiest Supply Chain on Earth* brings this contradiction into sharp focus. What began as an investigation into lithium-ion batteries became something larger. "This was a book on batteries, I thought, a topic that might cause eyes to glaze over during dinner talk," Niarchos writes. "But as I delved further into the world of lithium-ion, I realized that it was not simply a story about sockets and charges—it was also a story about control and immense power."

That power—both geopolitical and mechanical—should interest anyone in our industry. The electrification movement doesn't represent a shift away from heavy mechanical systems. It's a shift to different applications of the same fundamental technologies we've been refining for decades.

The scale is staggering. The DRC supplies roughly 70 percent of the world's cobalt. Australia and South America provide much of the lithium. Indonesia processes nickel. At every stage, the work depends on equipment our industry knows intimately: autonomous haul trucks with drivetrains handling 400 tons, conveyor systems running continuously, crushers and ball mills operating under enormous loads.

Consider the ring gears on a 40-foot SAG mill—semi-autogenous grinding mills that pulverize ore into powder fine enough for battery production. These represent some of the most demanding applications in power transmission: continuous operation, massive torque loads, impact forces in harsh conditions. When these systems fail, production stops and the entire supply chain stalls.

Niarchos spent years reporting from mines, processing facilities, and manufacturing plants across multiple continents. While his focus is on geopolitics and human cost, the mechanical reality threads through every chapter. China didn't just invest in mines; they invested in

smelters, refineries, and the machinery to run them. They understood that the energy transition would require serious industrial infrastructure, not just better software.

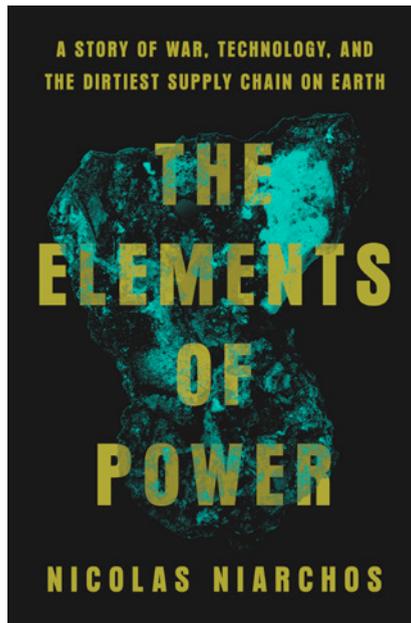
What Niarchos describes amounts to a troubling bargain. The "green transition," he argues, has been "cleaner power at home for pollution and suffering elsewhere." In this rush for green energy, he writes, "the world has become utterly reliant on resources unearthed far away and willfully blind to the terrible political, environmental, and social consequences of their extraction."

Those consequences include child labor in artisanal cobalt mines, environmental damage from nickel processing, and a widening gap between how electrification is marketed in wealthy countries and the industrial reality in places where raw materials are extracted.

For those of us designing and manufacturing power transmission components for mining and materials processing, these aren't abstract concerns. Our gearboxes, drive systems, and conveyor components are part of this supply chain. The equipment we build enables the extraction and processing that makes electrification possible.

Niarchos doesn't offer easy answers, and neither should we. The energy transition is happening. Demand for battery metals will only increase. The question his book poses—without quite stating it directly—is whether the industry can evolve toward more efficient extraction and processing, more durable equipment that reduces replacement cycles, and greater transparency about where our products operate and how.

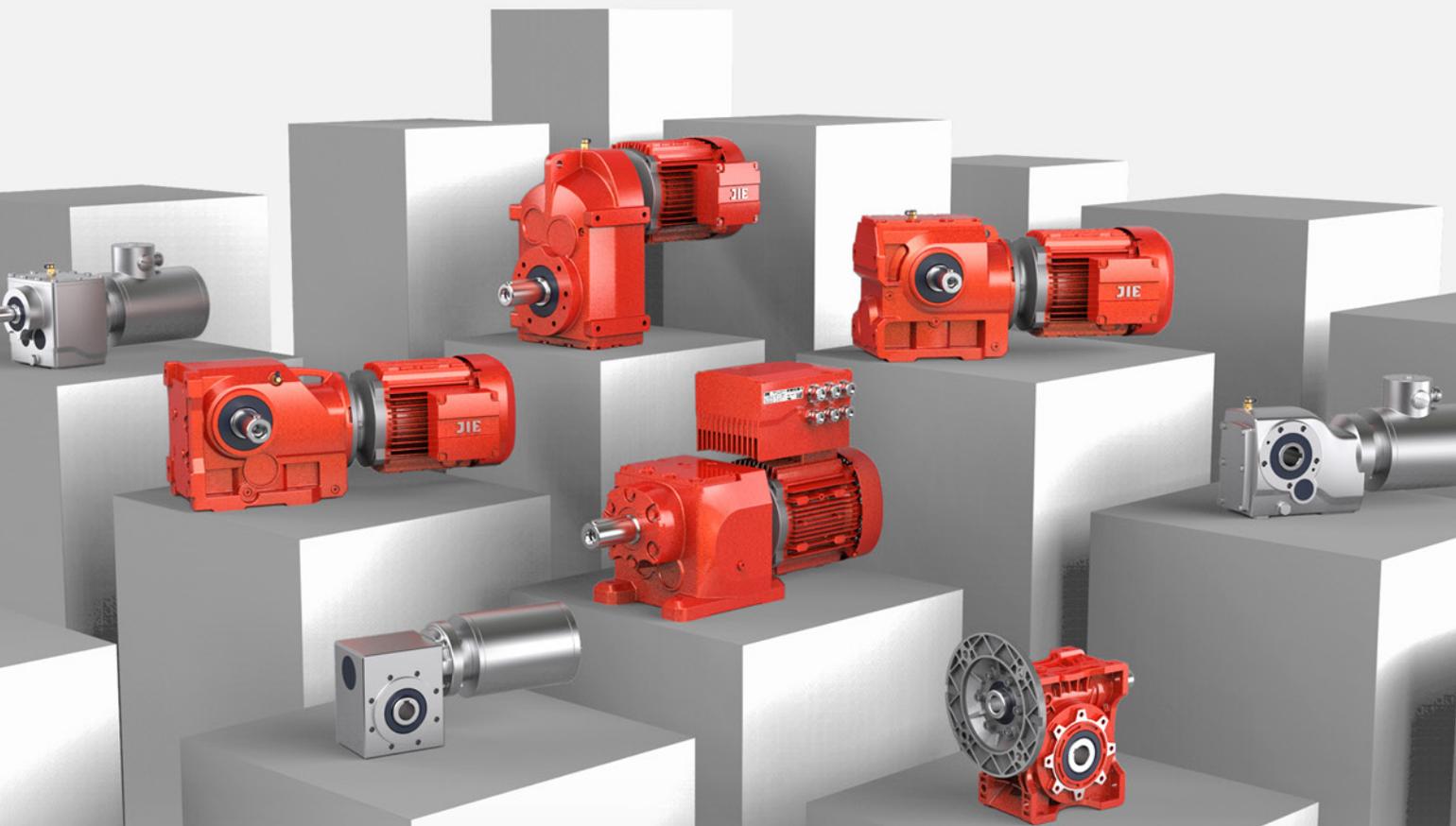
Electric vehicles may have simpler drivetrains than their combustion predecessors, but the industrial systems producing their batteries are extraordinarily complex and mechanically intensive. The future is electric, certainly. But it runs on power transmission systems operating in some of the most demanding applications on earth. Whether that's simply the reality of progress or a challenge the industry should address more directly is left, appropriately, for readers to consider.



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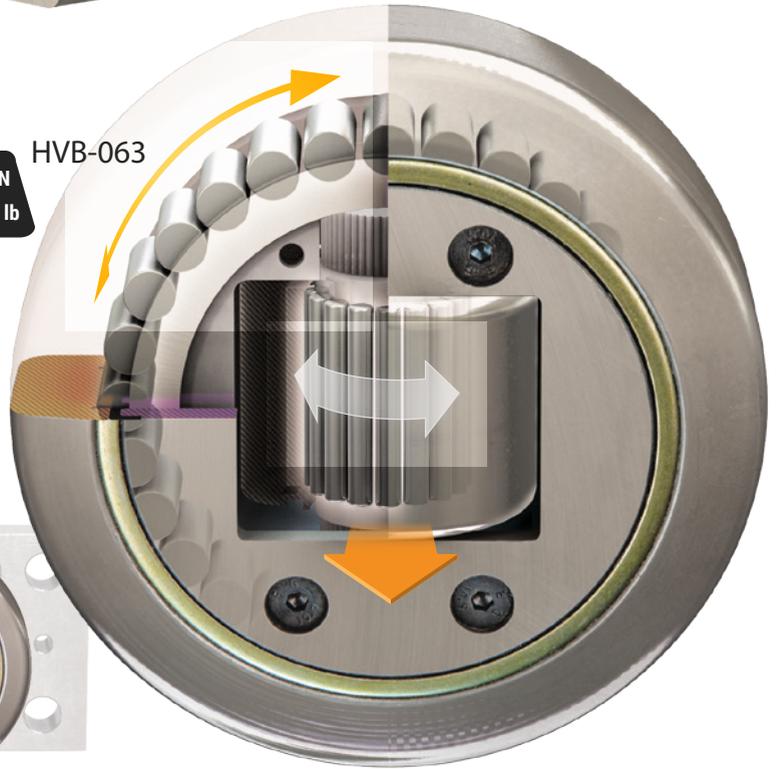
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