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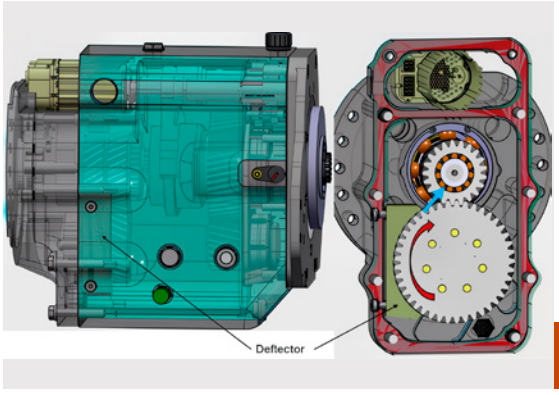

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Vol. 19, No. 8. POWER TRANSMISSION ENGINEERING (ISSN 2331-2483) is published monthly except in January, May, July and November by The Motion + Power Manufacturers Alliance, 1001 N. Fairfax Street, Suite 500, Alexandria, VA 22314, (847) 437-6604.

Periodicals Postage Paid at Elk Grove Village IL and at additional mailing offices.

Re: "Harnessing Noether's Theorem for Gear Optimization," by Aaron Fagan (*PTE*, October Issue)

When I turned the page and saw the article and that black-and-white photo of Emmy Noether, unmistakably from the early 20th century, I'll admit I paused for a moment. The image seemed oddly out of place in *Power Transmission Engineering*, a magazine known for its focus on modern machinery, materials, and motion. Out of curiosity, I wanted to see how an early-century mathematician's theorem could possibly connect to the gear industry.

Within a few paragraphs, I was hooked.

Aaron Fagan's ability to tie Noether's concept of symmetry and energy conservation to modern gear design was fascinating. The idea that every vibration or loss of efficiency can be traced back to a "broken symmetry" struck me, because, in my world of workholding, that principle plays out every single day.

As a marketing professional in precision manufacturing, I often look for ways to explain the invisible value behind rigid, accurate workholding. Fagan's article provided an unexpected bridge. When gears are machined, even the smallest imbalance or flex in the setup creates vibration, wasted energy in its purest form. But when a part is held with absolute precision and rigidity, that energy stays where it belongs: in the cut, not in the fixture or the spindle.

It reminded me that conserving energy isn't just about motors or lubrication; it starts at the point of contact between the machine and the part. In that sense, Noether's theorem isn't just theoretical physics; it's the perfect metaphor for what companies like Hainbuch strive for every day: mechanical symmetry, repeatability, and the kind of stability that keeps energy from slipping away unnoticed.

Thank you for publishing such an unexpected and thought-provoking piece. It's not often that an article makes you think about physics, philosophy, and precision workholding all at once.

Warm regards,

Michael E. Larson

Marketing Director, Hainbuch America

PTE™
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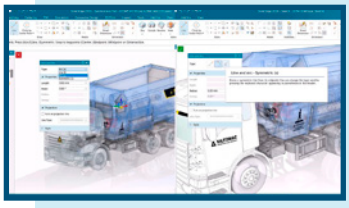
PTE REVOLUTIONS

Lubrication 2025

Lubrication is driven by sustainability, technological advancements and efficiency demands, leading to the increased use of bio-based lubricants, synthetic oils and smart lubrication systems. The industry is also focusing on developing longer-lasting lubricants, managing machine cleanliness and creating specialized fluids for emerging technologies. The trends and topics in lubrication today include sustainability, reduced downtime, formulation flexibility and accelerated training. Here are a few of the latest news stories from the PTE website.

powertransmission.com/lubrication-2025

Siemens Discusses Designcenter Solid Edge with AI and Cloud-Driven Enhancements



Siemens Digital Industries Software has announced the latest updates to its *Designcenter Solid Edge* software, including new capabilities in AI and improvements in productivity, documentation and user experience. These updates will help design and engineering teams work faster, smarter and more collaboratively across on premise and cloud environments. This interview with Dan Staples, vice president of R&D, Mainstream Engineering at Siemens Digital Industries Software examines the latest enhancements to the software package.

powertransmission.com/siemens-discusses-designcenter-solid-edge-with-ai-and-cloud-driven-enhancements

AS SEEN IN *GEAR TECHNOLOGY*

Marketing Mensch

In the September/October issue of *Gear Technology* we said farewell to a longtime colleague and friend, Dave Friedman, who retired at the end of October. As Associate Publisher, Dave's main role has been in advertising sales, and although his name and face didn't often appear in our pages, that doesn't mean he wasn't an important contributor since joining our team in 2009.

geartechnology.com/marketing-mensch

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MPMA MEDIA
1001 N. Fairfax Street, Suite 500, Alexandria, VA 22314
Phone: (847) 437-6604
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EDITORIAL
Publisher & Editor-in-Chief
Randy Stott
stott@agma.org

Senior Editor
Matthew Jaster
jaster@agma.org

Senior Editor
Aaron Fagan
fagan@agma.org

GRAPHIC DESIGN
Design Manager
Jess Oglesby
oglesby@agma.org

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

Materials Coordinator
Dorothy Fiandaca
fiandaca@agma.org

CIRCULATION
Subscriptions Manager
Jessica Schuh
schuh@agma.org

MANAGEMENT
President
Matthew Croson
croson@agma.org

FOUNDER
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.*

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ZERO-MAX®

Don't Get Left Behind

A couple of weeks ago I rode in a Tesla with the self-driving feature turned on. Our vehicle navigated perfectly, going from highway driving to congested downtown city driving, never missing a beat even when having to change multiple lanes through bumper-to-bumper traffic.

That's just one small example I've witnessed over the past few weeks that highlight for me just how far artificial intelligence has come and how quickly it's grown. Can you believe that ChatGPT was publicly released only three years ago?

Now it's everywhere and showing no signs of stopping.

At the November board meeting of the Motion + Power Manufacturers Alliance, I had the opportunity to sit down with executives from the gear and bearing industries, and AI is definitely on everyone's mind.

One discussion centered around the future of workforce, and we talked about which jobs will likely become obsolete in the next 10 years. While there wasn't universal consensus, some of the jobs mentioned were engineers, middle management, lawyers, doctors, salespeople, and even (gasp!) writers and editors.

When you add in the fact that industry is also working hard to automate most low-paying, redundant factory jobs, it's easy to see that employment relevance is going to become a scarcer and scarcer commodity in the future. A recent Gartner report suggests that even corporate executives are beginning to have their decision-making challenged by board members armed with AI agents.

It's possible that no jobs are safe in the long run. Not yours, not mine, and not even our bosses.

But there remains a healthy skepticism for AI and its capabilities. At MPT Expo, I spoke with two software engineers—from the same company—who had basically opposite attitudes toward AI. The first engineer said he routinely uses AI to help generate code and finds it an extremely useful tool that makes him more productive. The other turned up his nose, refusing to even consider the idea.

Clearly, in a lot of cases, AI isn't there yet, and it deserves our mistrust—today. There are way too many examples of hallucinations, misalignment and unforeseen consequences. AI can't do everything—yet. But remember, just three years ago it couldn't do anything at all. And now I'm cruising around town in a self-driving car.

AI isn't going away. Whatever it's capable of today will be eclipsed by what it's capable of tomorrow. That's not a prediction. It's a guarantee.

So if you're not thinking about it, talking about it and planning for it, you are surely going to be left behind.

PTE

Randy Stott
Publisher & Editor-in-Chief

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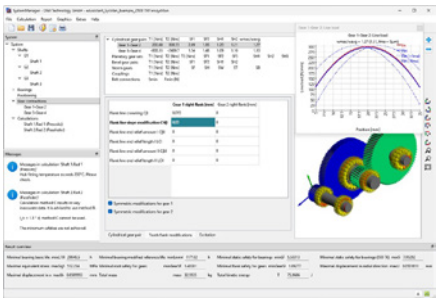
GWJ TECHNOLOGY

Presents Advanced Features for Precise Drivetrain Calculation



GWJ Technology GmbH presents the new version of its *SystemManager*, which serves as an extension for the established calculation solutions *eAssistant* and *TBK*. With numerous innovations and optimizations, the software provides engineers with enhanced capabilities for modeling, calculating, and analyzing complex drivetrain systems.

A significant advancement is the integration of shaft-hub calculations for parallel keys, interference fits, and involute splines. This allows calculations and data to be managed and exchanged directly within the system, with the corresponding individual modules being accessible in the system environment.

The *eAssistant* or *TBK* modules can be opened directly in the system. Additionally, a new message window enhances transparency by centrally displaying notifications and results from the system calculation, as well as the bearing, gear, and shaft-hub calculations. The user interface has also been optimized: a new toggle in the status bar now allows for automatic recalculation after any input changes. All results, including graphics, are immediately updated, enabling users to instantly see the effects of parameter changes.

Furthermore, the STEP import for shaft geometries has been enhanced. A defeaturing option allows elements such as chamfers, radii, or holes to be removed. The bearing databases from SKF and NSK, along with the corresponding catalog data, have also been updated.

At the system level, multiple load cases can now be defined and flexibly selected for calculations.

The calculation of the line load distribution for gears has also been further developed. A supplementary flank line deviation (fma) can now be specified for the gear connection. This allows alignment errors, such as manufacturing-induced flank line deviations of the gears or parallelism errors of the shafts, to be taken into account. The line load calculation is then performed with the additional fma, where only the tooth engagement stiffness at constant gear tilt angles is considered. This is then incorporated into the loadbearing capacity calculation according to ISO 6336 Method B via the face load factor.

The representation of shaft stiffness through wheel bodies has also been significantly improved. Instead of the previous two options, there are now five possibilities available, including the use of a 3D FEM mesh to account for wheel body stiffness.

Additionally, rotationally symmetric wheel body geometries can now be defined directly at the force element, while complex geometries can still be represented via 3D elastic components. In the area of visualization, users benefit from expanded sectional views. In addition to quarter-section views, a 180 degree section is now available. Imported housings can be displayed with custom section directions, and 3D elastic components are also shown in the 2D views.

With these enhancements, GWJ Technology emphasizes its commitment to providing engineers and technicians worldwide with powerful tools for seamless and precise drivetrain calculations. The new version of the *SystemManager* enables the modeling of even more complex relationships in a realistic manner, significantly optimizing system design.

gwj.de

KOLLMORGEN

Introduces System for High-Performance, Affordable Precision Motion

Kollmorgen has introduced the Kollmorgen Essentials motion system, a new line of servo motion solutions that makes high-performance motion control easier and more affordable for virtually any axis of motion. These thoughtfully preconfigured systems enable simple sizing and selection, while multiple onboard communication protocols ensure seamless integration into the most common controller environments. With unmatched ease of installation and commissioning, Kollmorgen Essentials ensures reliable performance across key industrial applications, from packaging and warehouse automation to material handling and forming. This is achieved while significantly reducing engineering time and overall system costs.

Each Kollmorgen Essentials motion system combines an optimally matched servo drive, a servomotor with integrated absolute multi-turn feedback, and a combined power/data cable.

The Kollmorgen Essentials drive includes multiple protocol options, allowing the user to select between fieldbus types: EtherCAT, EtherNet/IP or Profinet at time of install. The multi-axis synchronization capabilities allow designers to have precise control of multi-axis systems via a choice of CIP Sync, Profinet IRT or EtherCAT. This fieldbus flexibility gives all customers access to Kollmorgen's high-performance motion within their existing environments, without the typically associated higher system cost. It also simplifies the ordering processes and

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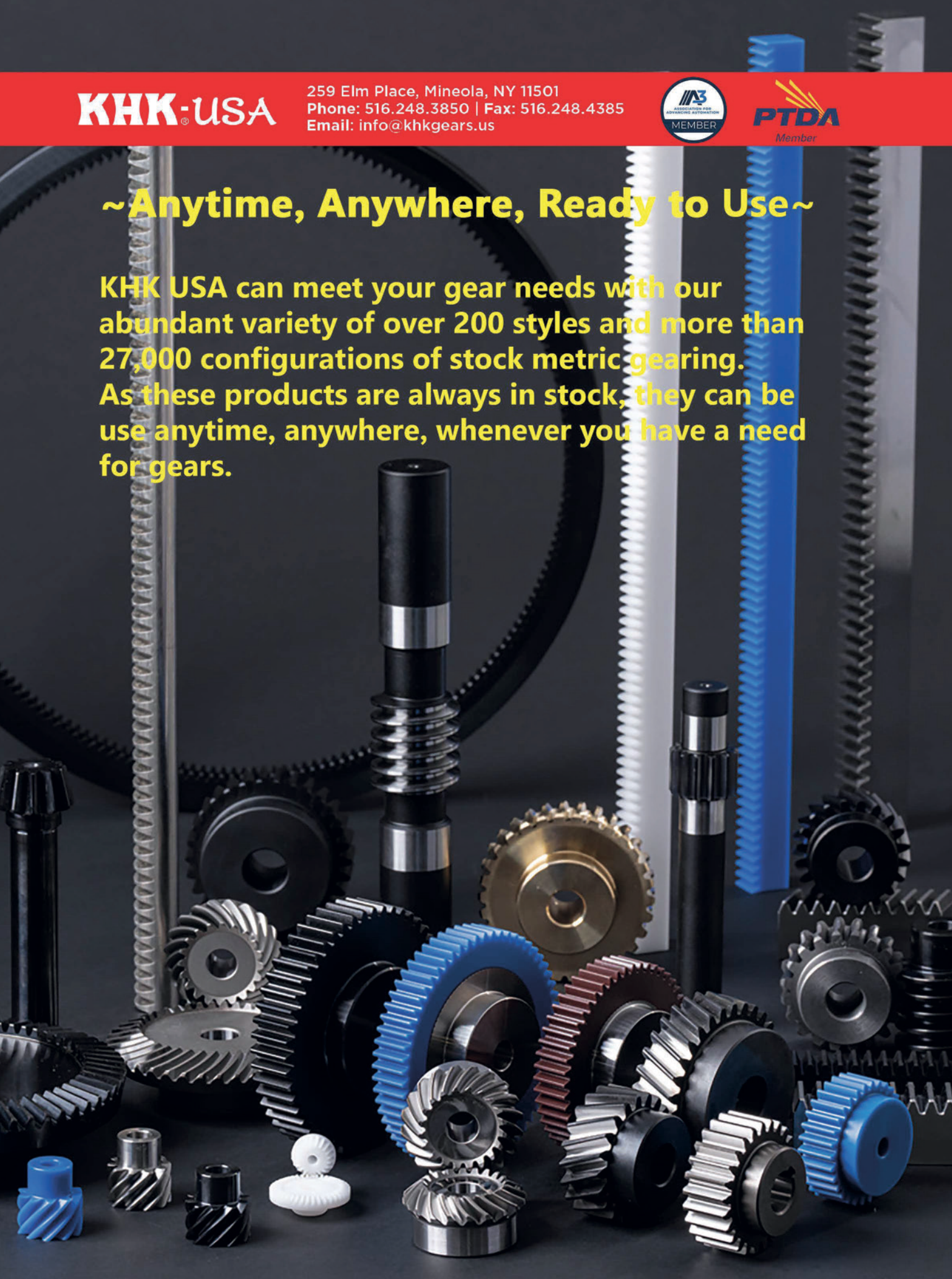
~Anytime, Anywhere, Ready to Use~

KHK USA can meet your gear needs with our abundant variety of over 200 styles and more than 27,000 configurations of stock metric gearing. As these products are always in stock, they can be use anytime, anywhere, whenever you have a need for gears.



inventory management for machine builders supporting different types of communication protocols for a global customer base. Functional safety capabilities are provided through integrated dual-channel STO, SIL2/Cat 3 PLd.

These compact, feature-optimized drives are easy to install and commission with the Express Setup feature in the *Kollmorgen WorkBench* software. Drive setup, configuration and tuning has been simplified, even for engineers with little motion experience, with the simplified graphical configuration tool that supports them throughout the entire commissioning process. And the full suite of *WorkBench* tools is also included for more advanced motion programming and tuning tasks.

The Kollmorgen Essentials servo drive is available for supply voltages of 120–240 or 240–480 VAC and delivers continuous power up to 4,000 watts at 3, 6 or 12 amps.

Kollmorgen Essentials servomotors are rated at 120, 240, 400 or 480 VAC and are designed for the most common power requirements from 200 to 4,000 watts. Each winding delivers a rated speed of 3,000 rpm, with peak performance reaching up to 6,000 rpm. An integrated 24 VDC brake is optionally available. Industry-standard mounting reduces the need for excess inventory and improves field flexibility. With a simple, innovative shaft key kit, users can adapt the shaft configuration to any coupling type—ready, off-the-shelf, for any application.

kollmorgen.com

RULAND

Offers Single Beam Couplings for Light-Duty Applications

Ruland now offers MI-series single beam couplings, expanding its zero-backlash beam coupling line to include one, four, and six beam styles. Single beam couplings are ideal for light-duty applications with low torque requirements such as encoders, tachometers, and small analytical devices.

Ruland single beam couplings feature a single helical cut that allows for greater angular and axial misalignment than comparable multiple beam couplings, making them well suited for systems where precise alignment is difficult to achieve. Their compact design and low bearing loads help protect sensitive system components, extending equipment life and improving overall reliability.

MI-series couplings are available in clamp or set screw styles with inch, metric, and inch-to-metric bore combinations ranging from 3/32 to 3/4 in. and 3 to 20 mm. They have pure metric outer diameters and lengths to better match international design standards. Hardware tests beyond DIN 912 12.9 standards ensure the coupling reaches its maximum performance capabilities.

The addition of single beam couplings expands Ruland's beam coupling size range, with outer diameters now up to 50 mm. This gives designers more flexibility to select the right beam coupling style—single, four, or six beam—to meet the performance, misalignment, and space requirements of their application.

Ruland single beam couplings are carefully manufactured from high-grade 7075 aluminum bar stock sourced from North American mills in Ruland's ISO 9001:2015 certified advanced manufacturing facility in Marlborough, Massachusetts. All Ruland couplings are RoHS3, REACH, and Conflict Minerals compliant.

ruland.com

ZERO-MAX

Offers a New Gas Nitriding Option to Protect Overhung Load Adaptors

Zero-Max offers a unique Gas Nitriding option to protect Overhung Load Adaptor (OHLA) shafts while enhancing overall system performance.

Because OHLAs are most often used in harsh outdoor environments including exposure to heat, rain, humidity, salt water, dirt and debris, protecting the OHLA shaft can be an important consideration. The new Gas Nitriding (Gaseous Nitrocarburizing) option for OHLA shafts provides superior corrosion resistance, surface hardness to boost strength and durability, and adds lubricity to the shaft, which benefits shaft seal life by reducing friction and wear.

zero-max.com

ABB

Vertical Hollow Shaft Motors Deliver Deep-Well Pump Performance

ABB's new vertical hollow shaft (VHS) motors are built for vertical turbine pump applications where performance, reliability and longevity are critical. The line reflects ABB's commitment to innovation, energy efficiency and customer-centric engineering.

ABB VHS motors reduce downtime with a top-mounted coupling and hollow shaft that provide quick, direct access to the pump shaft. This design simplifies work for operators, making routine service faster and easier.

VHS motors offer NEMA Premium (IE3) efficiency, high-thrust capability and drop-in design compatibility, filling a critical market need for durable, low-maintenance solutions in water, agriculture and industrial pumping systems.

With a compact, robust design, VHS motors deliver smooth power transmission, require minimal upkeep and offer extended service life in harsh environments.

"ABB vertical hollow shaft motors are purpose-built to elevate operations across multiple industries," said Terry Bell, ABB product manager. "From irrigation systems to municipal water supply, these motors offer unmatched reliability and performance, helping customers reduce maintenance and overall operational cost."

ABB VHS motors use heavy-duty, extra high-thrust bearings designed to withstand the intense axial loads of deep-well and vertical-turbine pumps.

Designed to match industry-standard dimensions, ABB VHS motors provide a true drop-in fit, cutting installation time for new builds and motor replacements.

new.abb.com/motors-generators

NORD
Electric Motors Deliver Reliability, Versatility and Energy-Efficient Performance

Electric drives in industrial applications consume up to 70 percent of the total energy required, creating great potential for optimization. Nord Drivesystems meets these demands with a range of powerful, energy-saving electric motors including asynchronous, synchronous, explosion protected, and smooth body versions. These motors are built in-house for high availability, deliver high-efficiency, and meet all common global efficiency regulations and standards. Thanks to the modular design, they are compatible with the full Nord gear unit and variable frequency drive portfolio and can also be used as stand-alone motors.

Nord motors are constructed with superior insulating methods to provide excellent moisture protection, low temperature rise, and voltage spike resistance in accordance with NEMA MG 1. Low rotor inertia and high starting torque allow peak performance in difficult applications involving high start/stop cycling rates or rapid acceleration/deceleration. Standard motors offer protection from the elements and include design benefits such as shaft lip seals on both ends of the motor shafts, stator to endbell connections sealed to exclude moisture, double coated magnetic wire insulation, corrosion resistant alloy materials, threaded cable entry holes, and more. While standard features address the most common requirements, there are many additional selections to configure Nord motors to meet system requirements.

Nord produces four different lines of three-phase asynchronous motors with a power range of 0.16–75 hp for operation in a wide variety of applications. While smooth-body motors are ideal for hygienic washdown environments like the food and beverage industry, two-speed and single-phase motors provide the necessary power for machine tools, pumps, conveyor belts, and fans, and standard three-phase motors offer protection against electrical and mechanical overload in countless applications. In the standard power range, IE3 motors retain the same overall dimensions as lower efficiency motors for easy drop-in replacement when switching efficiency classes.

nord.com

DODGE INDUSTRIAL

Launches StratoLink Disc Couplings

Dodge Industrial, Inc. has announced the launch of its StratoLink disc coupling line, a major expansion of the Dodge couplings portfolio. The first model to launch is the D71 Series, which meets API 610 standards and is engineered for maximum torque, simplified rebuilds, and seamless interchangeability in existing installations.

Key advantages include:

- Delivers an average of 26 percent greater torque capacity than existing designs
- 11 percent larger bore ranges than previous designs, on average, enabling a lighter coupling that reduces loads and extends driven equipment life
- Patent-pending bushing engagement system that eliminates hammering and other unsafe rebuilding practices, making rebuilds easier and up to two times faster than loose disc pack couplings
- Drop-in interchange of the center member assembly allows for easy replacement in existing applications without needing to modify or move connected equipment

"For decades, engineers have faced limited choices when specifying disc couplings, and StratoLink changes that," said Vance Chavis, global product manager for couplings at Dodge Industrial. "By combining higher torque capacity, larger bores, easier rebuilds, and drop-in compatibility, we've created an exciting new alternative. StratoLink is a powerful example of how Dodge continues to deliver practical innovations that make a real difference for our customers in the field."

For over 70 years, Dodge has delivered innovative coupling technologies and is trusted worldwide to extend the life of driven equipment and minimize downtime. From elastomeric to metallic solutions, Dodge offers one of the broadest coupling portfolios in the industry. With the introduction of StratoLink, Dodge reinforces its legacy of coupling innovation by helping engineers optimize system performance, reduce downtime, and increase productivity across various industries, including oil and gas, mining, pulp and paper, and power generation.

dodgeindustrial.com

CATERPILLAR

Introduces Cat C32B Diesel Engine

Caterpillar has introduced the Cat C32B diesel engine, a new power platform featuring best-in-class power density and enhanced durability for large off-highway machines and equipment.

Available now at Cat dealers worldwide, the new 32.1-liter, 12-cylinder engine has been re-engineered with numerous design improvements to boost power density and reliability while extending the time between rebuilds when compared with the previous generation engine on newly developed engine ratings.

The C32B reliably delivers power up to 895 kW (1200 hp) and 5,861 Nm (4,323 lb-ft) for U.S. EPA Tier 4 Final and 839 kW (1,125 hp) and 5,499 Nm

(4,056 lb-ft) for EU Stage V. A version for less regulated territories offers a peak rating of 1,007 kW (1,350 hp) and 6,166 Nm (4,548 lb-ft).

The engine is ideal for large loaders, cranes, dredgers, hydraulic power units, paving, surface hauling equipment, trenchers, pumps, forestry equipment, compressors and bore/drill rigs, among other applications.

"For nearly 20 years, the Cat C32 engine platform has set the standard for premium power and endurance in construction, mining and other industrial applications," said Steve Ferguson, senior vice president of Caterpillar Industrial Power Systems. "The new Cat C32B builds on this field-proven reputation with a series of upgrades and new technologies that will drive the superior performance of off-highway equipment for years to come."

The new C32B engine has been redesigned from the bottom up with power density and durability in mind. The new engine block is made from a strong cast-iron alloy known for its durability with internal changes made to increase structural capability.

The induction hardened crankshaft includes larger journal diameters and increased bearing area to handle higher loads. The connecting rods also include larger journals to increase durability by optimizing bearing performance.

caterpillar.com

SEW–EURODRIVE
Launches DriveTag

SEW-Eurodrive has announced the U.S. launch of DriveTag, a customized barcode labeling service engineered to simplify product identification, streamline logistics and optimize internal material flow for industrial customers.

Designed for today's high-volume, high-efficiency operations, DriveTag empowers manufacturers, OEMs and system integrators to achieve faster throughput, fewer errors and greater traceability, all through a simple yet powerful labeling solution.

Each DriveTag is a custom-engineered barcode label applied directly to SEW-Eurodrive products or their packaging. Customers define the data embedded in the tag, such as their own material number, purchase order number, project number and the SEW serial number, creating a fully personalized system that mirrors their internal processes.

DriveTags are available in multiple barcode formats, including DataMatrix, Code 39, Code 128 and PDF417, ensuring compatibility with existing scanners and data-capture systems. With one quick scan, users can instantly identify products electronically, eliminating manual data entry and reducing errors across receiving, warehousing, assembly, and service operations.

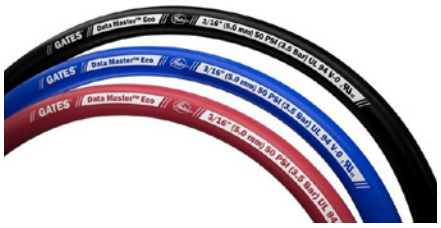
seweurodrive.com

GATES CORPORATION
Strengthens data center portfolio

Gates Corporation has launched Data Master Eco. This next-generation liquid cooling solution is designed to support hyperscale data centers and high-performance computing (HPC) conditions to maximize uptime, reduce environmental impact and meet the complex AI-enabling, data center-centric operating environment requirements. Data Master Eco showcases Gates materials science and process engineering expertise to critical challenges in modern computing: balancing thermal performance, uptime and environmental impact.

"The Data Master Eco and our broader Data Center Solutions

portfolio underscore our strategy to lead in high-value, high-growth markets," said Ivo Jurek, chief executive officer of Gates. "As AI-enabled data centers scale to meet the market demand, and the need for advanced thermal-management solutions becomes essential, we're focused of delivering application specific, high-performing liquid-cooling technologies that will define the next generation of global infrastructure."



The Data Master Eco redefines liquid cooling performance through sustainable, efficient manufacturing. Its halogen-free design offers a cleaner alternative that reduces environmental impact without compromising reliability or safety. Building on that foundation, Gates is streamlining its manufacturing process for Data Master Eco to cut energy use by approximately 75 percent compared with alternatives, eliminating natural gas, water and steam traditionally used to cure and strengthen hose materials. The company's advanced curing method also reduces carbon emissions at the source and increases production efficiency. The result is a 15 percent lighter, flexible, ultra-clean cooling hose that maintains the reliability of the Gates Data Master family.

"Data Master Eco embodies our commitment to sustainability through innovation," said Mike Haen, vice president, global product line management and marketing at Gates. "We're giving data centers a way to lower their environmental footprint without compromising thermal performance or reliability."

Data Master Eco expands the Gates Data Center Solutions portfolio, a complete ecosystem of Open Compute Project-aligned (OCP), liquid-cooling components engineered for AI and HPC environments. Building upon recent product innovations over the past year, Gates continues to steadily advance its overall portfolio in clean, direct-to-chip cooling solutions with flexible hoses, efficient quick-connect couplings, and ultra-compact pumps that optimize thermal performance and reliability. With the addition of Data Master Eco, Gates adds to its scalable, energy-efficient cooling solutions portfolio to help customers meet both sustainability and performance goals, reinforcing the company's continued investment in technologies to support global digital infrastructure growth.

gates.com

STAFFORD MANUFACTURING CORPORATION

Offers Components for OEM and Maintenance Solutions

A wide range of standard and custom shaft collars, couplings, and mounting devices that are suited for use in robotic systems and equipment have been introduced by Stafford Manufacturing Corp. of Wilmington, MA.

Stafford shaft collars, couplings and mounting components include one- and two-piece shaft collars, the Staff-LokTM hinged collars which open-close easily by hand, micro-adjustable collars, rigid couplings, precision sleeve couplings and adapters. Ideally suited for OEM design and maintenance applications, the firm manufactures over 4,000 standard parts.

Available in a wide range of materials, sizes and configurations, Stafford shaft collars, couplings and mounting components can also be manufactured to customer specifications. Parts are available in steel, paintable steel, anodized aluminum in colors, brass, plastics and other materials. Sizes

range from 0.25” to 6” I.D., depending upon the part and material.

staffordmfg.com

VESCONITE BEARINGS

Confirms PFAS-Free Status Material

Vesconite Bearings is pleased to confirm that its long-established Standard Vesconite bearing material is completely free of PFAS (per- and polyfluoroalkyl substances) and has been since its development in 1969. This includes the absence of PTFE (polytetrafluoroethylene), a commonly used fluoropolymer that is now increasingly targeted under international environmental legislation due to its persistence in the environment. With tightening PFAS regulations across the European Union, the United States, and other jurisdictions, Vesconite Bearings offers manufacturers, plant operators and OEMs a proven, compliant alternative that does not compromise on performance.

“Standard Vesconite was engineered from the beginning to be a dry-running, self-lubricating material,” says Vesconite Bearings CEO Dr Jean-Patrick Leger. “More than 50 years on, its PFAS-free formulation is gaining new relevance as industrial users seek to move away from fluorinated substances without sacrificing durability or efficiency.”

Standard Vesconite’s dry-running performance is made possible through internal lubrication that reduces the need for external greasing. This translates into smoother operation, lower maintenance, and longer service life — all without relying on environmentally contentious additives.

Importantly, Standard Vesconite’s composition and performance profile make it suitable for a wide range of bearing and wear part applications in sectors such as agriculture, water treatment, mining, construction, marine, and food processing. Its dimensional stability, low coefficient of friction, and chemical resistance ensure reliability in challenging operating environments.

“Standard Vesconite gives users peace of mind that their operations won’t be impacted by future restrictions,” says Leger.

“It’s a time-tested material that’s already helping companies meet compliance requirements while reducing maintenance costs and improving operational performance.”

For industries seeking reliable bearing and wear solutions that support PFAS-related compliance, Standard Vesconite remains a forward-looking, environmentally responsible choice.

vesconite.com

Optimize Cobots for Worksite Efficiency

Precision and productivity strengthen automation and motion control opportunities

Sean Akell, Motion Automation Intelligence

Figure 1—Cobots are ideal for machine tending applications like the one shown here. They can often tend multiple machines at once to free up workers for more important tasks. Image courtesy of Motion Automation Intelligence.

Collaborative robots have been hugely beneficial for manufacturers of all sizes over the past 15 years, and their share of the total robot market continues to grow every year. As of 2025, hundreds of different cobot models are available from dozens of manufacturers. Today, we will discuss the differences between industrial and collaborative robots, advantages of cobots, typical cobot applications, case studies, and some specific robotic solutions.

Let's begin by looking at problems facing manufacturers today.

- The cost of goods has increased dramatically.
- Engineers are in high demand, and labor rates have skyrocketed.
- Many companies are seeing a lack of skilled workers, and supply chain disruptions are unprecedented.
- Inflation remains high.

So, how can you address these issues within your company? One way would be to automate some of your production processes.

Let's look at industrial robots, which have some significant pros and cons:

1. They have been used across manufacturing verticals for quite some time.
2. Industrial robots can run at very high speeds with high repeatability and carry very high payloads.
3. A big downside is that they can be dangerous to your workforce. Industrial robots are very heavy and must be framed or caged to protect your team.
4. As industrial robots are difficult to program, your business would need a dedicated programmer on staff, or you could outsource that work. Thus, industrial robots have a significant financial cost to deploy and support them effectively.

An alternative to industrial robots would be collaborative robots (cobots). According to the Robotic Industries Association, a cobot is a robot specifically designed for direct interaction with humans within a defined shared workspace.

There are many advantages with cobots, which are:

- Specifically designed to work alongside people.
- Safer to use and do not require guarding.
- Have a lighter payload and are very easy to program.
- Offer high flexibility, low cost of integration and fast return on investment.
- Help manufacturers automate simple, repetitive tasks such as machine tending (Figure 1), assembly, processes (e.g., painting, glue dispensing, welding), part testing and material transport.

Simple, standardized tasks, such as palletizing, are ideal for cobots. If you have labor that workers may not want to do, such as dull, dirty or dangerous tasks, a cobot may be a perfect fit.

Cobots have helped our customers, such as a medical device manufacturer with employees manually loading and unloading a grinding machine. This was a situation where skilled employees were fulfilling a mundane task. Motion Automation Intelligence (Motion Ai) devised a solution and added cobots to the process. The cobots pick up the parts from a feed mechanism and offload the finished pieces to a conveyor for inspection. The average cycle time was cut by over 50 percent, freeing up employees to focus on their own skillsets. The manufacturer saw increased product quality, throughput and employee satisfaction, as well as a reduced overall cost.

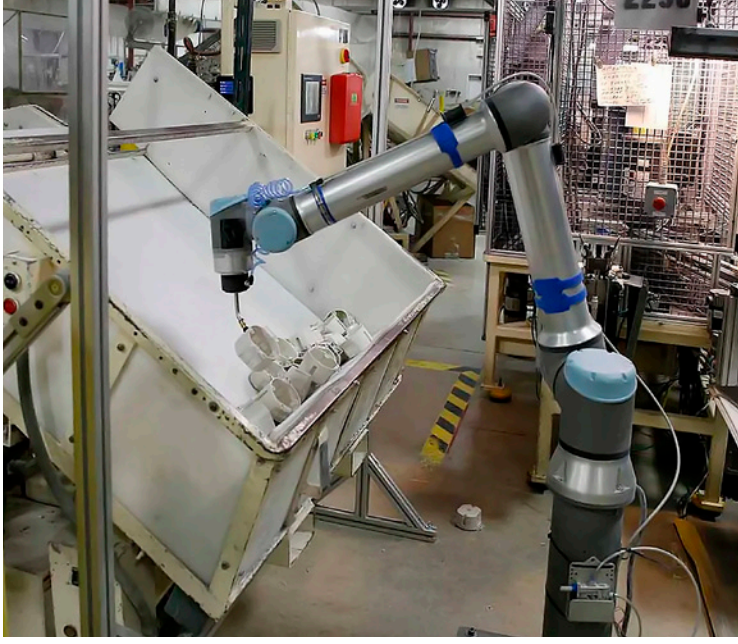


Figure 2—Using a vacuum gripper to pick parts out of a bin is another common task for cobots. Image courtesy of Motion Automation Intelligence.

End-of-Arm Tooling (EOAT) Options

Many challenges that our customers face can be solved with a cobot and a gripper. However, depending on the individual needs of the manufacturer and their process, a wide array of end-of-arm tooling options is available. These include electric grippers, pneumatic and vacuum grippers (Figure 2), wrist cameras, vision systems, and dispensing, palletizing, machine tending, welding and screwdriving options.

- *Electric grippers* are the most popular tooling option for some common cobot applications, including machine tending and pick and place. They typically come in two- and three-jaw configurations, offering precise control that allows you to vary your grip force, speed and position. This lets them handle different part types with ease.
- *Pneumatic grippers* use pressure from a compressed air supply to open and close the gripper fingers. Since most manufacturing facilities have access to compressed air already, deploying pneumatic grippers is easy and cost-effective. The largest benefit of these grippers is that they can provide a high amount of gripping force in a small package.
- *Vision systems* consist of 2D or 3D cameras that give the cobot vision. They allow the robot to locate objects, recognize patterns or scan barcodes. This may eliminate the need to present parts to the robot in a structured way since it can locate objects on its own. Vision systems also help the cobot carry out optical inspections, e.g., checking parts for defects.

Figure 3—End of line palletizing is the perfect example of a labor-intensive job that can be done with cobots. Image courtesy of Motion Automation Intelligence.

- *Dispensers* are end-of-arm tools that uniformly dispense liquids. The most common applications for dispensers are gluing and sealing. These are perfect cobot applications because of the monotonous and repetitive nature of the work. A dispenser ensures you always use the same amount of product in the same way, reducing errors and waste. Standard, built-in path planning software tools enable a user to quickly implement dispensing about a unique 3-D path for the part contour needed.
- *Screwdrivers* are a niche solution, but we are seeing more of them. Recently, our team at Motion Ai automated several applications that required this EOAT type. Our screwdriver version comes with all the software and hardware needed to automate this mundane task. Today's screwdriving solutions are smaller and less complex than their predecessors, making them viable for manufacturers of all sizes.
- *Palletizing solutions* are the ideal answer for many projects for our customers. Motion Ai offers an off-the-shelf solution that includes software and hardware to optimize this task that can be especially tedious for human workers. Once the hardware is set up, simply enter your box dimensions, weight and pallet layout into the software, and you can be palletizing in a matter of minutes—with no motion programming necessary (Figure 3).

In both screwdriver and palletizing solutions, the main benefit is ergonomics. Each screwdriver and palletizer installation gets the job done more efficiently and usually faster, allowing workers to take on other, less strenuous tasks.

The ecosystem of products that has developed around collaborative robots means that these days, almost any application can be solved with an existing solution. And if an off-the-shelf solution doesn't exist, check with your distributor for options. A full-service distributor will have experienced engineers who design custom cobots to solve applications like those listed above, plus a full line of motion control and automation products to complete your automation projects.

The Latest Cobot Trends

What does the future hold? We are already seeing cobots become more intelligent through advanced AI integration. With AI, cobots can adapt to dynamic environments, learn from data, and make real-time decisions. This allows cobots to become even more efficient by optimizing movements and improving advanced inspection tasks.

Becoming more common in the marketplace, cobots are getting more affordable. The expansion of the cobots-as-a-service (CaaS) model, where people can rent before buying, has lowered the barrier to entry even further. This means that cobot technology is now available to businesses of almost any size. Cobots are also being used in non-manufacturing applications in industries such as retail and agriculture.

As cobots continue to evolve and become more accessible, a wide range of industries are empowered to enhance productivity, flexibility and innovation in their operations.

`motionind.biz/47toJV2`

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Sean Akell has over 21 years of experience in the automation industry, working in various roles, including customer service, applications engineering, inside sales and marketing at Motion Ai (formerly Axis New England). He has been writing about collaborative robots since their introduction to the North American market over 12 years ago. He holds a B.S. in mechanical engineering from Northeastern University.

Greener Days

Embracing sustainable, lightweight and energy efficient bearing technologies

Matthew Jaster, Senior Editor

Despite a lukewarm sustainability agenda here in the United States, global bearing manufacturers continue to be motivated by eco-friendly technologies, environmental awareness and energy efficiency regulations. Material innovation is one of the key strategies to reduce environmental impact moving forward. Concerns include energy consumption in manufacturing, waste generation, emissions from lubricants and raw material extraction. The end goal is to provide longer-lasting components with less waste.

Timken Focuses on Energy Savings and Advanced Bearing Solutions

The Timken Company published its corporate social responsibility (CSR) report, highlighting advances in environmental sustainability, social impact and product innovation in August 2025. The report details Timken's progress toward its target to reduce aggregate Scope 1 and Scope 2 greenhouse gas (GHG) emissions intensity by 50 percent by 2030. From its 2018 baseline year through the end of 2024, Timken decreased emissions intensity by about 42 percent, demonstrating the company's dedication to climate action and responsible operations.

Other report highlights include:

- Doubling capital investment in energy efficiency projects from 2023 to 2024 and achieving a 15-fold increase in renewable energy use since 2018, reinforcing Timken's company-wide effort to identify and share best practices for saving energy and reducing emissions.
- Diverting 88 percent of waste from landfills in 2024 and reducing total annual waste generation by 40 percent since 2018, reflecting sustainable resource management principles that are embraced throughout the organization.
- Expanding global employee development and well-being programs while demonstrating Timken's focus on empowerment and inclusion, as reflected in a 91 percent participation rate from salaried staff in our employee engagement survey.

Timken EnviroSpexx roller bearings are designed to increase efficiency and reduce energy consumption, which affects carbon footprint.

- Investing in next-generation STEM education. In 2024, Timken invested $1.25 million in global STEM programming and expanded partnerships with organizations including FIRST and the Girl Scouts, reaching thousands of students worldwide.
- Delivering innovative, sustainable products—like EnviroSpexx bearings for energy savings and advanced solutions for vertical farming, precision agriculture and medical robots—that help customers reduce energy use, cut waste and improve performance in demanding applications.

EnviroSpexx tapered and spherical bearings are designed with enhanced geometries that reduce torque, lowering the amount of electricity needed to operate pumps, compressors, motors, gearboxes, and other continuously running industrial equipment.

In a recent study on light industrial gearboxes, Timken EnviroSpexx roller bearings reduced torque by 10 percent per gearbox compared to standard bearings. Over five years of operation, this torque reduction could save $5,000 in energy costs and reduce carbon emissions by 25,000 pounds per gearbox. Similar results were calculated for compressors and pumps.

Timken EnviroSpexx roller bearings provide sustainable solutions to help original equipment manufacturers and end users reduce energy costs and carbon emissions.

timken.com

SKF Launches Venture

SKF recently announced the launch of SKF Ventures, a new initiative aimed at accelerating innovation, exploring emerging technologies, and developing future-oriented industrial solutions. The initiative supports SKF's strategic direction and reinforces its commitment to long-term value creation through innovation.

Mikael Krook, director, SKF Ventures, said it will serve as a platform for testing, refining, and scaling innovative ideas into real-world solutions.

"Innovation is central to our strategy of achieving profitable growth and SKF Ventures adds a new dimension to how we innovate. By combining our deep industrial expertise with external collaboration, we can accelerate the development of solutions that are smarter, more sustainable, and more relevant to our customers," says Annika Ölme, chief technology officer and senior vice president, technology development at SKF.

As industries undergo rapid transformation, driven by digitalization, sustainability demands, and evolving customer expectations, SKF Ventures will serve as a platform to identify and develop new opportunities to grow and create future business. By engaging with startups, technology partners, and external innovators, SKF Ventures will bring new perspectives and capabilities into SKF's ecosystem.

"SKF Ventures is about looking beyond today's challenges and identifying the technologies and business models that will shape the future of our industry. It serves as a platform for testing, refining, and scaling innovative ideas into real-world solutions that deliver value for our customers and enhance our long-term competitiveness. This is how we stay relevant, resilient, and ready for the future," says Mikael Krook, director, SKF Ventures.

SKF Ventures will operate across three key areas: scanning for emerging technologies, exploring and validating new ideas through open innovation, and building ventures that can scale into sustainable businesses. This approach complements SKF's internal R&D and strengthens its ability to respond to fast-changing market dynamics.

The initiative is expected to deliver tangible outcomes, including faster innovation cycles, early access to breakthrough technologies, and the creation of new business models. Many of the ventures will focus on areas such as energy efficiency, circularity, and digital solutions which are key priorities for SKF and its customers.

SKF Ventures will also strengthen the company's position within the broader innovation ecosystem, enabling it to partner more

effectively with the startup and technology community. This will support SKF's ambition to lead in industrial transformation and deliver long-term value through innovation.

skf.com

Bearing Megatrends with Schaeffler

For decades, Schaeffler has been developing innovative precision rolling bearings and drive systems for leading machine tool manufacturers. Key components include linear guidance systems and linear motors for main axes, precision bearings for main spindles, as well as rotary table bearings and torque motors for rotary tables, milling heads, and portal milling machines. The industry's megatrends—automation and multi-process machining—are having a direct impact on the development of new machine axes, and therefore on the rolling bearings and drive systems themselves.

Christian Straub, manager sector development industrial automation, explains: "For machine tool automation, we are now developing a dedicated class of rotary table bearings—streamlined to the essentials, with low-maintenance operation, tailored stiffness, and designed for lower speeds."

For spindle bearings and rotary tables in multi-process machines, however, the requirements are quite the opposite. "Here, higher speeds and stiffness are required, which we achieve with high-end components such as spindle bearings made of the high-performance rolling bearing steel Vacrodur, and YRTS series bearings for turn-milling tables," adds Straub.

Schaeffler recently showcased these new precision angular contact ball bearings for driven tools at EMO in Hannover. The PTB (Precision Tool Bearings) series has been newly developed as a cost-efficient solution for both original equipment and the reconditioning of driven tools.

In addition to the double-row screw drive bearings ZKLN-HC and ZKLF-HC (with flange mounting), Schaeffler's portfolio now also includes the three-row DKLFA screw drive bearings with ceramic rolling elements. These hybrid bearings provide a reliable solution to prevent false brinelling on the raceways. This damage pattern typically occurs in short-stroke applications, where small oscillating movements displace the lubricant from the rolling contact.

The PTB (Precision Tool Bearings) series has been newly developed as a cost-efficient solution for both original equipment and the reconditioning of driven tools.

In the linear technology sector, Schaeffler is expanding its range of monorail guidance systems to include the newly developed KLLT series of four-row linear recirculating ball bearing and guideway assemblies, designed specifically for applications in production machinery peripherals and for lighter handling systems.

DKLFA screw drive bearing with ceramic rolling elements.

The defining feature of this series is its X-arrangement, which allows the assemblies to mate more effectively with substructures that have minor shape errors, without generating significant constraining forces.

For axes outside the machining area, such as pallet changers, Schaeffler is showcasing the new YRTA rotary table bearing series. Bearings in this series have been designed specifically for the requirements of highly rigid "automation axes." A particularly innovative option is the YRTAG design, in which a customer-specific gear toothing is integrated into the inner ring of the bearing. This enables manufacturers to save valuable installation space, reduce weight, and, above all, shorten assembly time.

schaeffler.us

Sustainable Supply Chains

There continues to be a push toward corporate social responsibility and the integration of sustainable technologies in bearing manufacturing. Machines need to run faster, longer and safer. This is where low-friction, limited lubrication, lightweighting, remanufacturing and recycled materials can play a significant role in the future of manufacturing. Companies that collaborate with suppliers providing recycled materials and encouraging responsible material sources will be better prepared for the changes facing manufacturers tomorrow.

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A Focus on Craftsmanship

Nord Drivesystems provides gearmotors for Georgia-based automation provider

Consider the following scenario: guided by vision sensors, a robot spots a product on a moving conveyor, determines its exact position and, in one fluid motion, picks it up and places it into a waiting assembly, carrier tray, or shipping container. What human operators once found tiring—or at least tedious, the robot performs flawlessly, hour after hour, even long after its flesh-and-blood coworkers have gone home for the evening.

A robot spots a product on a moving conveyor, determines its exact position, picks it up and places it into a waiting assembly, carrier tray or shipping container.

Given the ongoing shortage of skilled workers, we can expect to see many more such scenarios, especially as the U.S. ramps up its reshoring efforts. That's where John London, director of operations at MESH Automation, comes in. "Getting parts and products positioned precisely without fail—there's little room for error," he explained. "That's long been one of the primary challenges with many competing automation systems. But not for us."

Since its founding in 1999, MESH Automation of Dawsonville, GA, has been meeting these and other automation challenges head-on. The company designs and builds robotic palletizing, machine tending, material handling, and warehouse control systems for an eclectic mix of customers across practically every industrial manufacturing sector.

Whether they're building solutions for automakers and their tier suppliers or food processors, roofing material producers, fertilizer manufacturers and many others, MESH and its 40+ employees work to provide robust and reliable automation systems by focusing on craftsmanship, attention to detail, and commitment to excellence.

Proud Partnerships

Part of this success stems from strategic partnerships with some of the leading names in automation. These include Fanuc, Siemens, and Cognex, to name a few, all of which contribute to MESH Automation's reputation for quality and dependability. But with automation comes the equally important need to bring products and materials to and from the machine tool, packing station, or inspection system, and do so without fail.

For this critical task, MESH depends on a supplier with equivalent recognition throughout the industry: Nord Drivesystems. "I like to tell people that, even though we build conveyors, we're not a conveyor company," said London. "Still, we make a lot of them, and pretty much all are located within 30 feet or so of a robot."

For the past three years, he adds, each of these conveyors has used Nord helical worm gear motors to move whatever's sitting on top of it.

This partnership began thanks to a COVID-induced supply chain disruption; after MESH Automation's previous gearmotor supplier ran into inventory problems, London and his team reached out to their distributor, Motion Automation Intelligence of Birmingham. The sales representative there suggested they give Nord a try. Unfortunately, the very first shipment hit a snag—the motors arrived damaged in transit.

"That's when I knew Nord would be a good company to work with," London said. "Their standard lead time was six weeks at the time, but they were able to deliver replacement motors in just two, keeping us on schedule. That told me a lot about their emphasis on customer service."

This support level continues to this day. In one recent example, a MESH apprentice accidentally wired three motors incorrectly, causing them to burn out during startup. After being notified of the situation, Nord's Charlotte plant prepared replacements within a few hours, allowing a MESH project manager to pick them up that afternoon. "That was a big deal for us, and it reinforced what I already knew: Nord Drivesystems is a solid company, as is our relationship with them," London added.

Diverse Needs

The partnership with Nord has served them well. As noted earlier, MESH enjoys a diverse customer base, with no industry segment exceeding 25 percent of its business. "We don't want just one industry feeding us," London explained. "Despite their differing needs, however, we're able to cost-effectively deliver automated systems to each of these industries due to our use of pre-engineered platforms, which we can easily modify for specific applications.

No two are identical, although we do use terms around here like 'half identical' and 'three-quarters identical' to describe the level of customization needed to meet customer requirements."

Nord helps in this respect as well. For instance, MESH technicians can quickly change the gear ratio on any motor, a normally onerous chore made possible by Nord's modular, interchangeable components. This flexibility allows them to easily adjust the speed and torque to match the application without having to stock additional components. And when a special order is called for, noted London, "They've pretty much had whatever we need in stock or available within a couple of weeks."

Whatever the customization level, these platforms often fall under the "MAC" family of automation cells—the MACTend for machine tending, the MACPac for packaging tasks, the MACGrind for finishing small- to medium-sized parts, and so on. Together with its assortment of process-specific "bolt-on" modules, each offers a starting point for MESH engineers to design what are effectively custom solutions but without the associated price point.

Prove It

Among the many customer success stories posted on the company website is a manufacturer of carpet tiles, which needed to feed "master" tiles to a press that cuts them into smaller pieces, a step known as "planking." Here, MESH delivered a cell containing a pair of vision-equipped robots and custom end-of-arm tooling able to replicate the delicate but ergonomically taxing motions of a human operator.

In another, a company that constructs hurricane-proof sheds wanted an automated way to screw the wall and roof panels to the wooden frame. In the past, this operation proved both labor-intensive and error prone. Yet MESH designed a system with two robots, each armed with a screw gun to fasten the panels, following pre-programmed paths and working around window and door openings while ensuring consistent attachment quality.

MESH Automation utilizes Nord helical worm gearmotors for conveyor systems.

And a company supplying machined components to its automotive customer desired to augment its human workforce by going "lights out" for three days at a time. This endeavor wouldn't be notable except for the fact that two different castings were used to produce six different part numbers, which meant that the system had to be "smart" enough to identify each workpiece before loading it into the CNC lathe. MESH accommodated this requirement by integrating a vision inspection system into the cell, reading each casting number and tracking it both during and after machining.

Each of these solutions and many others share a common theme: the need for dependable conveyors to move products, parts, and materials into and out of the cell. Without them, nothing happens, which is why the company continues to rely on Nord products, despite their being a bit more expensive than those of the previous supplier.

"We buy around seventy Nord gearmotors each year and are actually paying slightly more than we did before, but the partnership we've built is well worth the extra money," London said. "We're not one to beat someone up on price and then run away when there's an issue—instead, we place great value on suppliers who offer a fair price and stand behind their products. That's what Nord does."

Fast Movers

MESH's latest project may be its most ambitious yet: a robotic induction system for e-commerce sortation, which debuted at the recent ProMat 2025 trade show. The system uses a vision-guided robot to pick items from bins, scan barcodes on either side of the box, package, or envelope, and place each on a high-speed conveyor feeding a bomb bay-style sorter. Here again, the system depends on Nord worm gearmotors to keep everything moving.

London noted that the scanning capability eliminates a key limitation of current systems, where operators must place items with barcodes facing upward. "Our system doesn't care which way the label faces. It also picks 1,800 items per hour—well beyond what a human operator can achieve. We think it's the first such solution on the market."

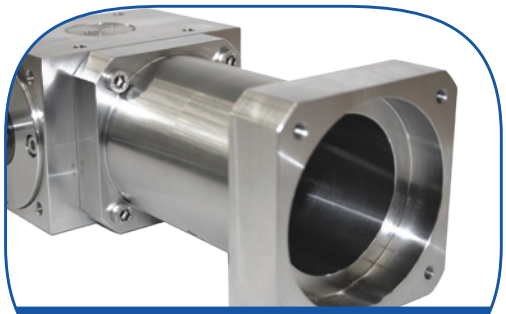
When asked a question that's at the top of mind for many—whether automation is putting people out of work—London pushed back.

"Our robotic cells don't replace people—they move them to better jobs. For example, I've seen how the companies that implement automation can often expand their quality control efforts. They put more energy into making sure products meet higher standards. And because workers no longer have to perform the repetitive, oftentimes strenuous tasks common in manufacturing, they're able to spend more time on process improvement, oversight, and other value-added activities. It's better for everyone involved and makes the company more profitable to boot. That's what automation delivers."

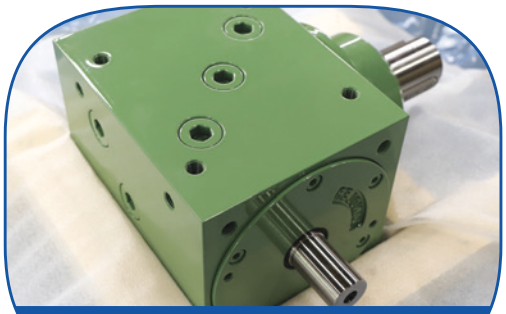
nord.com

When off the shelf just won't do.

With our enormous variety of standard components and custom machining capabilities, a custom-designed and manufactured gearbox for specific applications is something we do all the time.



Custom Flanges



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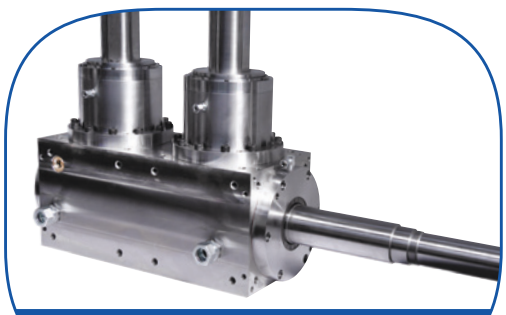
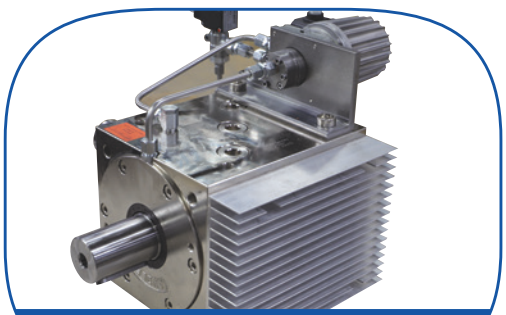


Complete Redesigns



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Safe, Reliable Spindle Operation

Development of a load limit diagram for a motor spindle using *MESYS*

MESYS AG

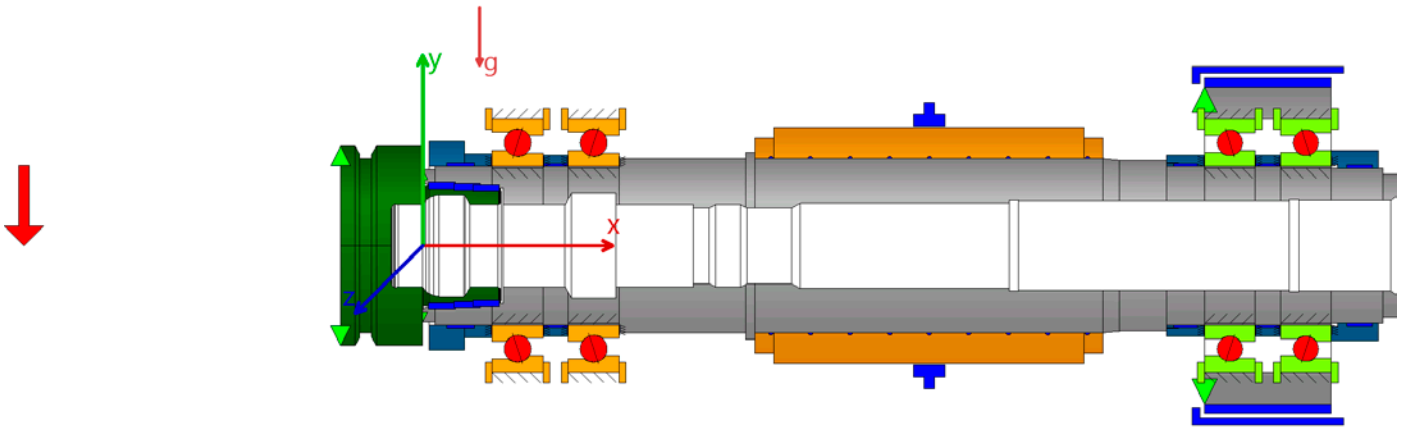

Figure 1—Motor spindle.

The load limit diagram of a motor spindle serves to graphically represent the permissible operating range as a function of parameters such as rotational speed. It enables a quick assessment of the conditions under which the spindle can be operated safely and reliably without exceeding mechanical, thermal or dynamic limits. Such a diagram is a key tool for the design, selection and evaluation of spindle systems in mechanical engineering particularly in the field of machining where high demands are placed on precision, performance and service life.

The same methodology can also be applied to electric motors in general, where torque, speed, thermal and structural limits likewise play a central role in design and application. Whether in machine tools, robotics, automotive engineering or industrial drives—a systematically developed load limit diagram provides a solid foundation for the safe and efficient use of the motor at its intended operating point.

To better understand these interrelationships, this article aims to explain the systematic derivation of a load limit diagram. It addresses both the physical fundamentals and the practical limitations arising from bearing arrangement, drive system, cooling and structural design. The objective is to identify the key influencing factors that determine the spindle's limit behavior and to present them in a transparent, simulation-based format using *MESYS*.

Specification:

The investigated hypothetical application is a high-speed motor spindle for aluminum machining, with a maximum torque of 10.75 Nm and a maximum rotational speed of 36,000 rpm. An HSK-F63 interface is used as the tool holder. The applied tool radius is $r = 12$ mm, corresponding to an end mill with a diameter of 24 mm.

Bearing Concept:

The spindle is supported by two spring-preloaded O-arranged tandem bearing sets, each consisting of a front and a rear bearing pair. The following bearing configurations are used:

- Front bearing pair: 7010, contact angle = 18°
- Rear bearing pair: 7010, contact angle = 18°, spring-preloaded with 1,300 N

This arrangement corresponds to a typical configuration for high-speed motor spindles. It allows for the accommodation of thermal expansion in the axial direction while maintaining high stiffness and performance capacity.

Mounting Orientation:

The spindle is horizontally mounted, which prevents the front bearing set from being unloaded by gravity. This positional effect is considered in the calculation.

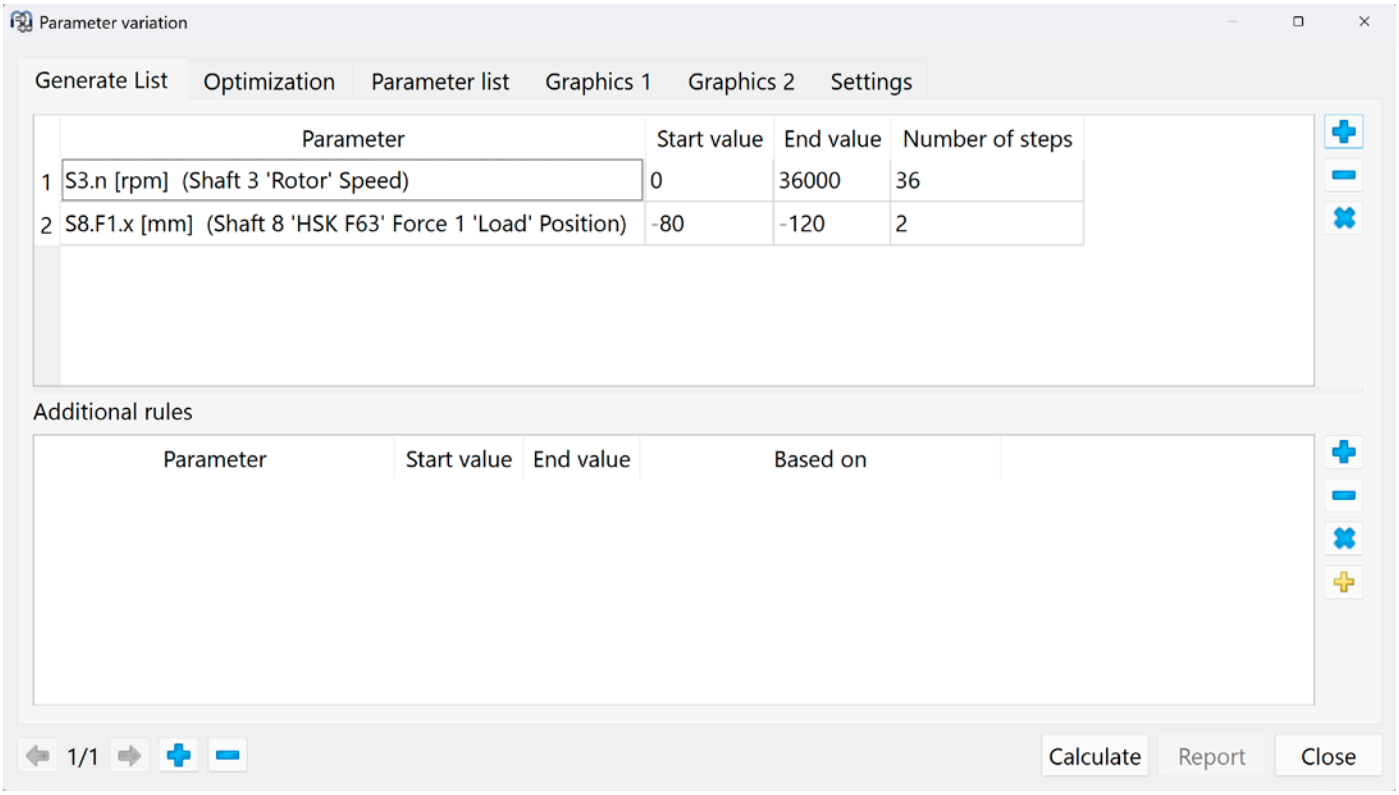

Figure 2—Parameter list.

Influencing Factors Requiring Limitation

Mechanical Limits

- Maximum speed: Limited by bearing capability, rotating parts, centrifugal forces, or balancing quality
- Maximum torque: Limited by motor, windings, rotor structure, or inverter performance
- Tangential tool force: Induces bending moment in the spindle
- Radial force: Degrades spindle kinematics
- Axial force: Especially critical when negative
- Combined radial/axial load: Leads to asymmetric bearing loading
- Spindle orientation: In vertical position, gravity may unload front bearing set

Bearing-Related Limits

- Bearing misalignment: Affects kinematics and contact pressure
- Hertzian contact pressure: Influences fatigue life
- Spin-to-roll ratio: Affects kinematics
- Ball lead/lag: Affects kinematics

Thermal Limits

- Rotor power loss: Temperature gradient across shaft segments
- Bearing seat heating: Temperature gradient alters preload, kinematics, and bearing life
- Thermal expansion: Affects the compensation or behavior of the bearing pair

Methodology for Limit Curve Determination

For the present study, a set of exemplary limiting conditions is defined to generate a technically consistent load limit curve for the motor spindle. These conditions serve illustrative purposes and enable a transparent delimitation of the permissible load range as a function of rotational speed. Naturally, more complex and realistic criteria may be considered in subsequent studies for the generation of, for example, a full load limit map.

For the simulation described, a worst-case load scenario was defined at three working positions with axial distances from the spindle nose of $x = -80 / -100 / -120$ mm:

- Tangential force: 100%
- Axial force: –33%

The following limit states are considered in the simulation:

- Minimum Hertzian pressure: p_{min} > 500 MPa
- Maximum Hertzian pressure: p_{max} < 2,000 MPa
- Spin-to-roll-ratio < 0.3
- Maximum transferable torque: *Mx* < 10.75 Nm

Parameterization and Evaluation

The *MESYS* shaft calculation module is used to determine the load limit curve. The optimization function for parameter variation “maximize input based on conditions” is applied

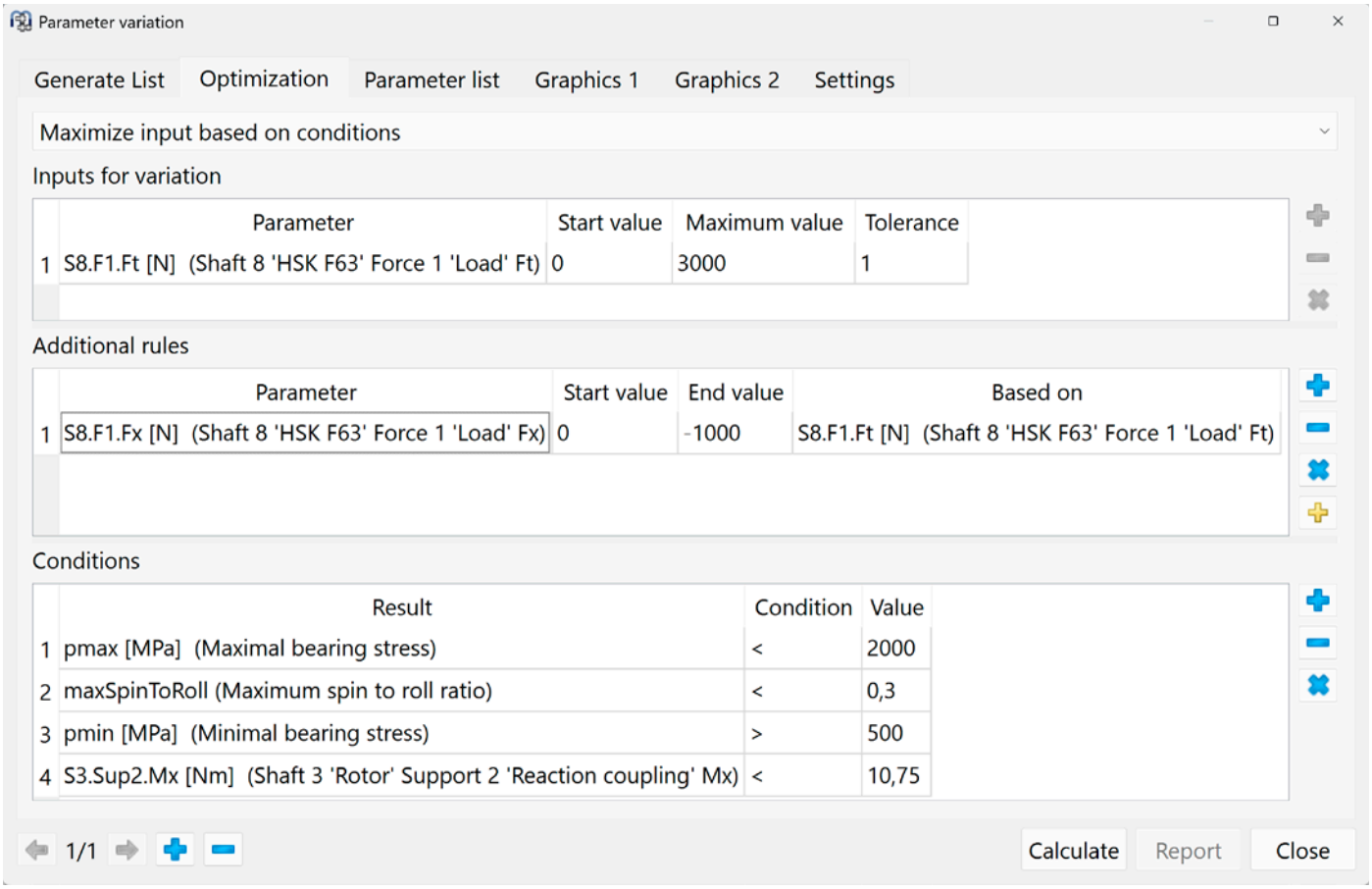

Figure 3—Optimization criteria.

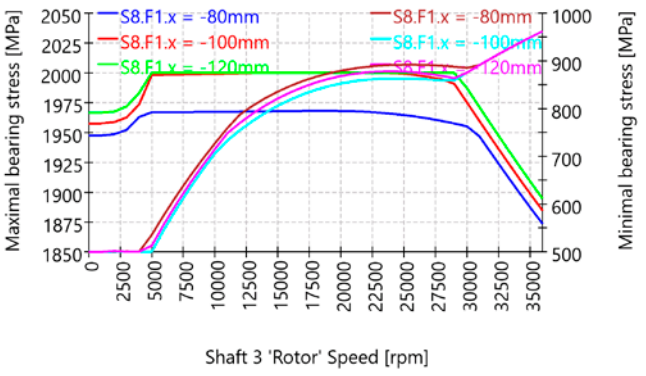

Figure 4—Contact pressures min/max.

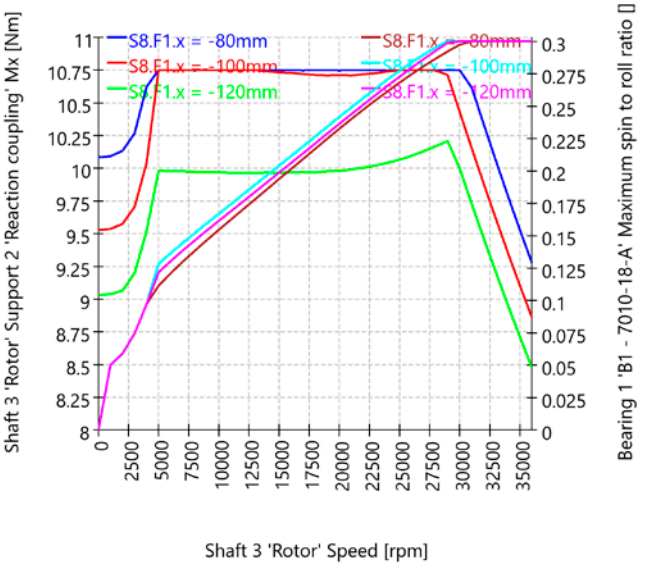

Figure 5—Output torque and kinematics at rolling bearing 1.

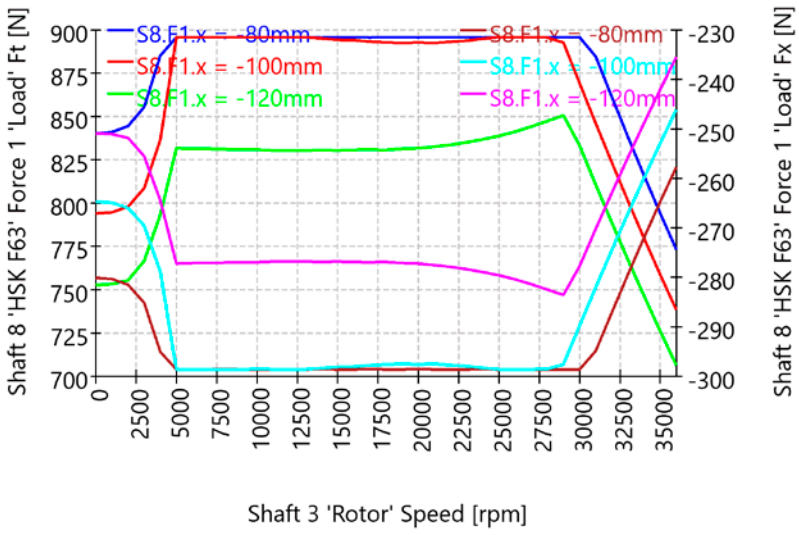

Figure 6—Load limit diagram.

to determine the maximum permissible loads while complying with defined limit values.

The software iteratively increases the load if all limit conditions can still be met simultaneously. In this way, a maximum permissible force combination is determined for each speed level.

- p_{min} limits $x = -100$ mm up to 4,000 rpm
- p_{max} limits $x = -100$ mm between 13,000 and 24,000 rpm
- p_{max} does not limit $x = -80$ mm
- Mx limits $x = -100$ mm from 5,000 to 12,000 rpm and from 25,000 to 28,000 rpm
- Spin-to-roll ratio limits $x = -100$ mm at B1 from 29,000 to 36,000 rpm
- The motor power cannot be fully exploited at $x = -120$ mm, as p_{max} is the limiting factor

Results and Interpretation of the Load Limit Curve

The resulting load limit diagram shows the maximum permissible load on the motor spindle as a function of rotational speed, while complying with all previously defined limit conditions.

Key findings from the curve envelopes:

At low rotational speeds (< 5,000 rpm), the load is limited by falling below the minimum bearing pressure. This is intended to prevent bearing tilting and potential loss of contact.

In the range between approximately 5,000 and 30,000 rpm, a wide usable band emerges in which the spindle's load capacity can be largely exploited without reaching critical bearing conditions. This range is therefore considered an economically efficient operating window.

From around 30,000 rpm onward, the spin-to-roll criterion at rolling bearing 1 becomes the limiting factor, as radial loads at very high speeds can disturb the bearing kinematics and lead to associated issues.

Overall, the generated load limit curves clearly illustrate both the design reserves and the physical limitations of the spindle. They provide a basis for defining suitable application ranges, planning machining strategies, and avoiding critical overloads.

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PTE

Advanced Gearbox Lubrication Analysis: A Virtual Lab for Design Optimization

Benjamin Beckelynck

For over two decades, our Montreal-based engineering simulation consultancy has provided advanced solutions to a diverse range of industries. Our expertise has facilitated the resolution of complex engineering challenges, leveraging the latest technologies in computational fluid dynamics (CFD) and heat transfer analysis. Among our recent projects, one particularly notable case involved a company specializing in converting combustion engine vehicles to electric vehicles. That company developed a compact electric motor paired with a 2-speed gearbox, illustrated in Figure 1, designed to optimize performance and efficiency.

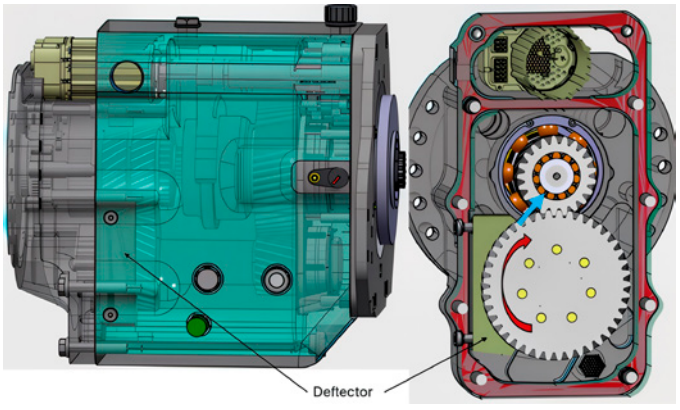


Figure 1—Two-speed gearbox isometric and cutaway views showing the deflector.

During the development process, the manufacturer identified a critical region that could lead to an overheating bearing problem. Figure 2 shows a cut view centered on the narrow gap between the second gear and the input gear. Anticipating this problem, the manufacturer added a deflector to their design. The goal was to guide more lubricant toward the narrow gap to induce better cooling of the bearing. They built a test bench and faced the anticipated problem.

Despite the deflector, they observed some damage on the input gear bearing. Paint labels were placed on the neighboring gears and indicated high temperatures confirming the overheating problem. To expedite the iteration process and identify a viable solution, the client sought our assistance to develop a comprehensive analysis workflow that could replicate the problem and test potential solutions efficiently.

Our first objective was to reproduce the problem, by simulating the exact same configuration as the one on their test bench. Once correlated, we could investigate the results, understand the lubricant behavior and test several concepts to solve the overheating problem. This case presented an excellent opportunity to demonstrate the capabilities of advanced simulation techniques in addressing real-world engineering problems, ultimately contributing to the company's success in developing reliable and efficient products.

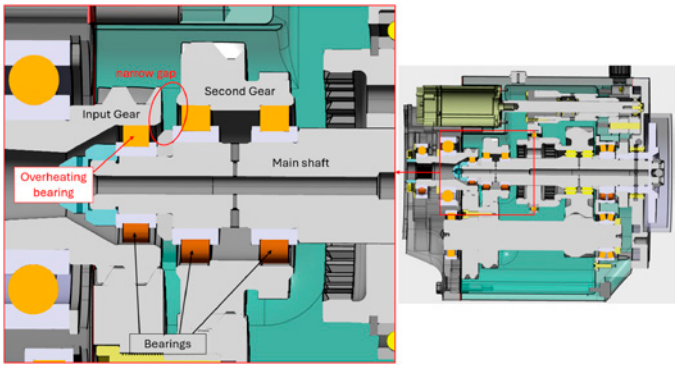


Figure 2—Cutaway view of the gearbox, zoomed on the narrow gap region.

Experimental Test Bench Challenges

The process of constructing a gearbox prototype is both time-consuming and costly. Each new design requires a unique set of components, often necessitating specialized manufacturing procedures. The lead time for producing these components can be extensive, encompassing material procurement, machining, assembly, and quality checks. Additionally, the cost associated with manufacturing a single prototype is high, as the procedures do not exist yet and the machinery might not be adapted.

Once a prototype is built, any design changes mean starting the process over again. This iterative cycle can be exceedingly slow, with each iteration requiring new parts, leading to significant delays in the development timeline. The slow pace of physical prototyping makes it challenging to quickly test and refine new design concepts, ultimately slowing down innovation and optimization efforts.

Extracting precise engineering data from a physical test bench is another major hurdle. The dynamic and complex nature of gearbox operation makes it difficult to gather

accurate and comprehensive data, essential for informed design decisions.

One of the primary challenges is visualizing the behavior of lubricant within the gearbox. Lubricant splashing, crucial for cooling and lubrication, occurs rapidly and chaotically, making it difficult to observe and analyze. Windows in casings and high-speed cameras are sometimes used to capture these dynamics, but these methods have limitations. The visibility inside the gearbox is restricted, and the high-speed cameras required for capturing fast events are expensive and can only provide limited views.

Churning loss, the resistance created by lubricant splashing against rotating parts, is a critical factor affecting gearbox efficiency. Accurately measuring churning loss in a physical test bench is challenging. It requires precise instrumentation capable of capturing the subtle differences in torque. The sensors and equipment needed must be carefully calibrated and maintained to ensure accuracy. Torque loss measurement is the sum of the churning loss, the bearings loss, seal friction losses and the gears friction, making churning loss only estimation challenging.

Temperature measurement on fast-rotating parts and small bearings presents another significant challenge. Thermocouples, sensitive paint and labels are commonly used, but placing these sensors on moving parts is complex. Ensuring that the sensors remain in contact and provide accurate readings while the parts are in motion is difficult. Additionally, the small size of bearings and the high rotational speeds make it hard to obtain precise temperature data. Usually, a paint label can be placed on a neighboring shaft, but not on the bearing itself. And it is telling you if the temperature has reached a certain threshold but does not give you the value.

The challenges associated with physical gearbox test benches underscore the limitations of traditional prototyping and testing methods. The time and cost of building prototypes, combined with the difficulties in extracting accurate engineering data, significantly hinder the efficiency of the development process. These challenges highlight the need for advanced simulation techniques and virtual models, which can provide a more efficient, cost-effective, and comprehensive approach to gearbox design and analysis. By leveraging these technologies, engineers can rapidly iterate designs, test multiple conditions and scenarios, and extract detailed insights without the constraints of physical prototyping.

Numerical Challenges in Modeling Gearbox Lubrication

Numerically, modeling gearbox lubrication involves significant challenges. Lubricant splashing is a highly turbulent and transient process, necessitating a transient CFD analysis with a sufficiently long simulated time to achieve a developed flow. This typically requires four to eight seconds of physical time, depending on the geometry's size and complexity, and demands substantial computational power. The new XFlow 2023 solver supports both NVIDIA and AMD GPU cards, allowing for significantly reduced runtimes, from weeks of computing time to days, making this process accessible. XFlow employs a particle-based Lattice Boltzmann solver, offering multiphase and moving parts modeling capabilities, irrespective of the system complexity, gear types and lubrication methods (Ref. 1).

Heat transfer, being a slower process, is typically resolved through steady-state analyses. The Abaqus implicit solver is widely recognized in both industry and academia for its effectiveness. Lubrication involves heat extraction from solid parts through convection, a challenging aspect to quantify in transient analyses with rotating parts. The equation for convection, also known as the heat transfer convection equation, is typically expressed by Newton's law of cooling. This law describes the heat transfer between a surface and a moving fluid. The equation is as follows:

$$Q = h * A * (T_s - T_f) \tag{1}$$

where

Q is the rate of heat transfer (in W)
h is the convective heat transfer coefficient, HTC (in W/(m^2·°C))
A is the surface area in contact with the fluid (in m^2)
T_s is the temperature of the surface (in °C)
T_f is the temperature of the fluid far from the surface (in °C)

The convective heat transfer coefficient (h) is evaluated during the transient CFD analysis at every time increment, on all surfaces. The values of h are highly uneven across the circumference of the gears due to their rotation and the turbulent nature of the splashing. To use these values in a steady-state heat transfer analysis, the h values at each finite element node must be averaged over their respective displacements. Rotating parts are represented by hundreds of thousands of nodes, making the data processing and transfer from a transient CFD analysis to a steady-state heat transfer analysis a major challenge.

In the company's project, we faced these numerical challenges head-on. The process required meticulous discretization of gear profiles and the modeling of roller and ball bearings, involved using advanced post-processing tools and visualization techniques, along with automating data processing. Utilizing advanced solvers and leveraging our GPU card power enabled us to overcome these challenges, providing reliable and actionable insights into the lubrication issues and potential solutions.

Simulation Workflow Development: Building the Virtual Model

Developing an analysis workflow for gearbox lubrication involves several critical steps that must be meticulously executed to ensure accurate and reliable results. The process begins with CAD preparation in Dassault Systèmes 3DExperience using CATIA applications.

CAD Preparation

If the geometry is not native to the 3DExperience platform, it needs to be imported, with STEP files being the most robust option. Once imported, the assembly must be filtered to retain only the relevant parts for the lubrication simulation. Bolts, rivets, and parts not in contact with the lubricant should be removed. Unnecessary features, such as bolt and rivet holes, must be defeatured to avoid small vertices, unsuitable lattice sizes, and poor resolution. The casing, typically composed of several parts, should be merged to create a single watertight envelope. This is crucial for XFlow's lattice generation to accurately recognize fluid domain boundaries. To expedite the CFD scenario definition, it is recommended to group parts rotating at the same speed into the same sub-assembly, allowing the equation of motion to be set once.

Modeling bearings poses a challenge due to their many separate moving parts, such as balls or rollers. A simple donut shape would prevent any lubricant movement across the bearings. Bearings could be considered as porous zones, but this approach requires calibration and experimental data or a specific analysis. Given XFlow's proficiency in handling rotating parts, we decided to model each ball and roller within the main bearings. The motion of ball or roller is complex, as each rotates around its own center. To simplify the setup, we applied a uniform motion equation to all balls or rollers, averaging the velocities of the bearing's external (V_e) and internal case ((V_i)) : (V_e+V_i)/2.

Once the relevant parts are selected and defeatured, the assembly is reorganized, and the casing is made watertight. The parts are then ready for meshing.

Discretization

Having a unified shared mesh is crucial for accurate data transfer between the CFD and heat transfer analysis. In the CFD analysis, discretization involves representing a continuous solid in a tessellated environment. Spherical and cylindrical shapes must be finely discretized to ensure realistic interactions with the fluid. A coarse mesh would create a rough interface, leading to excessive interaction with the fluid.

For the heat transfer analysis, meshing serves to represent continuous parts within an element-based solver. A mesh that is too fine demands more computing power, primarily RAM, and increases runtime. Additionally, it requires longer data processing to map the heat transfer coefficient accurately. Meshing solid parts involves discretizing them for the conduction equation, balancing the need for detail with computational efficiency. The equation of conduction, also known as Fourier's law of heat conduction, describes the rate at which heat energy is transferred through a material due to a temperature gradient. For three-dimensional heat conduction, Fourier's law is expressed as:

$$q = -k\nabla T \tag{2}$$

where:

Q is the heat flux vector (in W/m^2)
k is the thermal conductivity of the material (in watts per meter per degree Celsius, W/(m·°C))
∇T is the temperature gradient vector (in °C/m)

Since the equation is linear, the element order can also be linear. We mostly utilized tetrahedral linear elements, applying an absolute sag criterion to refine areas with small radii to capture finer details. The bearings were meshed with linear hexahedral elements. The specific mesh size was determined to balance accuracy and computational efficiency. In total, we had nearly one million elements. This mesh information is then transferred to XFlow to construct the CFD analysis scenario.

Transient CFD Scenario Definition

Setting up the scenario in XFlow takes less than an hour for the user. A turbulent multiphase transient analysis is defined, considering incompressible flow. The Lattice-Boltzmann method in XFlow uses the Wale-Adapting Local Eddy (WALE) turbulence model. The gravity effects are specified by an acceleration constant in the vertical direction. The lubricant was 75W140 oil with properties defined at 85°C. The initial lubricant level is set by specifying a coordinate in the vertical direction, representing 2L of lubricant inside the gearbox. The motions of gears and bearings are defined using angular velocity equations over time. The input gear rotates at 6000 RPM.

The minimum lattice dimension is determined based on the narrowest region where the lubricant flow needs to be captured. A visual of the lattice used in the analyses is shown in Figure 3. To ensure an accurate velocity gradient, at least three to five lattice volumes should be present in the narrowest region, indicated by the red arrow. Local refinement regions must be defined carefully to fully encapsulate the entire rotating body; otherwise, the solid-fluid interface will not be modeled accurately.

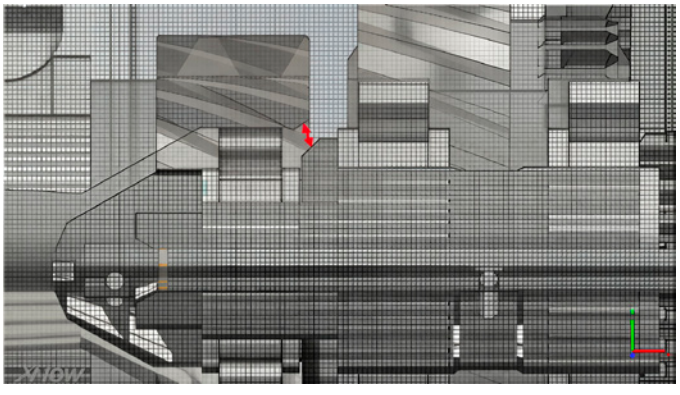


Figure 3—Lattice representation around the narrow region of the overheating bearing.

The time increment is defined by the smallest lattice volume and the highest solid tangential velocity:

$$dt = \frac{l}{v * 10\sqrt{3}} \tag{3}$$

where:

dt is the time increment (in s)
l is the lattice size (in m)
v is the tangential velocity (in m/s)

The total simulation time is based on the geometry's size and should be set to ensure that the flow is fully developed and stabilized. If the initial simulation time is insufficient, a restart can be performed to extend the total time. Monitoring the analysis during computation helps determine when the flow has fully developed. Using the NVIDIA GV100 card, it took 32 hours to simulate one second.

Transient CFD Results Analysis and Data Processing

While the analysis is running, the user can monitor scalar variables through graphs. To determine if the flow is fully developed, key values such as torque on rotating parts and lubricant volume within specific regions should be observed. These variables should stabilize and tend towards a fixed value to confirm that the flow has reached a steady state. Due to the highly turbulent nature of the splashing, some oscillations may appear and must be interpreted carefully. However, there should be no significant variations or trends indicating an increase or decrease. Figure 4 illustrates the distribution of the lubricant in different volumes of the gearbox. After 2 seconds, around 56 percent of the lubricant is inside the rear half, and 57 percent is in the half left.

On the graph, a transient phase is evident during the first second with important oscillations, before the flow begins to stabilize.

Once the flow is confirmed to be fully developed, the first post-processing phase begins. At this stage, a wealth of information can be extracted prior to the heat transfer analysis. Qualitative insights are derived from the generated animations, which offer valuable visuals inside the gearbox, revealing details that would otherwise be impossible to observe. In Figure 5, the left image shows a global cut view of the gearbox with a colored representation of the lubricant velocity. The right image shows a cut view in another direction, allowing for visualization of the lubricant movement close to the overheating bearing. These visuals serve as a first qualitative indicator to evaluate the lubrication efficiency.

Visualizing the flow velocity, dark areas are noticed above the deflector. It seemed that the flow was obstructed by the deflector, and very little was directed towards the overheating bearing. We tried removing the deflector.

Figures 6 and 7 present a comparison of the lubricant movement with (left) and without (right) the deflector.

The red bent arrow tells the rotation direction of the intermediate gear. In the left image, the darker areas above the deflector and next to the gearbox floor indicate lower lubricant velocity, which could indicate some recirculation pockets inducing inefficient cooling. In the right image, without the deflector, the lubricant velocities are higher, suggesting that the lubrication should be more efficient. Without the deflector, the lubricant flows faster closer to the gearbox floor, moves up faster against the left wall and more lubricant seems to come in contact with the overheating bearing.

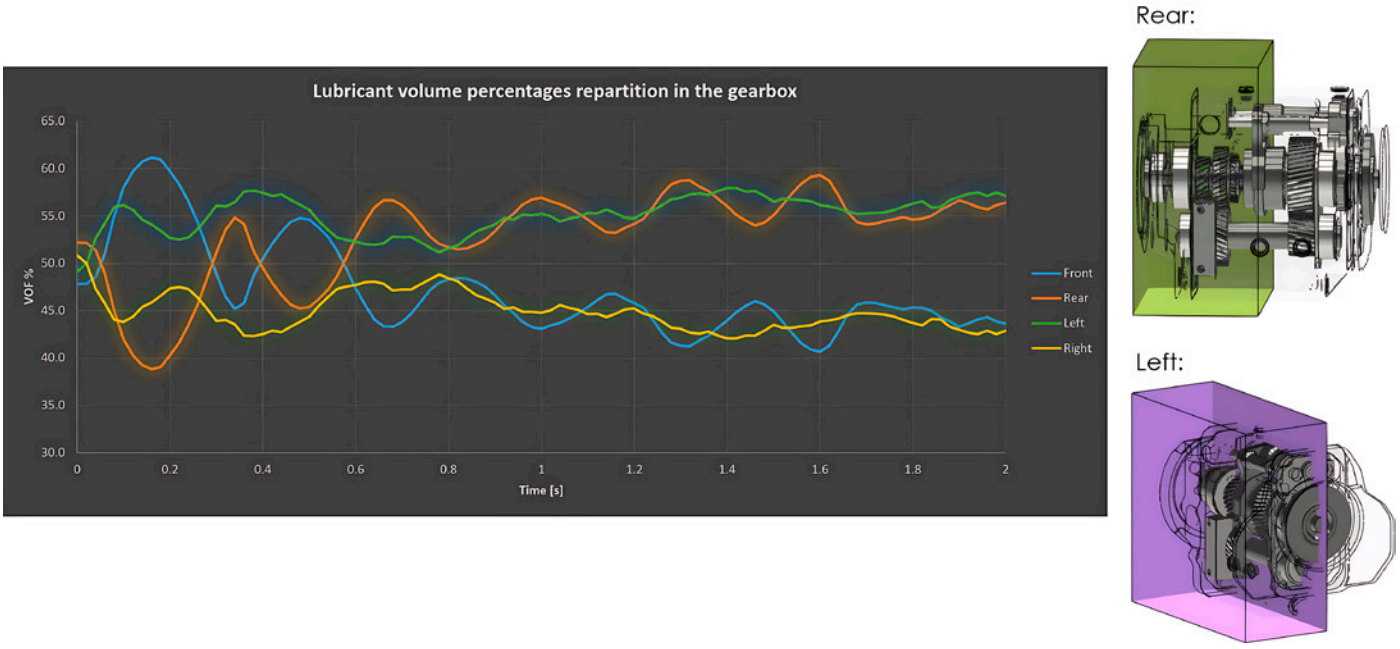


Figure 4—Graph showing the distribution of lubricant inside different volumes of the gearbox, the right images illustrate the rear and left volumes.

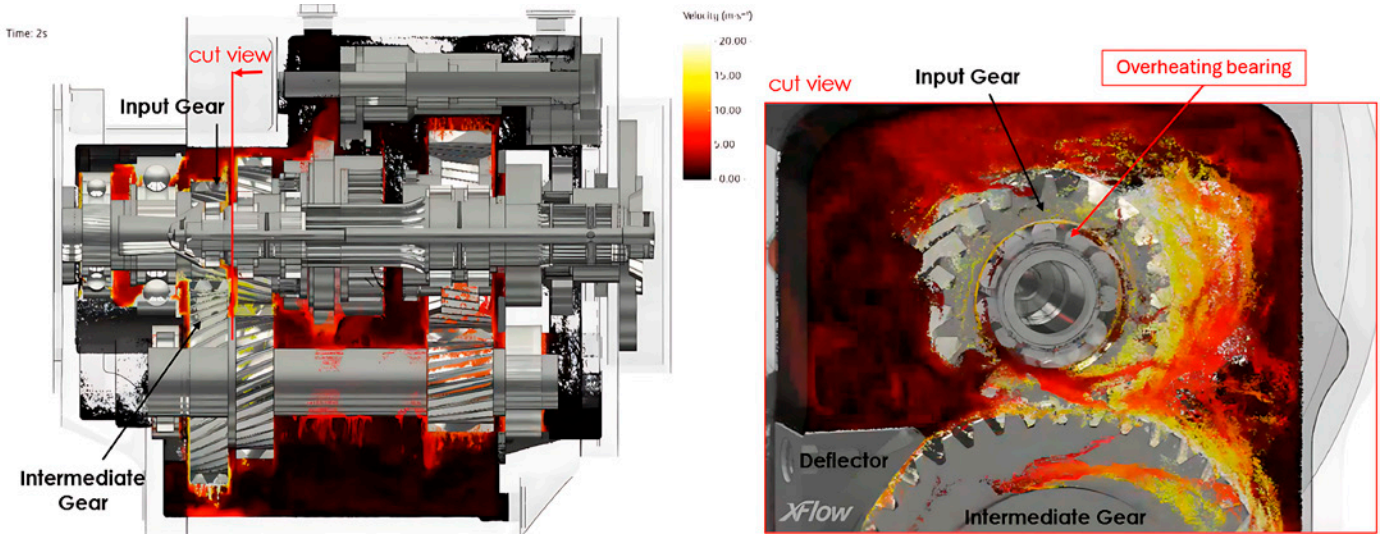


Figure 5—Cut views inside the gearbox with colored visualization of the lubricant movement close to the overheating bearing.

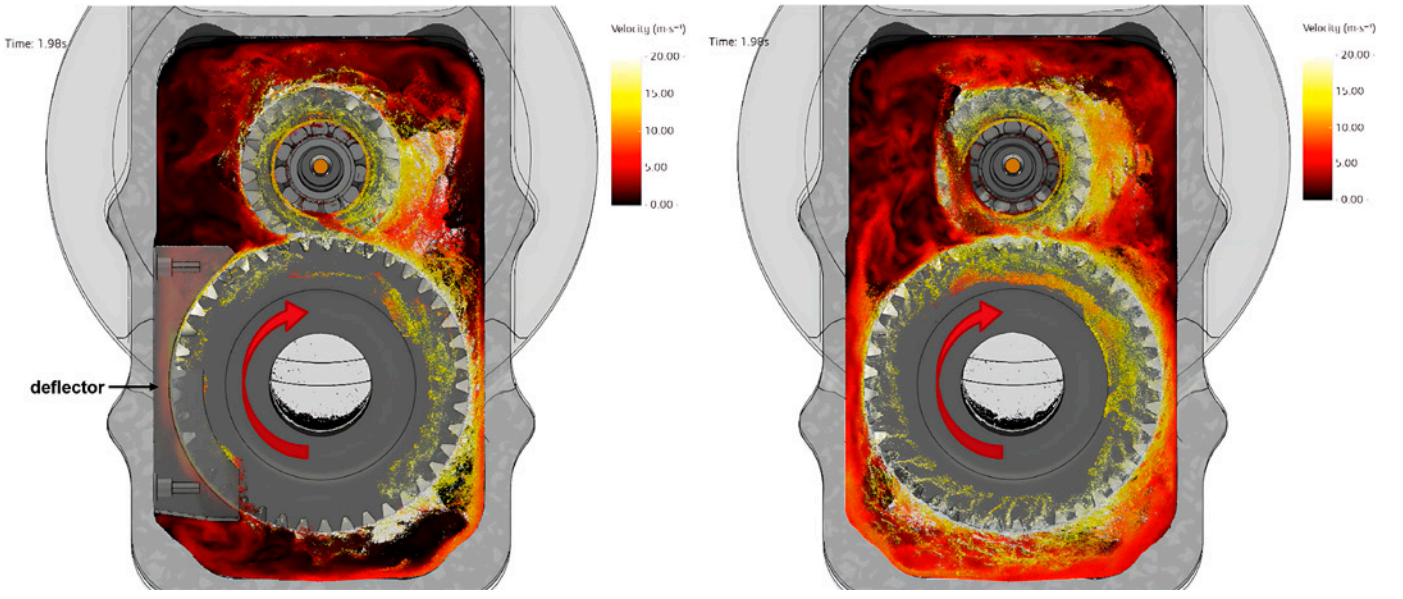


Figure 6—Comparison of the lubricant motion with (left) and without (right) the deflector, showing more movement without the deflector.

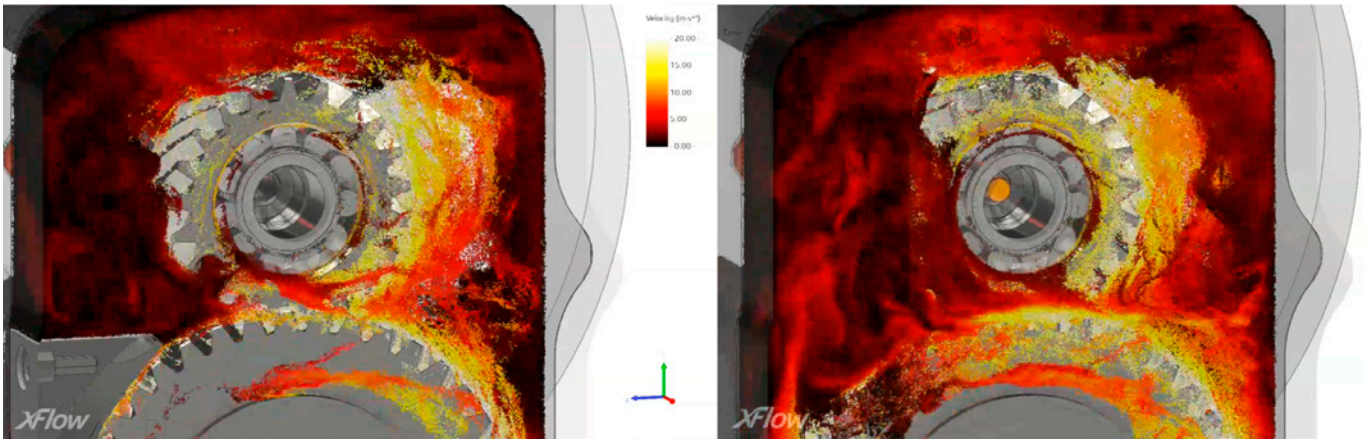


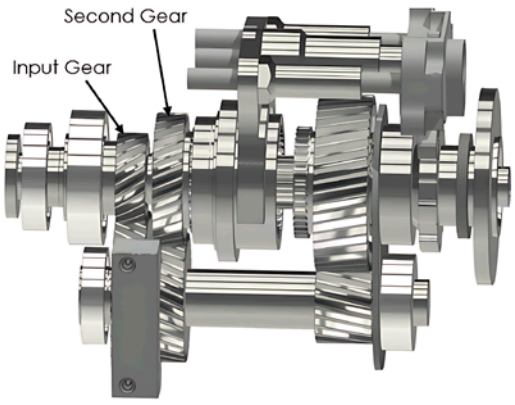
Figure 7—Comparison of the lubricant motion with and without the deflector, zoomed in on the overheating bearing, showing better lubrication without the deflector.

A zoomed-in image in Figure 7 confirms that more lubricant appears to reach the overheating bearing without the deflector. Without the deflector, in the right image, more colored particles are seen in front and around the overheating bearing. Another visual tool can be used to evaluate the cooling efficiency, using the wet areas. They can be displayed by projecting the flow onto solid surfaces. Because the flow is very turbulent, these visuals are challenging to obtain precise information from.

While these observations are qualitative, quantitative data can be extracted to compare the two designs.

Churning losses of all rotating parts provide measurable values to track and compare. Figure 8 reveals a table comparing the measured churning losses on the input and second gear, with and without the deflector. The graph on the right shows the evolution of the churning loss (moment, Mx) with time. After the transition phase that lasts for about 0.5 seconds, the value stabilizes, and an average is computed.

Churning loss [N.m]	Input Gear	Second Gear
With deflector	0.1002	0.1176
No deflector	0.2420	0.7650
ratio x	2.4	6.5



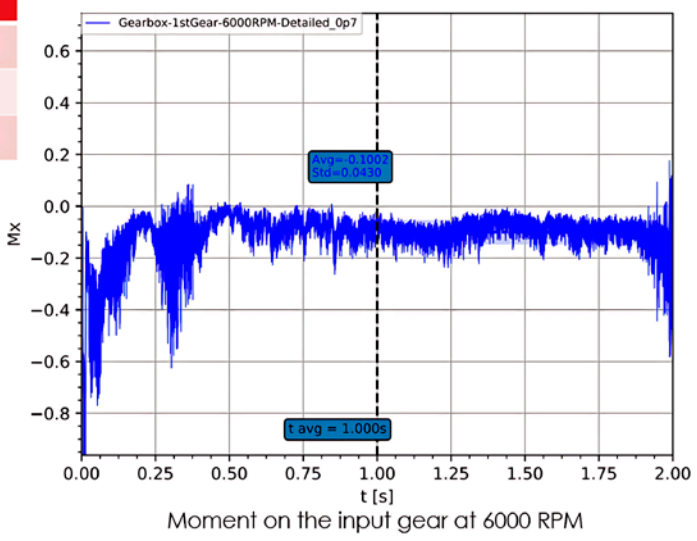


Figure 8—Churning loss estimation of gears showing more important churning losses without the deflector.

Target Cyl.	With deflector	No deflector	Ratio x
Mass Flow [L/min]	11.6	37.7	3.3
VOF [%]	4.5	12.6	2.8

Entry #1	With deflector	No deflector	Ratio x
Mass Flow [L/min]	0.3	1.4	4.7
VOF [%]	4.4	8.7	2.0

4.7x more lubricant enter in the entry #1, on an area **2x** larger.

Entry #2	With deflector	No deflector	Ratio x
Mass Flow [L/min]	2.0	4.5	2.2
VOF [%]	15.1	35.3	2.3

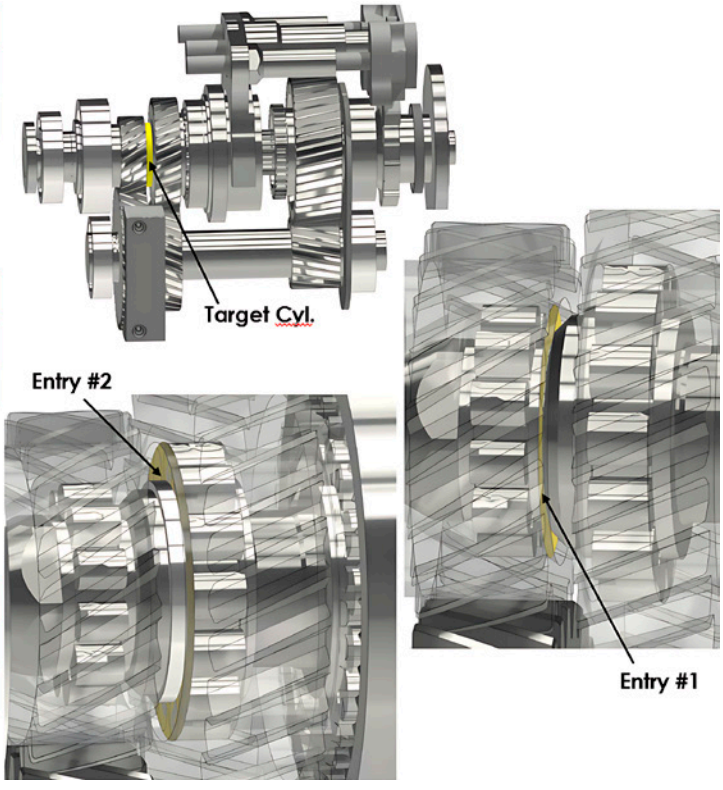


Figure 9—Surface integrals measuring the amount of lubricant in specific areas, indicating that more lubricant enters the narrow region without the deflector.

Churning loss refers to the resistance created by lubricant splashing on a rotating part. Higher churning loss indicates greater lubricant activity. We observed that the churning losses on the input gear are 2.4 times higher without a deflector, and 6.5 times higher on the second gear.

Creating surfaces for post-processing allows the integration of the quantity of lubricant passing through them with time, enabling comparison of the amount reaching specific areas of concern. The distribution of lubricant on these surfaces can also be measured in terms of VOF percentage (volume of fluid). A higher VOF percentage indicates that the lubricant covers a greater area of the surface. In Figure 9, the tables present the quantity of lubricant crossing several surfaces, allowing for comparison with and without a deflector. The Target Cyl refers to the narrow gap between the input gear and the second gear. The Entry #1 refers to the access to the overheating bearing, below the input gear. Entry #2 identifies the access to the roller bearing below the second gear.

Both mass flow and VOF distribution show higher values without the deflector. Through Entry #1, which leads to the overheating bearing, 4.7 times more lubricant flows, indicating that the cooling could be more efficient without the deflector.

The heat transfer coefficients (HTC) are scalar values projected onto all surfaces and can be exported for each part into a text file containing the HTC values and the associated node coordinates (x, y, and z). The user must select a time span during which the flow is fully developed, typically covering at least one rotation of the slowest gear. For each time increment within this period, a text file must be exported. During the heat transfer analysis, the mesh is static, so the node coordinates from the initial increment must also be exported. These initial node coordinates are then associated with the average HTC values at each node, for every part. This process is automated using a Python script. Once the HTC values are processed, they can be imported into the heat transfer analysis to predict the temperatures accurately.

Heat Transfer Scenario Definition

To define the steady-state heat transfer analysis, several parameters need to be set. The thermal conductivity of all materials must be specified. In our project, the casing was made of aluminum while all other parts were made of steel. Thermal contacts between all solid parts must also be defined, as thermal interfaces are never perfect and depend on factors such as surface finish or roughness. We referred to the *Spacecraft Thermal Control Handbook* (Ref. 2) to determine the thermal contact resistance or interface thermal coefficient.

The heat generated by each bearing was defined based on data provided by SKF (Ref. 3), the bearing manufacturer. This data covered 97 load cases for when the first gear is engaged and 43 load cases for the second gear, each representing a specific input gear rotation speed and torque. From these combinations, we selected three worst-case scenarios that generated the most power loss.

Next, the heat transfer coefficients (HTC or film coefficient) at each node were imported to define film conditions that characterize the convective heat exchange, along with an estimated fixed lubricant temperature. Figure 10 illustrates the mapping of the film coefficients on the gears around the narrow region. Given the highly turbulent nature of lubrication inside the casing, assuming a constant temperature throughout is acceptable. The lubricant temperature can be easily adjusted to run multiple scenarios, allowing for the study of its sensitivity on the predicted solid temperatures.

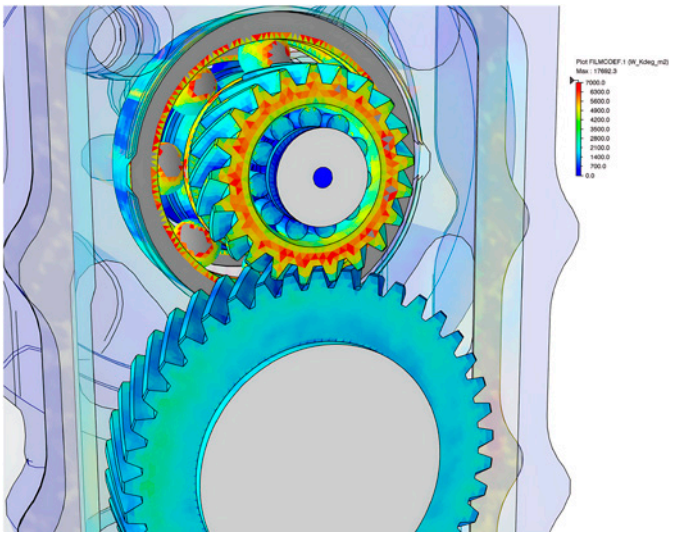


Figure 10—Cut view inside the gearbox showing the convective heat transfer coefficients projected on solid surfaces.

Heat Transfer Post-Processing

The main output is the predicted temperatures of bearings and solids for a particular load case. Figure 11 shows the predicted temperature with the deflector.

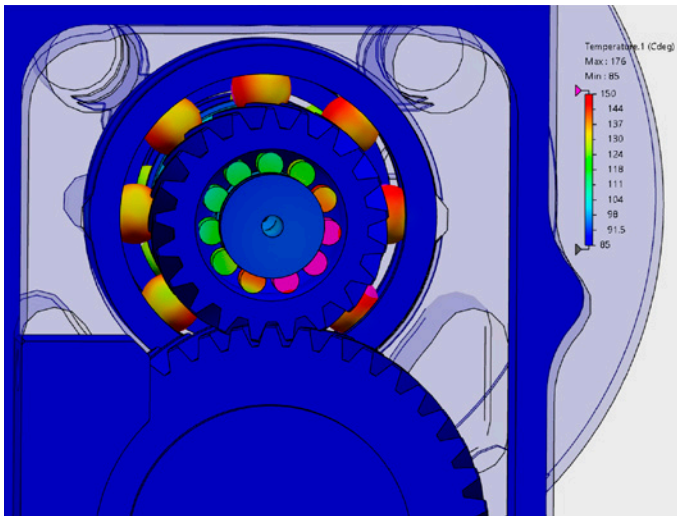


Figure 11—Predicted temperature around the narrow region with the deflector.

In reality, the temperature should be uniform on all bearing rollers due to their high rotational velocity. But considering that the film coefficients are averaged during just one simulated second, to keep calculation cost reasonable, and that the heat transfer analysis is steady state with fixed geometry, a temperature gradient can be observed on the bearing. To remain conservative, the maximum predicted temperature can be used. This misrepresentation of reality is explained by numerical reason, but the interpretation of the results remains acceptable and allows for design comparison and performance evaluation. According to the bearing spec sheet, the bearing could start to accumulate damage above 150°C. The analysis prediction of a maximum bearing temperature of 176°C correlated well with the manufacturer's damage observations on the roller bearing.

Figure 12 reveals the same prediction of temperature without the deflector. It clearly confirms the fact that the lubrication appeared to be better without the deflector, offering better cooling of the overheating bearing.

Ironically, the manufacturer attempted to solve the anticipated overheating problem with the deflector actually exacerbated it.

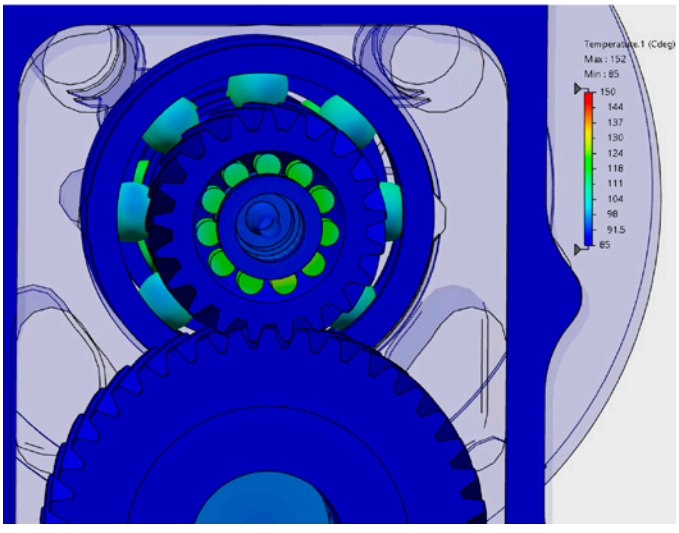


Figure 12—Predicted temperatures without the deflector on and around the problematic bearing.

The steady-state heat transfer analysis completes in a matter of minutes. Running the entire set of load cases is feasible within a few hours of computing time. If the thermal conductivities or thermal resistance values are not well known, these parameters can be quickly and easily varied to study their sensitivity on the predicted temperatures.

Heat flux is another valuable output. Represented by symbols or arrows, it helps the user visualize how heat is being transferred within the gearbox. By focusing on specific surfaces to output the heat flux, the user can evaluate the amount of heat exchanged through solid contact (conduction) and the amount extracted by lubrication (convection).

Correlation with Experimental Data

Correlation of the developed workflow is an essential step to ensure its accuracy and reliability. The process involves several stages, beginning with the visual comparison of lubricant splashing. Slow-motion videos recorded using high-speed cameras are matched with animations generated from the CFD analysis. This visual correlation provides a qualitative assessment of the simulation's accuracy in replicating real-world conditions.

The second stage involves measuring the churning loss of the gearbox. The total torque loss on the test bench includes bearing losses, gear friction, seal friction, and churning losses. Accurate evaluation of the other three components is necessary to isolate and compare the churning losses with the torque measured in the CFD analysis. This quantitative comparison validates the simulation's accuracy in predicting torque losses due to lubricant movement. The solver has been validated based on comparison with experimental data (Ref. 4). Two different scenarios, one single gear and two engaged gears, are tested experimentally and compared with numerical prediction. Figure 13 shows the comparison of experimental versus numerical churning losses estimation using XFlow 2022 solver. It shows a good correlation at various speeds.

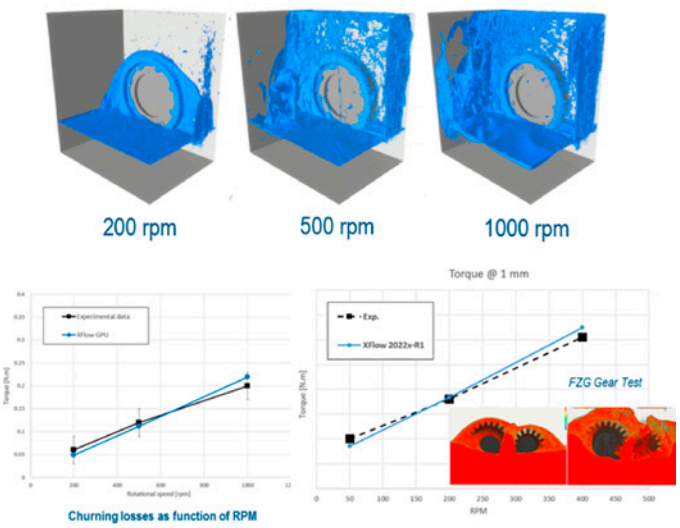


Figure 13—Correlation of churning loss measurements between experiments and numerical predictions (Ref. 4).

Temperature measurements represent the third stage of validation. Temperature data collected on the test bench are compared to the simulated overheating conditions. Ensuring that the CAD model used in simulations accurately represents the prototype on the test bench is critical for this comparison. The same lubricant temperature, applied torque, and rotational speeds must be represented in both physical and simulated environments.

In our project with the gearbox manufacturer, the prototype on the test bench was an earlier version of the design. The test bench lacked a sensor capable of

measuring torque losses, which would have allowed us to extract the total churning loss. Additionally, a few temperature labels were installed on shafts that had been altered between the prototype and the CAD model. These labels provided a range of temperatures reached or indicated if the maximum temperature had been exceeded.

The company's team acknowledged that the lubrication animations we provided were comparable to what they had observed through the casing window of their test bench. Our predictive model was able to reproduce the overhearing problem, estimating a temperature of 176°C, above the limit that the bearing can endure without damage.

In many companies, the test team and the CFD analysts work separately. The test team often does not know what information the CFD team needs to correlate their models. Consequently, test reports are frequently incomplete and lack the crucial data required to validate the workflow. Greater collaboration between the test and CFD teams is necessary to build identical prototypes for both the test bench and the simulations. Strategic placement of thermocouples is essential for comparing predicted and actual temperatures, and churning loss measurements should be taken to gain confidence in the accuracy of the simulations.

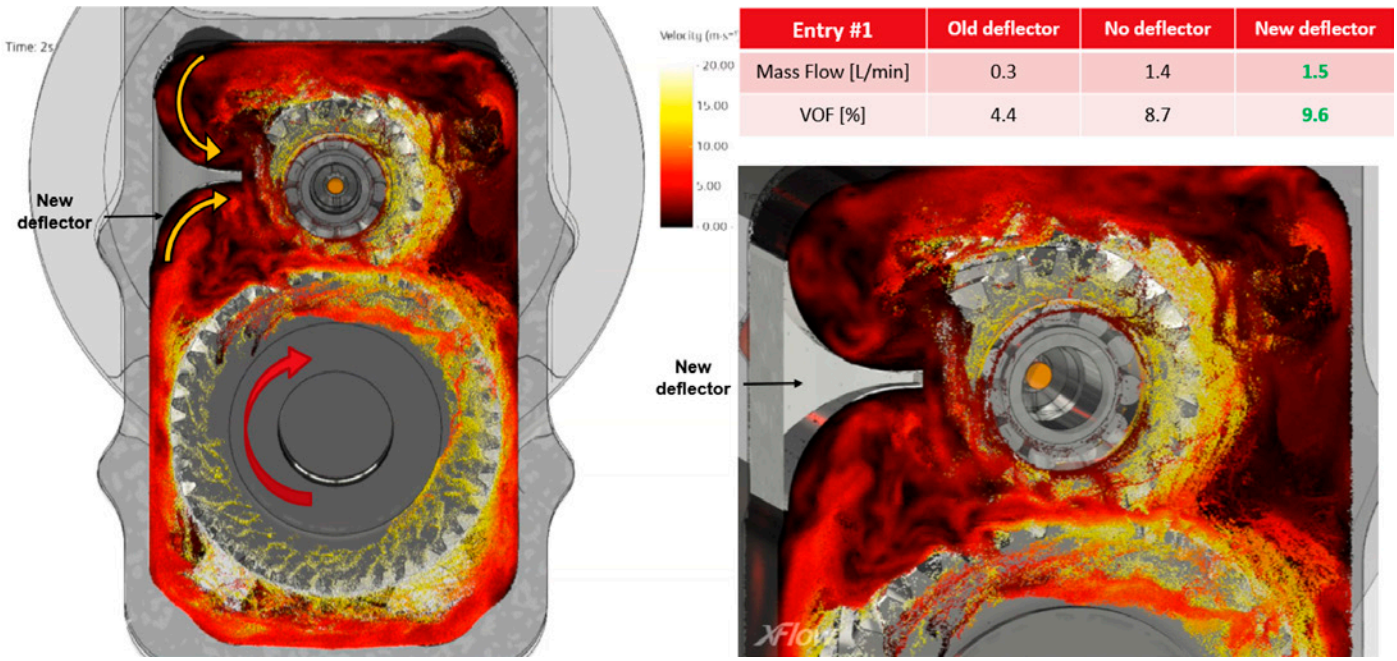
The Power of a Virtual Lab

The developed workflow offers numerous advantages, significantly enhancing the efficiency and accuracy of gearbox lubrication analysis. One of the primary benefits is the quick setup and analysis time. Engineers can prepare an analysis in just a few hours, with post-processing and animation generation automated using scripts. This efficiency allows for rapid iteration and comparison of design variations, enabling engineers to make informed decisions quickly.

Having a numerical model leads to a powerful virtual lab, allowing for the testing of multiple conditions and scenarios without the need for physical prototypes. Engineers can rapidly iterate designs, run designs of experiments (DOE), and find optimized solutions. By adjusting parameters such as gravity equations and initial lubricant levels, various operating conditions can be simulated, including road slopes, acceleration, braking and turning events. Different weather conditions can be modeled by altering lubricant properties, providing a comprehensive understanding of gearbox performance under a wide range of scenarios.

This capability enables the exploration of "what if" scenarios that would be impractical or costly to test experimentally. For instance, simulations can assess the gearbox performance without lubricant, test alternative lubricants, or evaluate the impact of component failures. This flexibility is invaluable for manufacturers, as it enhances their knowledge and expertise, leading to continuous improvement in product design and performance.

In the context of our project, the virtual lab allowed for testing several deflector designs intended to guide more lubricant towards the overheating bearing. The initial deflector design created local lubricant recirculation, which was impossible to detect experimentally. Simulations provided critical insights, revealing the inefficiencies of the initial design and guiding the development of optimized deflector configurations. The improved deflector design, shown in Figure 14, was based on the animations of the lubricant movement. It uses double slopes directing both the flow coming up on the left side wall, and the flow moving counterclockwise around the input gear.



Entry #1	Old deflector	No deflector	New deflector
Mass Flow [L/min]	0.3	1.4	1.5
VOF [%]	4.4	8.7	9.6

Figure 14—Qualitative and quantitative results using the new deflector, showing better lubrication performance compared to the initial deflector design.

No recirculation pattern, nor low velocity areas were observed. Figure 14 shows important lubricant motion near the overheating bearing. The table presents the comparison of flow quantity accessing the overheating bearing, indicating better performance. The improvements compared to without the deflector were not significant, but it shows that virtual testing allows us to quickly evaluate and compare designs.

Quantitative metrics such as churning loss, volume flow across surfaces, and temperatures allow for the ranking of different designs and sensitivity studies. This ranking helps design teams identify the most effective configurations and better understand the parameters that most significantly affect lubrication performance. By providing detailed insights into the lubricant distribution and heat transfer characteristics within the gearbox, the virtual model enables the development of more efficient and reliable designs.

Conclusion

This study has demonstrated the power and practicality of using advanced simulation techniques to tackle real-world engineering problems in gearbox design. By developing a comprehensive analysis workflow that leverages advanced CFD and heat transfer simulations, we successfully reproduced the overheating bearing problem that the manufacturer experienced on their test bench. We evaluated that their deflector design was responsible for flow obstruction, leading to less efficient cooling. Predicting temperatures on the solids, without the deflector, offered the manufacturer a quick solution to overcome the overheating problem. And by studying the lubricant motion from the analyses, we proposed a double-slope deflector that could improve the lubrication efficiency.

The virtual model approach offers a game-changing solution for gearbox manufacturers. By reducing the time and cost associated with physical prototyping, companies can quickly iterate on their designs, identifying and resolving flaws before they become costly issues. This workflow, which runs efficiently on GPU-powered systems, allows manufacturers to simulate complex lubrication dynamics and thermal interactions with remarkable accuracy and speed.

With this capability, manufacturers can explore a wide range of operating conditions, including extreme scenarios, to ensure their gearboxes perform reliably under all circumstances. The detailed insights gained from these simulations enable the development of optimized, high-performance designs that meet the market demand and become more competitive.

Furthermore, the integration of simulation and experimental validation fosters better collaboration between engineering teams, ensuring that the models used are both accurate and reliable. This synergy not only improves the design process but also builds confidence in the final product.

In summary, the adoption of this advanced workflow empowers gearbox manufacturers to innovate faster and more cost-effectively. By embracing numerical analyses and virtual labs, companies can enhance their product development cycles, leading to superior gearboxes that deliver improved efficiency, reliability, and longevity. This approach represents a significant advancement in engineering capabilities, positioning businesses to stay ahead in a competitive market.

PTE

Benjamin Beckelynck earned an aeronautical engineering degree from IPSA in France and a master's in mechanical engineering from Université Laval. After joining Optimec Consultants in 2016, he has led advanced multi-physics simulations and workflow development for structural integrity, design optimization, and virtual testing across diverse industries.

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TIMKEN
Expands Online Engineering Tools

The Timken Company has expanded its suite of online engineering tools available at engineering.timken.com. The platform now includes two new proprietary calculators and an enhanced "My Projects" feature for registered users, giving design engineers more powerful resources to optimize system performance and streamline workflows.

"Timken has always been committed to helping engineers design with confidence," said Michael Kotzalas, director—global customer engineering. "With the addition of these new calculators and project enhancements, we're making it even easier for customers to access expert insights, analyze performance, and collaborate efficiently."

Site users will be able to access two new calculators:

Bearing Spring Rate Calculator: Determines linear stiffness values of single-row tapered roller bearings under predetermined loads applied to the bearing. This tool allows users to evaluate whether a selected bearing will perform well under loads applied in both radial and axial directions.

Gear Forces Calculator: Calculates tangential, radial and axial forces resulting from meshing gears in a system. By entering gear parameters and operating conditions, design engineers gain valuable insights for proper bearing selection.

Timken's engineering tools website provides a suite of calculators, search capabilities and performance modeling resources, including the proprietary Timken Syber Bearing System Designer. Data from the tools can be exported into common design programs, output into CAD drawings, or saved for future use, helping engineers quickly simulate real-world conditions and make informed design and purchasing decisions.

timken.com

RENK
Supplies 12 Double Marine Gear Units for Six RoPax Ferries

Renk Group AG has received an order to supply 12 NDSL-3600 double marine gear units. The first of these are to be delivered to the customer Kongsberg Maritime Sweden AB in the fourth quarter of 2026. The gear units will be used in six RoPax ferries belonging to an international shipping company.

"Renk has established itself as a leading provider of gear units in the maritime sector, having supplied over 500 TI/SO transmission systems worldwide. The Renk NDSL-3600 gear units will not only ensure maximum operational reliability in the new ferries, these will also help to improve passenger travel comfort thanks to Renk's vibration-optimized design," said Dr. Georg von Witzleben, CEO marine and industry.

The Renk gearboxes are a core component of the drivetrain, which will be equipped with advanced green technology. They provide a high level of energy efficiency and therefore help to reduce carbon emissions. This represents a key contribution by Renk to decarbonization in shipping.

The ferries will be the first methanol-powered vessels to be operated in the Mediterranean area; each NDSL-3600 gear unit will be driven by two methanol dual-fuel motors. Integrated multiple disc clutches enable a range of drive modes, including highly efficient on-board power generation via an integrated PTO shaft. Renk NDSL gearboxes are the benchmark for robust and reliable modern marine applications.

renk.com

SKF
Redesigns Industrial Organization to Increase Competitiveness

SKF is redesigning parts of the Industrial business to further increase its competitiveness and accelerate profitable growth. The new set-up, which will be implemented with immediate effect, will drive business synergies across the full value chain globally and simplify structures to accelerate execution regionally.

The functions "Operations" and "Commercial Excellence" are combined into one which will enable a stronger alignment, governance and end-to-end execution across the full value chain. The business area "Independent and Emerging Businesses" will be discontinued. Its stand-alone entities will be organized into "Specialized Industrial Solutions" to further strengthen these strategic core businesses as they are tailored according to respective business and market needs.

"As the separation of the Automotive business is progressing, we have the opportunity to adapt our set-up for the Industrial business. This is a natural next step in our strategic journey and with clearer and more efficient structures, we will strengthen both our strategic and commercial capabilities," says Rickard Gustafson, president and CEO.

SKF is announcing the following changes in Group Management:

Hans Landin, senior vice president, group commercial excellence bearings,

is appointed to lead the new organization of stand-alone businesses and assume the role as president specialized industrial solutions.

Joakim Landholm, senior vice president group operations and chief sustainability officer, will assume the role as senior vice president commercial and operations development.

Susanne Larsson, senior vice president finance and CFO, will in addition to her current role assume the role as chief sustainability officer.

Thomas Fröst, president, independent and emerging businesses, will leave group management today but will remain in an advisory role during a transition period.

"A sharpened industrial focus will evolve our strengths and with this new organizational set-up we aim to create even more progress for our customers and for us as a company. On behalf of SKF, I would also like to thank Thomas for his valuable contribution during many years of employment in building these core businesses, and I wish him all the best for the future," says Gustafson.

skf.com

SOLVE INDUSTRIAL MOTION GROUP

Acquires B&B Manufacturing

Solve Industrial Motion Group has announced its acquisition of B&B Manufacturing, (B&B) a US manufacturer of power transmission and precision mechanical components.

B&B, in business for over 27 years, consists of five locations, and is headquartered in La Porte, Indiana. B&B is North America's largest synchronous drive pulley manufacturer, specializing in synchronous drive solutions. B&B products include timing pulleys, synchronous belts, v-belt sheaves, taper bushings, idlers, and roller chain sprocket. B&B also brings with it two recent acquisitions, Diversified Specialties and JJC Associates.

"The B&B acquisition greatly expands Solve's domestic manufacturing capabilities and allows us to be a full spectrum provider of drive train solutions," said Ernie Lauber, CEO of Solve (pictured above). "Our customers will greatly benefit from B&B's domestic manufacturing, which enables faster lead times and significant made-to-order capabilities."

"I am very excited for the opportunity this brings to B&B," said Bob Hamilton, founder of B&B Manufacturing. "Solve has built a great platform, and I am looking forward to seeing how we can accelerate growth together."

solveindustrial.com
bbman.com

ABB

Develops Next-Generation AI Data Centers with NVIDIA

ABB announced it is accelerating the development of gigawatt-scale next-generation data centers in collaboration with NVIDIA. Innovation will focus on the development and deployment of cutting-edge power solutions needed to create high-efficiency, scalable power delivery for future AI workloads. The research and development projects will support NVIDIA's planned introduction of 800 VDC power architecture for 1 megawatt server racks.

Delivering this level of power efficiently requires major advancements in power distribution technologies and architecture. Future data center power architectures will combine a medium voltage (MV) uninterruptible power supply (UPS) with direct current (DC) power distribution to the server room using solid-state power electronics devices.

"ABB is leading the development of the key new power distribution technologies that will create the next generation of data centers. We have been an early investor in the cutting-edge UPS, DC and solid-state electronics that will enable data centers to stay ahead of AI's growing power demands," said Giampiero Frisio, president, ABB Electrification. "This collaboration supporting the development of 800 VDC architectures for future data centers is one of the many ways we are engaging with the data center community to serve the needs of this dynamic market."

Global data center demand is forecast to rise from 80 GW in 2024 to reach around 220GW by 2030, with capital expenditure projected to exceed $1 trillion (Source: Dell 'Oro Group). AI workloads are expected to account for around 70 percent of this growth.

"As AI demands continue to grow around the world, data centers require new approaches to power distribution that improve efficiency and simplify designs," said Dion Harris, senior director, HPC, Cloud and AI Infrastructure, NVIDIA. "Through our collaboration, NVIDIA and ABB are supporting the industry in advancing toward 800-volt architectures that will enable the high-density AI infrastructure needed to fuel the next generation of AI."

ABB's portfolio for data centers encompasses intelligent power distribution systems, backup power solutions, digital monitoring, and other essential technologies that ensure continuous operations and optimize energy use for AI servers. Approximately 40 percent of ABB's scientific research in electrification is in areas critical to next gen data centers, such as electrical architectures, protection devices, DC distribution and cooling.

Recent ABB innovations that support the data center industry include ABB's HiPerGuard, the world's first solid-state MV UPS. HiPerGuard solutions help AI data centers increase their power density and energy efficiency in a smaller footprint. ABB's SACE Infinitus is the world's first IEC-certified solid-state circuit breaker and is designed to provide the speed and controllability needed to make direct current distribution viable.

abb.com

NORTH AMERICA UNDERGROUND MINING VEHICLE MARKET

Poised for Substantial Growth

The North America Underground Mining Vehicle Market is set for robust expansion, with its valuation expected to climb from USD 5.5 billion in 2025 to USD 9.8 billion by 2035, registering a strong Compound Annual Growth Rate (CAGR) of 6.0 percent over the forecast period, according to Future Market Insights, Inc. This significant growth is primarily fueled by a surge in mineral exploration, a heightened industry focus on worker safety, and accelerating investment in vehicle automation and electrification, according to a new report titled "North America Underground Mining Vehicle Market Size and Share Forecast Outlook 2025 to 2035."

The market's momentum reflects the region's increasing reliance on advanced machinery to meet the demands of deeper, more complex underground operations, particularly in the United States and Canada.

The shift toward sustainable and efficient mining practices is a core driver. The integration of advanced technologies like telematics, predictive maintenance, and sophisticated navigation systems is enhancing operational efficiency and reducing costly downtime. Furthermore, substantial investments in electrification and battery-powered vehicles are gaining traction as mining operators prioritize sustainability and compliance with environmental regulations.

Key insights from the segmental analysis highlight the following:

- Ground Support Dominates: The Ground Support equipment type segment is projected to hold the largest revenue share, accounting for 48.6 percent in 2025. This dominance is driven by the critical need for vehicles (such as roof bolters and shearers) that ensure structural stability and operational safety in deep mine shafts and tunnels.
- Coal and Metal Mining Fuel Application Demand: The Coal Mining application segment leads the market with a projected 44.9 percent share by 2025, sustained by continued regional reliance on coal for energy. However, Metal Mining and Non-Metallic Mining collectively are forecasted to account for a massive 65 percent market share, with the metal mining segment witnessing higher future growth at a CAGR of 6.8 percent.
- Mining Operators Prefer Ownership: The Mining Operators ownership segment is expected to command a dominant 57.2 percent of the total revenue share by 2025, indicating a strong preference for direct ownership to gain greater control over customized vehicle fleets, maintenance, and technological upgrades.

The United States is expected to be the most prominent regional market, projected to account for nearly 38 percent of the North American market through 2035, growing at a CAGR of 6.2 percent. Market growth here is supported by an established mining and excavation industry and the presence of numerous rental service providers, which are preferred by small mine operators looking to curb initial capital and maintenance costs. Canada and Mexico also exhibit steady growth, with Canada driven by an expanding mining sector and Mexico seeing moderate adoption, often favoring rental services due to a lack of robust government support for some mining activities.

The North America Underground Mining Vehicle Market is highly competitive, featuring both global giants and innovative startups. Leading key players—including Caterpillar Inc., Sandvik AB, Epiroc AB, and Komatsu Ltd.—are consistently investing in R&D to improve vehicle durability, efficiency, and embrace the twin trends of automation and electrification.

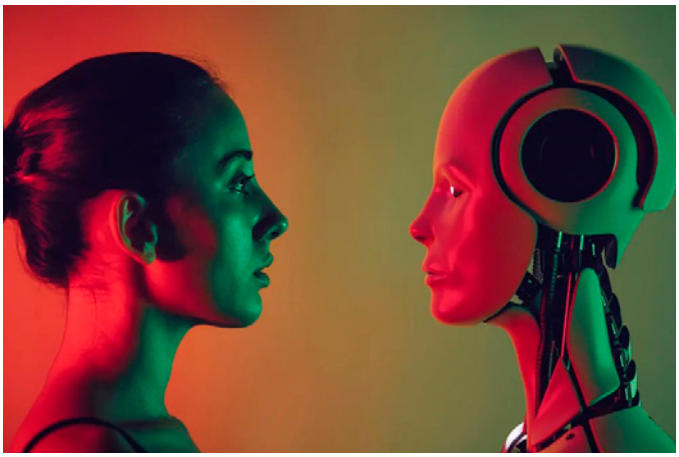
Recent strategic developments underscore this competitive drive:

- Sandvik AB secured a significant contract with BHP Group Ltd in February 2025 for underground mining equipment and automation products, demonstrating ongoing high-value fleet upgrades.
- Caterpillar expanded its offerings in September 2024 with the launch of battery-electric loaders and a portable fast-charging system, highlighting the race toward zero-emission underground fleets.
- Epiroc's acquisition of Meglab in March 2024 focused on bolstering its capabilities in electrification and telecommunications infrastructure solutions for the sector.

futuremarketinsights.com/reports/sample/rep-gb-9315

January 6–9

CES 2026



Attracting a diverse range of professionals, including executives, engineers, designers, and entrepreneurs, CES (Las Vegas) is an excellent opportunity to connect, collaborate, and grow your professional network. The broad range of exhibits and industries represented at the show can inspire innovative solutions. Industries include 3D printing, AR/VR/XR, AI, cloud computing/data, construction tech, cybersecurity and more. As CES 2026 approaches, the spotlight is once again on robotics—a sector that continues to redefine how we live, work and interact. This year's show floor promises a remarkable array of innovations, underscoring how robots are becoming deeply integrated into everyday life, from home automation and healthcare to hospitality and logistics.

powertransmission.com/events/ces-2026

January 20–22

PowerGen 2026

PowerGen (San Antonio, TX) is the premier networking and business hub for power generation professionals and solution providers. It unites power producers, utilities, EPCs, consultants, OEMs, and large-scale energy users. As the industry evolves toward cleaner and more sustainable energy, PowerGen fosters a progressive environment for both established professionals and new energy leaders driving the transition to a more sustainable future. The show invites technology experts, engineers, suppliers, decision-makers and thought leaders to join in exploring innovative solutions, learning from past and present projects and shaping the future of power generation. This includes a focus on The Total Energy Mix: Powering the Future, ensuring that all energy sources are considered in the journey towards sustainability.

powertransmission.com/events/powergen-2026

February 10–12

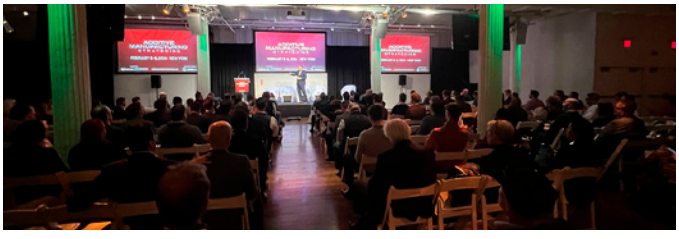
AIoT World Expo 2026

The AIoT World Expo (Fort Lauderdale, FL) is the premier event for exploring the convergence of Artificial Intelligence (AI) and the Internet of Things (IoT). This event serves as the gathering point for industry professionals to discover advancements, market opportunities, and understand the transformative power of AIoT across industries. Technologies include scalability, Edge, and AI data analytics, cloud solutions, machine learning (ML), and predictive analytics, cyber security and hybrid models. The show includes two key tracks AIoT Solutions and Services as well as AIoT Applications and Vertical Markets. Attendees will include corporate executives, IT, developers, engineers, data analysts, channel executives and more.

powertransmission.com/events/aiot-world-expo-2026

February 24–26

Additive Manufacturing Strategies – New York



This industry touchstone conference (New York, NY) brings together AM stakeholders from all over the world. AMS includes panels and keynotes on topics most critical in the fast-growing world of additive manufacturing. Bringing together the industry's leaders in a contained networking environment makes AMS the place for startups to access capital, for financial institutions and investors to sharpen their radars, and for the AM industry to focus on the business of AM. Topics include energy, medical devices, aerospace, defense, future forecast, software and more. MPMA's VP of Emerging Technology, Mary Ellen Doran, joins moderator Filippos Voulpiotis, managing director, 3Dnatives, Kevin Kassekert, chief executive officer, VulcanForms and Michael Corliss, vice president of technology, SBO/Knust Godwin for a panel on high-volume industrial part production at 9:55 am, Feb. 25, 2026.

powertransmission.com/events/additive-manufacturing-strategies-new-york

March 3–5

MDSM 2026

The MDSM Conference & Exhibition (Tallahassee, FL) brings together thought leaders focused on the latest technical advancements in motor, drive systems and motion control. Attendees will hear content in design, efficiency and application advancements in automation, robotics, manufacturing, utilities and automotive consumer and medical applications. Join leading engineers, manufacturers, system integrators, product developers, consultants and executives and discover how new technologies are improving performance and providing cost savings in a variety of applications. Tech tracks include topics on drive systems, industry trends, supply chain, motor performance, magnetics, test/simulation and more.

powertransmission.com/events/mdsm-2026

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Statement of Ownership, Management, and Circulation (Requester Publications Only)

1. Publication Title	2. Publication Number	3. Filing Date
POWER TRANSMISSION ENGINEERING	2 3 3 1 _ 2 4 8 3	10/1/2025
4. Issue Frequency	**5. Number of Issues Published Annually**	**6. Annual Subscription Price (if any)**
Monthly except Jan., May, July, Nov.	8	

7. Complete Mailing Address of Known Office of Publication (Not printer) (Street, city, county, state, and ZIP+4®) — Contact Person / Telephone (Include area code)

1001 N. FAIRFAX ST., SUITE 500, ALEXANDRIA, VA 22314

8. Complete Mailing Address of Headquarters or General Business Office of Publisher (Not printer)

1001 N. FAIRFAX ST., SUITE 500, ALEXANDRIA, VA 22314

9. Full Names and Complete Mailing Addresses of Publisher, Editor, and Managing Editor (Do not leave blank)

Publisher (Name and complete mailing address) RANDY STOTT

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Editor (Name and complete mailing address) RANDY STOTT

1001 N. FAIRFAX ST., SUITE 500, ALEXANDRIA, VA 22314

Managing Editor (Name and complete mailing address) RANDY STOTT

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13. Publication Title: POWER TRANSMISSION ENGINEERING
14. Issue Date for Circulation Data Below: SEPTEMBER 2025

15. Extent and Nature of Circulation			Average No. Copies Each Issue During Preceding 12 Months	No. Copies of Single Issue Published Nearest to Filing Date
a. Total Number of Copies (Net press run)			12,973	12,108
b. Legitimate Paid and/or Requested Distribution (By mail and outside the mail)	(1)	Outside County Paid/Requested Mail Subscriptions stated on PS Form 3541. (Include direct written request from recipient, telemarketing, and Internet requests from recipient, paid subscriptions including nominal rate subscriptions, employer requests, advertiser's proof copies, and exchange copies.)	4,433	3,294
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Sneaky & Supersonic

Matthew Jaster, Senior Editor

Lockheed Martin Skunk Works, in partnership with NASA, recently completed the first flight of the X-59, a revolutionary, quiet supersonic aircraft designed to pave the way for faster commercial air travel.

The X-59 is a one-of-a-kind supersonic aircraft designed to demonstrate the ability to fly at supersonic speeds while reducing the sonic boom to a gentle thump. In doing so, the X-59 aims to overcome one of the primary barriers to supersonic commercial flight, which is currently restricted over land due to noise concerns.

The successful development and flight testing will inform the establishment of new data-driven acceptable noise thresholds related to supersonic commercial flight over land, paving the way for a new generation of supersonic aircraft that can efficiently and sustainably transport passengers and cargo twice as fast as aircraft today. You read that correctly—twice as fast as aircraft today.

"X-59 is a symbol of American ingenuity. The American spirit knows no bounds. It's part of our DNA—the desire to go farther, faster, and even quieter than anyone has ever gone before. This work sustains America's place as the leader in aviation and has the potential to change the way the public flies," said Sean Duffy, acting NASA administrator.

In June, conducted a full-scale "dress rehearsal" to prepare how it will measure the noise generated by the X-59 quiet supersonic research aircraft in a stretch of California's Mojave Desert.

"The dress rehearsal was critical for us," said Larry Cliatt, sub-project manager for the Quesst acoustic validation phase, who is based at NASA's Armstrong Flight Research Center in Edwards, CA. "It gave us the opportunity to run through every aspect of our operation, from flight planning to data collection."

The first official flight of the X-59 recently took place from the Skunk Works' facility at U.S. Air Force Plant 42 in Palmdale, CA, before landing near NASA's Armstrong Flight Research Center in Edwards, CA. The X-59 performed exactly as planned, verifying initial flying qualities and air data performance on the way to a safe landing at its new home.

"We are thrilled to achieve the first flight of the X-59," said OJ Sanchez, vice president and general manager of Lockheed Martin Skunk Works. "This aircraft is a testament to the innovation and expertise of our joint team, and we are proud to be at the forefront of quiet supersonic technology development."

The X-59's Flight Test Instrumentation System (FTIS) serves as one of its primary record keepers, collecting and transmitting audio, video, data from onboard sensors, and avionics information—all of which NASA will track across the life of the aircraft.

"We record 60 different streams of data with over 20,000 parameters on board," said Shedrick Bessent, NASA X-59 instrumentation engineer. "Before we even take off, it's reassuring to know the system has already seen more than 200 days of work."

Through ground tests and system evaluations, the system has already generated more than 8,000 files over 237 days of recording. That record provides a detailed history that helps engineers verify the aircraft's readiness for flight.

nasa.gov/aeronautics/supersonic-flight

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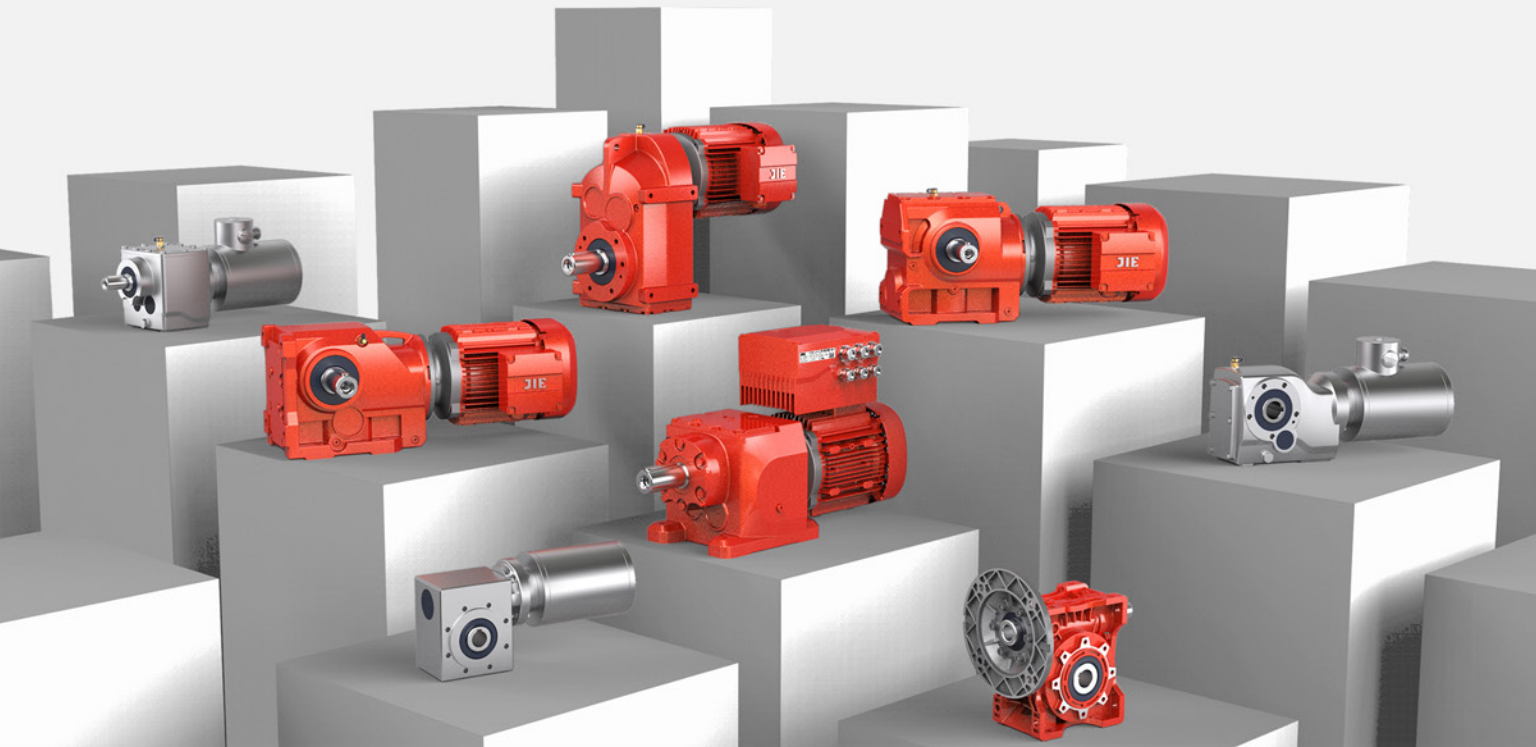

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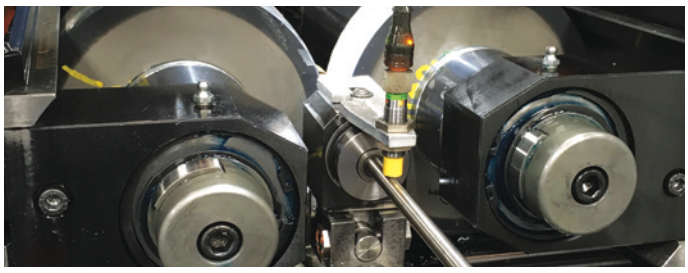

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