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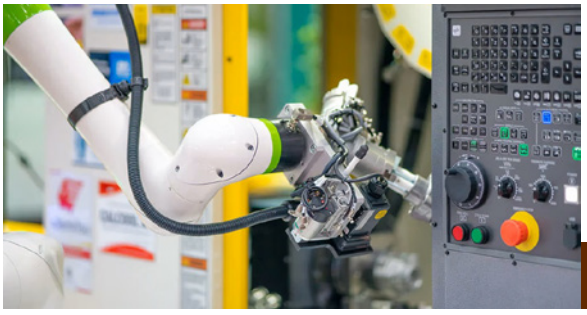

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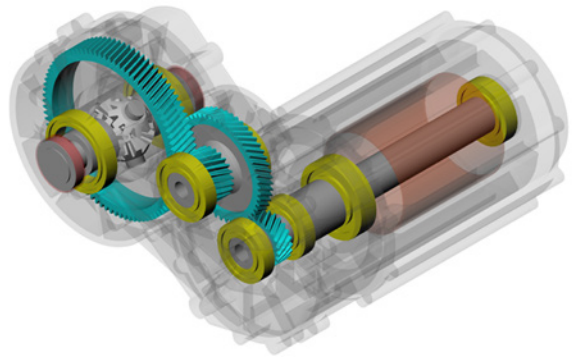

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BRAIN TEASER

Twice the Speed or Twice the Load?

A ball bearing in a gearbox application is running well within its rated capacity. The system is being redesigned, and the engineer must choose: either double the shaft speed or double the radial load—but not both.

Question:

Which change reduces the bearing's L10 life more?

Join the discussion

Comment at
linkedin.com/company/power-transmission-engineering
on LinkedIn or use
#PTEBrainTeaser
to share your answer.

Selected responses may be featured in an upcoming issue.
Answer revealed in the next issue.

Last issue we asked: Two identical motors drive a single conveyor through matched gearboxes and VFDs set to the same speed reference—will they share torque equally?

Answer: No—in practice, small differences in gearbox ratios, motor characteristics, and VFD tuning mean one drive inevitably "fights" the other rather than sharing the load. The standard fix is a master-follower control scheme, where one drive regulates speed and the other follows a torque reference.

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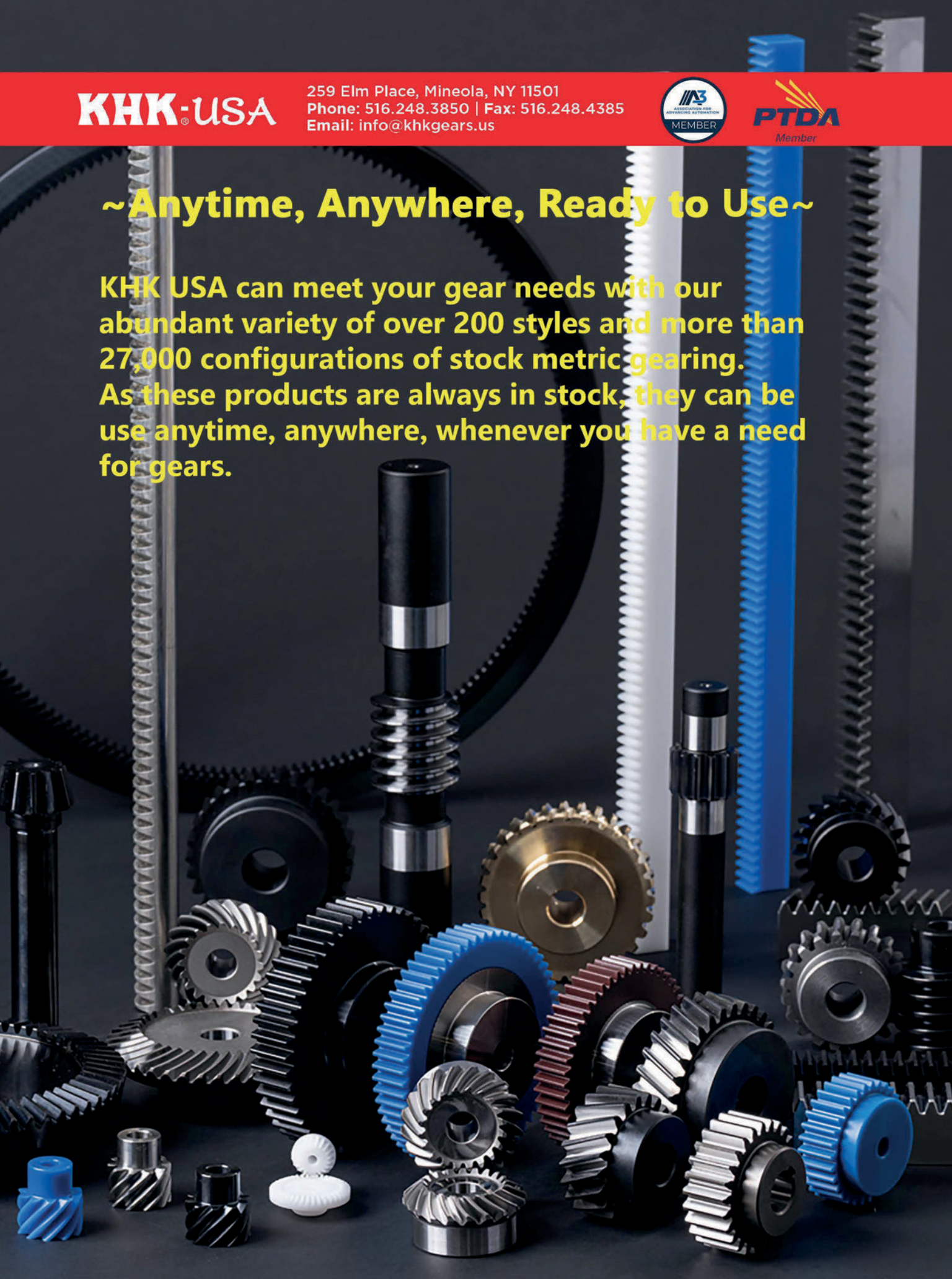

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PTE REVOLUTIONS

With the 250th anniversary of America, we're looking at some key manufacturing legacy companies pivotal to innovation here in the United States:

Engineering Legacy: Philadelphia Gear (1892)

George B. Grant founded Philadelphia Gear Works in 1892. At the time, the country needed raw materials like wood, copper, steel, and coal, as well as machinery for food production. Perfectly located to serve the booming steel and anthracite coal mines of Pennsylvania's Lehigh Valley, the company prospered as it helped meet the broad need for dependable gearing.

powertransmission.com/engineering-legacy-philadelphia-gear-1892

Engineering Legacy: Kaydon Bearings (1941)

Kaydon Engineering Corporation was founded in May, 1941, by A. Harold Frauenthal in Muskegon, MI. Previously, Frauenthal had worked his way from sales engineer to vice president of Bantam Bearings Corporation, filing many patents along the way. He chose Muskegon for the quality of the available labor and the cooperation of the business community, and named the company after his children, Kay and Don. The location on McCracken Street—still a Kaydon facility—was purchased and adapted for the manufacturing of bearings.

powertransmission.com/engineering-legacy-kaydon-bearings-1941

TRADE SHOW SPOTLIGHT:

Automate First Impressions

The Automate Show remains one of the trade show circuit's premier events. Year-over-year technology advances are notable, especially in components serving a wide range of manufacturing sectors. While automotive has long been the foundation of automation and robotics, the market share is gaining momentum in food and beverage, consumer goods, and life sciences applications.

powertransmission.com/automate-first-impressions

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Spaceship Orion on low-orbit of Earth. Artemis II space program. Elements of this image furnished by NASA.

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Long-Form Legacy

Matthew Jaster, Director, Editorial Content

Sadly, we do not currently provide a gigantic, six-volume manufacturing series on the history of gears, bearings, couplings, brakes and motors with descriptions and details that would make the likes of Leo Tolstoy or J.R.R. Tolkien jealous with envy. One day, at the very least, I'd like to put down on paper a travel narrative about the gear and bearing shops I've visited since 2008 and the impact each has had on U.S. manufacturing.

I've been thinking about this quite a bit as we celebrate America's 250th anniversary this summer. Big stories like Henry Ford's assembly line, our manufacturing ingenuity during World War II, the various NASA mission programs and the future of electrification, automation, and robotics.

Every machine shop has its own unique story.

One recent example was my visit to KA-Wood Gear & Machine Co. located in Madison Heights, MI. KA-Wood began in 1920 by Joseph J. Kloka and Alfred Underwood, with the last syllable of their last names comprising the KA-Wood company name. The company started in Detroit in a two-car garage.

By 1941, the company moved into a 3,300 sq. ft. building in Detroit and then to a 9,000 sq. ft. building located in Madison Heights in 1981. KA-Wood built a new state-of-the-art facility in 1994 which expanded into a 23,000 sq. ft. facility by 2008.

History slaps you right in the face, the second you step on the shop floor. From the large section of working Barber-Colman hobbing machines right down the aisle from an advanced Reishauer RZ-550 CNC Gear Grinder. Visitors will find a couple of Pfauters set up for hobbing worm gears not too far away from a row of innovative Mitsubishi GE15A hobbers.

The company works across industrial sectors including automotive, aerospace, mining, printing, packaging, machine tools and more. Visitors often stop by off the street and ask if the company can work on a specific gear for a lawnmower application or help with a gear for a classic muscle car.

Many U.S. manufacturing stories begin the same way: "We started the business in a two-car garage."

Over the years, we have been fortunate enough to capture this history and share it with *PTE* and *Gear Technology* readers. Our editorial team remains committed to preserving and celebrating the legacy of gears, bearings, couplings, and motors while continuing to cover the innovations and technologies shaping their future.

Some examples:

Revolutions: Our *PTE* Revolutions articles examine historical manufacturing stories from companies like Philadelphia Gear, Carlyle Johnson, The Hillard Corporation, Maxon and more: *powertransmission.com/topics/revolutions*

My Story: Our former *Gear Technology* blogger Charles Schultz requested colleagues to submit their gear origin stories back in 2019 and we have a nice library of blogs on how people first became interested in gear manufacturing: *geartechnology.com/search?query=my+story*

Gear Expo/Motion + Power Technology Expo: With the 40th anniversary of Gear Expo/MPT Expo taking place in 2027, now is a wonderful time to look back at how the trade show has evolved over the years: *powertransmission.com/a-history-of-motion-power*

Please continue to share your stories about how you became involved in mechanical power transmission and we will continue to provide "Long-Form Legacy" stories online and in print to celebrate these achievements.

Imagine for just a moment what the **NEXT** 250 years could look like here in America from a manufacturing and engineering perspective. Robots building robots to manufacture robots and one engineer sitting on a couch controlling it all with their "Mind Phone 17."

Truly boggles the brainwaves.

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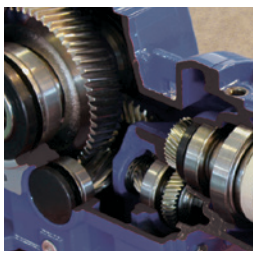

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FORCE CONTROL

Rebuilds Fast Brake for Control on Downhill Conveyors

Conveyors are critical equipment at aggregate plants and the downhill versions, loaded with tons of material, don't leave much room for error. When brakes fail and a belt gets away, the result is immediate and dangerous. Material moves where it shouldn't and equipment takes the hit. Unfortunately, that's exactly what happened recently at an Oregon aggregate plant. A brake failure caused a loaded belt to let loose, damaging both the belt and sections of the conveyor framework. Operators responded with front loaders and dump trucks, making repeated trips up and down the incline to clear material. With replacement parts carrying lead times of up to 20 weeks, there was real concern about how long the plant would remain down.

At aggregate operations, downhill conveyors are often responsible for moving large volumes of material continuously through the plant, so any loss of control can quickly affect multiple parts of the process. The conveyors were handling stone on an approximate 30-degree incline, each about 36 in. wide. In this type of application, consistent braking performance is critical to maintaining control of the loaded belt.

The system was originally equipped with Force Control Posistop brakes. By all accounts, they had run reliably for about 14 years. The oil-shear design delivered reliable results with no adjustment and almost no maintenance, while the enclosed design kept dirt and debris away. But a few years back, the maintenance team changed, and fluid levels and system pressure were not consistently maintained. At the same time, issues with the hydraulic power units (HPUs) and valves led to inadequate pressure to fully release the spring-set brakes. In this condition, the system was effectively "driven through" the brake stacks, generating excessive internal heat and accelerating wear. Ultimately, the brakes failed. Once a loaded belt starts moving uncontrolled, the impact adds up quickly.

Restoring Control After Failure

After the failure, plant personnel worked with Motion Industries in Medford, OR, to assess the damage and restore operations as quickly as possible. A bid was obtained for new replacement brakes, but the industry standard 20-week lead time was too long for the aggregate site to be out of production.

"Knowing how important it was to get the plant back into production, we contacted Force Control to see if there was any way to speed the process—either with new brakes or by rebuilding the damaged ones," said Motion Account Manager Todd Franklin.

The team pulled two Posistop FA-20 brakes, including power units and valves, and sent them out to the Fairfield, OH, factory. Teardown revealed significant internal heat damage consistent with the brakes being driven through under load, along with worn friction surfaces and compromised internal components. In both units, shafts required rebuilding, including machining undersized bearing journals and rebuilding shaft surfaces through a weld-and-grind process before returning components to final size.

Initial inspection also raised concerns about the condition of the valves and HPUs, which are critical to releasing the spring-set brakes. If these components fail to deliver sufficient pressure, the brakes will not fully release, leading to rapid heat buildup and potential repeat failure. Low or high fluid levels, faulty valves, or insufficient pressure (below 20 psi) can prevent proper release, leading to continued drag and heat buildup inside the brake stack.

The work included evaluation, repairs, cleaning, and testing. Force Control maintains inventory of internal wear components, so the team was able to begin repairs at once rather than waiting on long-lead replacement parts. Both units were turned around in about four

weeks, well ahead of the replacement timeline.

When the brakes were reinstalled, the system was brought back online within the scheduled outage window, bringing downhill conveyors back under control and stabilizing material flow through the plant. However, during initial startup, the system experienced added issues when the HPUs did not fully release the brakes, leaving them partially engaged and causing elevated operating temperatures above 220°F. Force Control personnel traveled to the site to troubleshoot, adjust brake stack clearances and replace the HPUs. After these corrections, the conveyors were back up and running. While pressure spikes were observed, the system was evaluated and confirmed to operate safely without damaging the brakes.

The shortened turnaround avoided an estimated 14 to 15 weeks of additional downtime and associated production losses, helping the operation return to normal production levels much sooner than expected. As part of the restart, the maintenance team received training on the system to support proper operation going forward. This included guidance on maintaining proper fluid levels and monitoring system performance to minimize heat buildup and prevent recurrence of the issue. With the rebuilt units in place, the conveyors returned to controlled operation.

Braking without Breaking

The key to the brakes' previous long service life is a unique Oil Shear design. Unlike dry braking systems that use a sacrificial friction disc which contacts the drive plates to stop, Force Control features a boundary layer of transmission fluid in shear between the friction discs and drive plates. As the parts come together, the fluid transmits torque between the two parts while also absorbing heat. This eliminates direct contact of the friction discs and drive plates during high-speed slip and supports consistent braking performance. Heat from the friction surface is dissipated as the fluid circulates to the housing.

Some systems use dry braking pads. When they wear, torque fade is introduced, which requires maintenance to adjust the gap. Systems that cut direct contact eliminate both the wear and the need for constant adjustment. Dry braking systems also generate high heat. With no good means of dissipating the heat, the friction plate glazes over, increasing torque fade and requiring further maintenance and adjustment.

Force Control's Posistop motor and coupler brakes are designed for long life with minimal maintenance in severe and critical applications, like downhill conveyors at mines and aggregate facilities. They are typically furnished as spring-set, pressure-release brakes, with pressure-set, spring-release configurations available in some models.

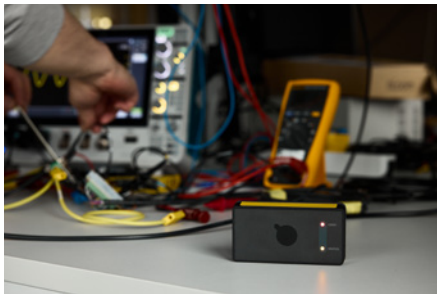
The multiple disc design reduces inertia of the brake, placing less load on the motor and improving efficiency for each cycle.

Posistop motor brakes mount to the back of brake motors, while coupler brakes mount to the drive end of the motor, often between the motor and reducer. Various model sizes offer torque from 6 lb. ft. to 2,030 lb. ft. and fit 56 frame up to 440 frame motors, with special flange mountings available for IEC, servo and other configurations. Spring-set configurations provide a fail-safe braking function, allowing the system to apply braking force in case of a loss of power or air pressure. Brake torque is sized to provide the holding force needed to control loaded conveyors under operating conditions.

The brakes use a totally enclosed sealed housing that keeps out dust, dirt, moisture and fumes. This protects internal components from environmental damage and allows the system to operate in demanding conditions. Units can be configured for horizontal or vertical mounting and can be air or hydraulically actuated. When equipped with a hazardous duty valve, they can also be used in hazardous environments.

forcecontrol.com

SONAIR
Unveils Safety-Certified 3D Ultrasonic Sensor for Human-Robot Collaboration



While the AI boom has made robots significantly more capable, the accompanying safety infrastructure has struggled to keep pace. Traditional 2D laser scanners, which are widely used to define safety perimeters for most mobile robotic systems, are unable to detect people and obstacles above or below a single plane.

"The bottleneck to safe human-robot coexistence isn't intelligence or speed," said Knut Sandven, CEO of Sonair. "It's safe perception; knowing reliably under any condition, that a human is nearby. This milestone certification is the first time a 3D sensor has been independently verified to meet that bar using sound instead of light—a new sensing modality that complements cameras where they fall short."

Designed for autonomous mobile robots and industrial automation, ADAR One delivers 180°×180° 3D spatial awareness, detecting people and obstacles at all heights, eliminating the limitations and blind spots that define today's 2D safety systems. Easy integration with a tiny footprint enables ADAR (acoustic detection and ranging) technology to be embedded flush into virtually any robot form factor, including humanoids.

"ADAR One does not merely replace a sensor. It introduces a new safety layer for robotics, a certified 3D perceptual foundation that sits beneath any camera, AI stack, or motion system, independently verifying that the space around a robot is safe," said Sandven.

ADAR One is already in series production and shipping on deployed industrial robots. Since the introduction of the beta version of ADAR one year ago, more than 80 global robotics companies have rigorously evaluated ADAR through Sonair's test program within. For many, safety certification is the moment they have been waiting for.

BeRobox has entered into an agreement with Sonair to deploy the safety-certified ADAR One sensor in future solutions. The agreement marks certified 3D safety arriving in one of industrial automation's highest throughput use cases, where machines and people share the tightest spaces.

"At BeRobox, innovation is not just about developing new products. It's about continuously integrating the best technologies available to simplify automation for our customers. Partnering with Sonair is another step in our mission to stay ahead through innovation and deliver the most advanced, user-friendly palletizing and depalletizing solutions on the market," said David Demers, CEO of BeRobox.

ADAR One was assessed as a human protection sensor according to the very demanding IEC 61496 standard for electrosensitive protection devices. In addition, the product meets two foundational standards: IEC 61508, the functional safety standard for electronic safety systems in high-risk industrial environments, and ISO 13849, the universal standard for safety-related parts of control systems.

The result: ADAR is rated SIL 2, (Safety Integrity Level 2) and PL d (Performance Level d) with a probability of dangerous failure (PFH) below 1.5×10^{-7} per hour.

ADAR has received an EC type-examination certificate from exida, a notified body under the Machinery Directive 2006/42/EC. In addition to the above-mentioned standards, exida has assessed ADAR's conformity to the essential health and safety requirements from the European machine directive.

Furthermore, ADAR is the first safety-certified embedded system to be built in Rust, a programming language especially designed for performance, safety, and reliability.

"This is precisely the role ADAR One is designed to play as a drop-in, pre-certified safety layer," said Sandven. "What used to be an engineering burden is now transformed into a commercial differentiator for all stakeholders."

sonair.com/contact

RULAND MANUFACTURING
Offers D-Bore Couplings for Secure Torque Transmission on D-Shafts

Ruland has introduced D-bore couplings designed to engage directly

with D-profile shafting to prevent slippage in critical motion-control applications such as semiconductor equipment, medical devices, and factory or warehouse automation systems. The couplings are available in disc, jaw, bellows, and oldham styles, allowing engineers to select the coupling type best suited to their application requirements.

D-bore couplings provide a secure mechanical connection by mating directly with the flat on a D-shaft. Unlike set screw connections that may loosen or slip on small shafts, D-bore couplings engage directly with the shaft profile to provide secure torque transmission. Traditional set screw connections can also be difficult to install reliably on smaller shafts where the screw may not seat properly on the D-profile and may loosen due to vibration or improper installation.

These couplings are particularly useful on shafts under 7 mm where standard keyways are unavailable. By eliminating the need for secondary shaft machining while improving shaft engagement, D-bore couplings simplify assembly and improve reliability in compact motion control systems.

Ruland D-bore couplings are available with bore sizes ranging from 3 mm to 10 mm and are manufactured from aluminum for lightweight performance and low inertia. Clamp and set screw hub configurations are available depending on the coupling style.

Ruland manufactures its couplings in its advanced manufacturing facility in Marlborough, MA, from meticulously selected North American bar stock using proprietary manufacturing processes. All couplings are RoHS3-, REACH-, and Conflict Minerals-compliant.

ruland.com

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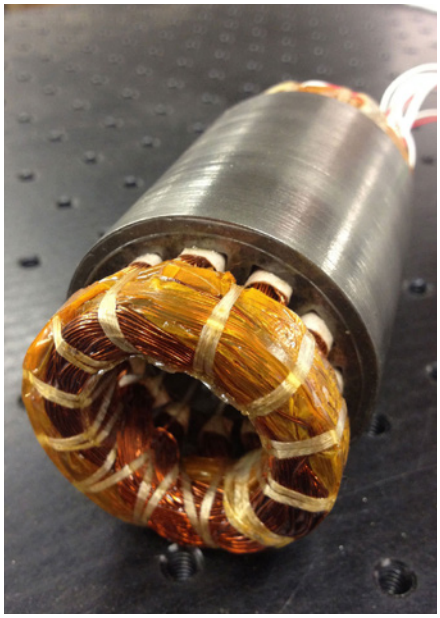


Arnold Magnetic Technologies Corp. introduced the next generation of high-efficiency electric machines with its Arnon non-grain oriented electrical steel (NGOES). Engineered for ultra-thin lamination and precision finish, Arnon helps manufacturers design smaller, lighter and more energy-efficient motors, generators and transformers, reducing core losses and improving performance at high speeds and frequencies.

With available thicknesses of 0.004 in., 0.005 in., and 0.007 in. (0.102 mm, 0.127 mm and 0.178 mm), Arnon represents a significant reduction from typical NGOES materials ranging from 0.30 to 0.47 mm. The company said thinner laminations reduce eddy current losses, minimizing heat buildup and enabling higher efficiency—especially in high-speed and high-frequency applications above

400 Hz and switching frequencies over 1 kHz.

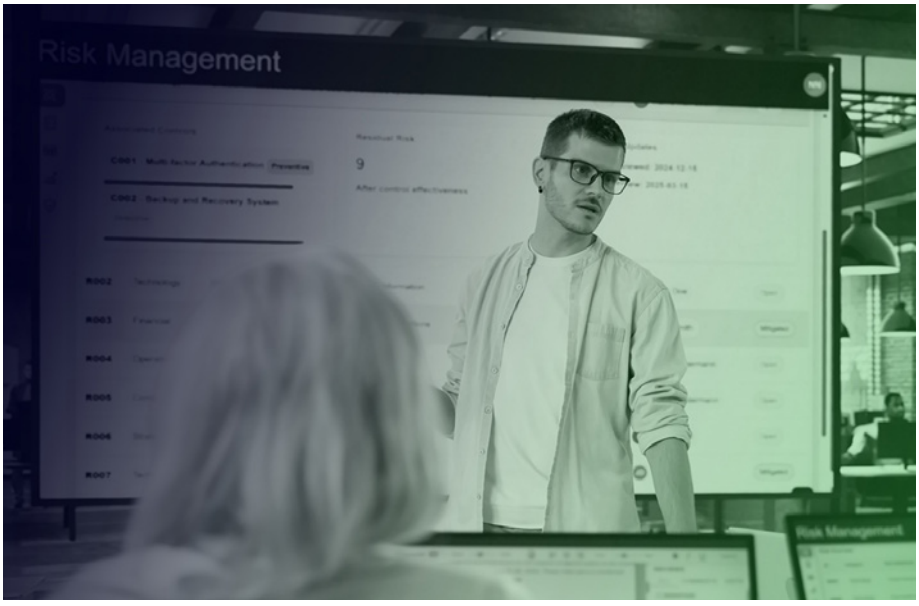
Arnon's low coercivity is 8–15 percent lower than alternative NGOES products, cutting hysteresis losses and improving total core efficiency. Motors built with Arnon have achieved efficiencies exceeding 98 percent, demonstrating measurable performance gains in demanding applications.

Arnon NGOES proves particularly advantageous in higher frequency motors and generators above 400 HZ. The thinner material offsets effects created by increased eddy currents and subsequent heat buildup. Thin laminations built with Arnon produce a more efficient unit and free up design constraints. Arnon laminations also lead the industry for switching frequencies above 1K Hz.

Arnon can lower core loss by up to 50 percent when compared to other NGOES, the company said.

Arnold has further advanced Arnon NGOES with its new MAP coating, an eco-friendly, water-based insulation that maintains low interlaminar losses at elevated frequencies. This sustainable coating system supports both high-performance and environmental design goals, helping manufacturers meet increasingly stringent energy efficiency standards.

arnoldmagnetics.com



ONEKEY
Enables Continuous Firmware Monitoring

The Düsseldorf-based cybersecurity company Onekey has developed digital twin technology that enables automated scans to monitor firmware around the clock. Onekey's monitoring system reanalyzes the firmware daily to ensure continuous security throughout its entire lifecycle. When new vulnerabilities arise, the constantly updated database and enhanced detection capabilities alert users to critical developments that could compromise a product's security.

"Manufacturers must know which software components are included in their products and which new vulnerabilities arise in order to react quickly and effectively protect their systems," CEO Jan Wendenburg said.

As part of a modern firmware monitoring approach, a product's firmware is continuously monitored, not just analyzed once. The goal is to automatically detect emerging security vulnerabilities in software components and assess their impact on existing products.

First, a detailed analysis of the firmware is conducted. This process identifies all the software components contained within the firmware and creates a structured software bill of materials (SBOM). Based on this information, dependencies within the software supply chain can be transparently mapped.

Next, the SBOM is continuously compared against global vulnerability databases. As soon as new security vulnerabilities are published, for example in an open-source library, it can automatically be determined whether an affected product contains the vulnerable component.

Onekey's CRA Fast Start program provides continuous monitoring throughout the entire product lifecycle. This program enables manufacturers of connected devices, machines and systems to rapidly and structurally assess compliance with the Cyber Resilience Act.

One method of implementing scalable security testing is through digital twins. This involves creating a virtual representation of the firmware, enabling security analyses to be conducted independently of the physical hardware.

These digital models can be continuously monitored to provide an ongoing overview of a product's security status. This gives manufacturers a centralized source of information for identifying and addressing security risks early on.

Another key aspect of firmware monitoring is automated risk assessment.

Therefore, Onekey's platform analyzes contextual information, such as affected components, exploitability of the vulnerability and potential system impact with firmware monitoring as one of its features. The result is a prioritized list of security issues that can be addressed in a targeted manner.

This information feeds directly into security incident response processes, helping Product Security Incident Response Teams (PSIRTs) deploy security updates more quickly and effectively.

"With the increasing number of connected devices and the growing complexity of modern software architectures, daily vulnerability checks are crucial for regulatory compliance and security," said Wendenburg.

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The View from Deep Space

John Crane supports historic Artemis II mission with critical equipment

Matthew Jaster, Director, Editorial Content

Artemis II space mission. Orion spacecraft with Moon. Elements of this image furnished by NASA.

NASA's successful Artemis II mission represented the first crewed lunar mission since *Apollo 17* in 1972 as well as a major leap forward in humanity's return to deep space exploration. The mission launched on April 1, 2026, and lasted approximately nine days, one hour and 32 minutes.

The goal was to validate the *Orion* spacecraft, space launch system (SLS) and move the needle for operational procedures on future lunar missions. The four astronauts also assessed life support, navigation and communication systems in deep space while sending some of the most beautiful photos of the moon back to Earth.

John Crane's contribution to the project formed part of a broader, multi-division effort across the Smiths Group, bringing together complementary technologies to support this mission-critical program.

Collaboration with the ArianeGroup

John Crane's introduction to the Artemis project began when the organization collaborated with the ArianeGroup.

"We came in contact with the ArianeGroup back in 2010 when they were looking for partners to provide sophisticated manufacturing capabilities for aerospace applications," said Jeroen Huizinga, senior director at John Crane. "They wanted to collaborate with us based on our experience as a filtration specialist making sieves for different applications."

The first physical product that came from this collaboration took a few years to develop as the companies worked together to optimize the design by combining ArianeGroup's experience and knowledge in space applications with John Crane's in-house manufacturing technology to create a working prototype.

The ArianeGroup is a contractor for the European launcher Ariane 6 and the M51 strategic missile. The organization has unique expertise in Europe in the field of spatial and orbital propulsion. ArianeGroup's contributions for the Artemis II mission included the propulsion subsystems, high-pressure helium tanks, propellant tanks, technical assistance, avionics assistance and complete final assembly and testing.

"We've worked with the ArianeGroup for several years on manufacturing technologies for the Ariane 5 and the Ariane 6 as well as the Artemis program," Huizinga said.

Ariane 6 is the new-generation launcher, designed to be modular, flexible, and versatile, to meet the needs of institutional and commercial customers in the space market.

A History of Manufacturing Excellence

John Crane, a member of Smiths Group, is a global leader in flow-control technologies and an innovator in solutions for rotating equipment across the energy and process industries. Its portfolio spans mechanical seals, couplings and filtration systems, supported by advanced service solutions and digital diagnostics for pumps, compressors, turbines and other rotating equipment.

John Crane supplied highly specialized filtration sieves for the Artemis II program, specifically for the spacecraft's propellant management devices (PMDs). These systems play a vital role in low-gravity environments by managing the separation of liquid and gas phases within

propellant tanks, enabling effective and reliable thrust during the mission.

"The challenge for this application is that the filtration sieves included a titanium outer ring and a thin, stainless-steel wire mesh which needed to be welded together. Most people will tell you that you can't weld titanium with stainless steel so our material scientists came up with a special procedure to weld the frames together so the components could endure the extreme vibrations, pressures and temperature variations needed for space travel," Huizinga said.

These components needed to be manufactured to exceptionally high specifications and offer consistent performance throughout the mission to ensure there was a guaranteed supply of liquid hydrogen for steering and engine operation, according to Huizinga.

Not exactly your run-of-the-mill industrial application by any stretch of the imagination. Liquid hydrogen was the primary propellant for Artemis II fueling both the core stage and upper stage. It is notoriously difficult to manage because tiny molecules can easily escape through microscopic gaps and seals.

NASA engineers, in fact, had to perform a series of tests on the liquid hydrogen sphere to ensure the tank functioned properly prior to the mission.

In addition to John Crane's contribution, other Smiths Group businesses supported the Artemis II mission. Flex-Tek supplied highly engineered components for the *Orion* SLS, including rigid tubing used for the safe transfer of fuel, gas and hot air within the rocket's main propulsion and air systems. Smiths Interconnect contributed high-speed cable assemblies and connectors critical to mission communications.

"Product reliability and integrity was absolutely key to the success of these components and everyone across the company knew what was at stake once the mission launched in April," Huizinga added.

Precision manufacturing of filtration sieves for the Orion spacecraft. **(Image: John Crane)**

Each filtration sieve is carefully assembled to support reliable propellent management in space. **(Image: John Crane)**

Across the Finish Line

The day of the mission there were nerves around the office. Huizinga said team members were paying close attention to the television as well as the skies above. Some engineers watched the launch take place on television while others patiently waited for live updates from NASA.

On the second day of the mission, NASA reported that *Orion* had performed a 5-minute, 49-second translunar injection burn using the European service module's (ESM's) AJ10 main engine. This was the only use of the main engine during the mission; subsequent maneuvers were conducted by the eight smaller R-4D secondary engines. The burn consumed approximately 1,000 lbs. (450 kg) of hypergolic propellant and placed the spacecraft on a free-return trajectory around the Moon, requiring only minor course corrections for the remainder of the mission.

By the sixth day, *Orion* had entered the Moon's sphere of influence and was officially 252,756 miles from Earth (beating the previous record held by *Apollo 13*).

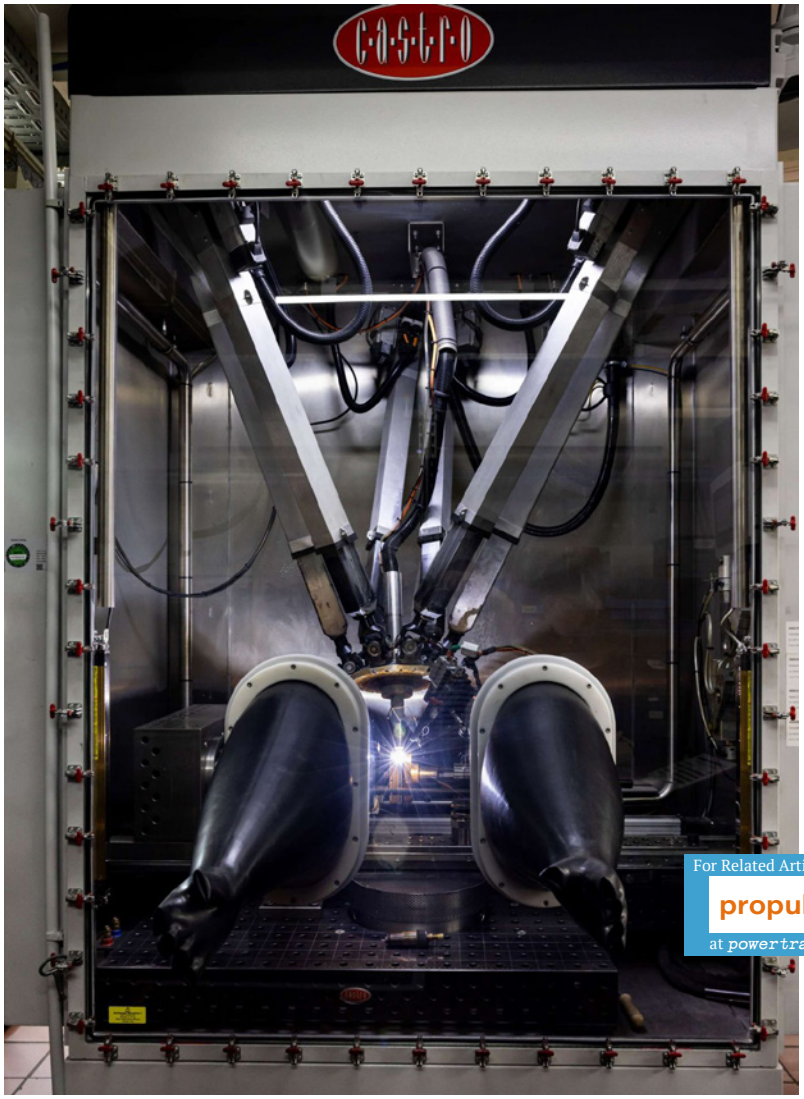
On day ten, *Orion* conducted an 8-second trajectory correction burn, the final firing of the ESM prior to reentry. NASA confirmed that the mission had consumed less than half of the fuel aboard the ESM. After the separation, the thrusters on the crew module fired for 19 seconds to push it away from the ESM and put it into the proper angle for reentry. Astronauts Christina Koch, Victor Glover, Jeremy Hansen, and Reid Wiseman returned to Earth safely on April 11, 2026.

Everyone involved in the Artemis II project at John Crane was keen to share the news of the successful mission.

"We have some nice samples and a display at one of the German plants that tells the story of how John Crane participated in the Artemis II project," Huizinga said. "I think all the different companies involved in the mission were extremely relieved and proud of their contributions to a project of this size and scope."

Ruben Alvarez, president of John Crane, said: "Artemis II is a powerful example of what's possible when deep engineering expertise, innovation and collaboration come together. At John Crane, we are proud to contribute specialized technologies alongside our colleagues across Smiths Group, helping enable a mission that pushes the boundaries of performance, reliability, and human exploration."

"Every piece of equipment for this kind of spacecraft needs to undergo a demanding qualification and



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Advanced welding technology helps produce mission-critical components for Artemis II.
(Image: John Crane)

acceptance program. During the sieve development phase, we had to combine the extensive sieve manufacturing expertise from John Crane with the space engineering know how of ArianeGroup. John Crane has proven to be a dependable supplier for such critical elements, and we are looking forward to continuing our cooperation," said Dr. Nicolas Fries, *Orion* propellant tank development lead at ArianeGroup.

What Comes Next

Huizinga believes Artemis III will be a continuation of the work John Crane has provided for earlier Artemis missions. During Artemis III, the SLS rocket will launch the *Orion* spacecraft and its crew to low Earth orbit and demonstrate rendezvous and docking capabilities with test versions from commercial human landing systems in development by Blue Origin and SpaceX. This mission is set to take place in 2027.

The company continues to collaborate with the ArianeGroup on filtration technology for other aerospace projects. The Smiths Group is also working on projects with the Indian space program.

The time and effort—not to mention the paperwork—needed to make the filtration technology work for Artemis II is something John Crane can celebrate for years to come.

Artemis II marked a historic step in inclusive space exploration and set a new human-distance record from Earth, inspiring global attention, and confidence in NASA's Artemis program. The mission bridged the gap between Apollo-era lunar exploration and the next generation of human spaceflight. The success of this operation will help NASA and other space agencies prepare a detailed roadmap for additional lunar missions as well as eventual missions to Mars.

"We played just a small role in a critical aerospace project and I'm always curious to know what they learned from the mission and what advancements will be applied to future space projects," Huizinga said. "The engineering and manufacturing capabilities alone, it's mind-blowing when you step back and think about it."

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Simplified Solutions

Bosch Rexroth offers flexible specification options for components in agriculture, off-highway and construction markets

Matthew Jaster, Director, Editorial Content

The hydraulics market is very mature, according to Terry Hershberger, mobile hydraulics technology leader, Bosch Rexroth. So mature, in fact, changes occurring from an innovation standpoint come in smaller and smaller increments on the hardware side. Today, it's all about bundling components in new ways and focusing on advancements in electrohydraulics and sensor technology.

This is the road map for component technology in the agriculture, off-highway and construction sectors in 2026. Large and small OEMs are building machines with smaller components that consume less energy, offer user-friendly controls/software and provide high degrees of automation.

Innovations in agriculture machinery come in small increments today.

Bosch Rexroth presented similar themes during ConExpo-ConAgg earlier this year "Our Electronic Open Circuit (eOC) is a great example of this. It's not a brand-new technology, but it gives us the ability to control our components in a more simplified way," Hershberger said.

The electrohydraulic eOC pump with a swivel angle sensor and pressure sensors is one of the central components in the eOC architecture. Combined with an ECU and the other components of the system it provides the control of the setpoint values for torque, pressure or flow. In combination with eOC software, characteristics in system dynamics and power control can be set, changed and combined—all with the notion of simplifying the system technology.

"Today, we really have a solid understanding of the interaction of all the components in electronic flow management, for example, Anything needing dynamic control and coordination such as an excavator are good candidates for this simplified solution. These were part of the many discussions we had at ConExpo–ConAgg," he said.

Next Level Flexibility

Hershberger shared some of these technologies with *PTE* during a post-show recap including the MPR radial piston motor, the MCR-F motor for wheel drives, RS valves, eLION motors, HMI for mobile machines, compact hydraulic solutions and more.

"A smaller, more compact design is the main feature of our MPR radial piston motor. Whether you're talking about conveyor systems, ground drive systems, etc., this motor fits very well into areas where customers are downsizing and optimizing their construction equipment," Hershberger said.

The Bosch Rexroth MCR-F is a compact, robust radial piston hydraulic motor specifically designed for direct wheel drive applications in mobile machinery. Operating in a radial piston design principle, it delivers high starting torque, mechanical efficiency, and smooth low-speed performance in open or closed circuits.

Additionally, Bosch Rexroth valve technology continues to expand with larger sizes and more scalable product portfolios. Rexroth Flow Sharing (RS) valves are optimized for electro-hydraulic actuation and ready for operator assistance functions targeting applications in areas such as construction, material handling and forestry.

The eLION product line continues to gain traction with technologies to manage thermal output and deliver optimal conditions for critical battery and electronic components performance. The flexibility of these drives, for example, enables higher power densities and noise optimization for high-speed electric motors. Easy integration, sensor-based monitoring and several strategies for drive solutions round out the key capabilities. Bosch Rexroth's knowledge of construction equipment is a huge advantage during the design phase of the eLION platform.

"We're seeing a push towards simplifying component design in this area as well," Hershberger said. "Now we're mixing and matching with traditional hydraulic power transfer or now with electronic technology and letting customers select the best drive solutions for their particular applications so they can select the products they need without getting bogged down in the details." This is the impetus for 'Simplified Solutions.'

The expanded HMI portfolio hints at making machine operation as efficient and safe as possible. This includes joysticks, foot pedals, power brakes and other products that can be selected. They provide intuitive component control and offer unique capabilities based on each individual machine.

"Trade shows like ConExpo are so important to meet face-to-face with our customers and have conversations about the obstacles they're currently facing in these markets. There were plenty of discussions on utilizing electrified solutions and specifying smaller and more compact components for future machine designs," Hershberger said.

Facing 2026 Industrial Challenges

Localization is as important today as it has been, however, tariffs, global economic uncertainties and the need to have service and support as close as possible to your customer base is imperative. Hershberger said these are the areas Bosch Rexroth is looking at today in the mobile machine market.

"Electrification discussions have slowed. It's happening in some areas faster than others and we're seeing the price of diesel and fuel in general fluctuate regularly. How many hours of operation will you get with electrified solutions? You know exactly what you're going to get with a fuel

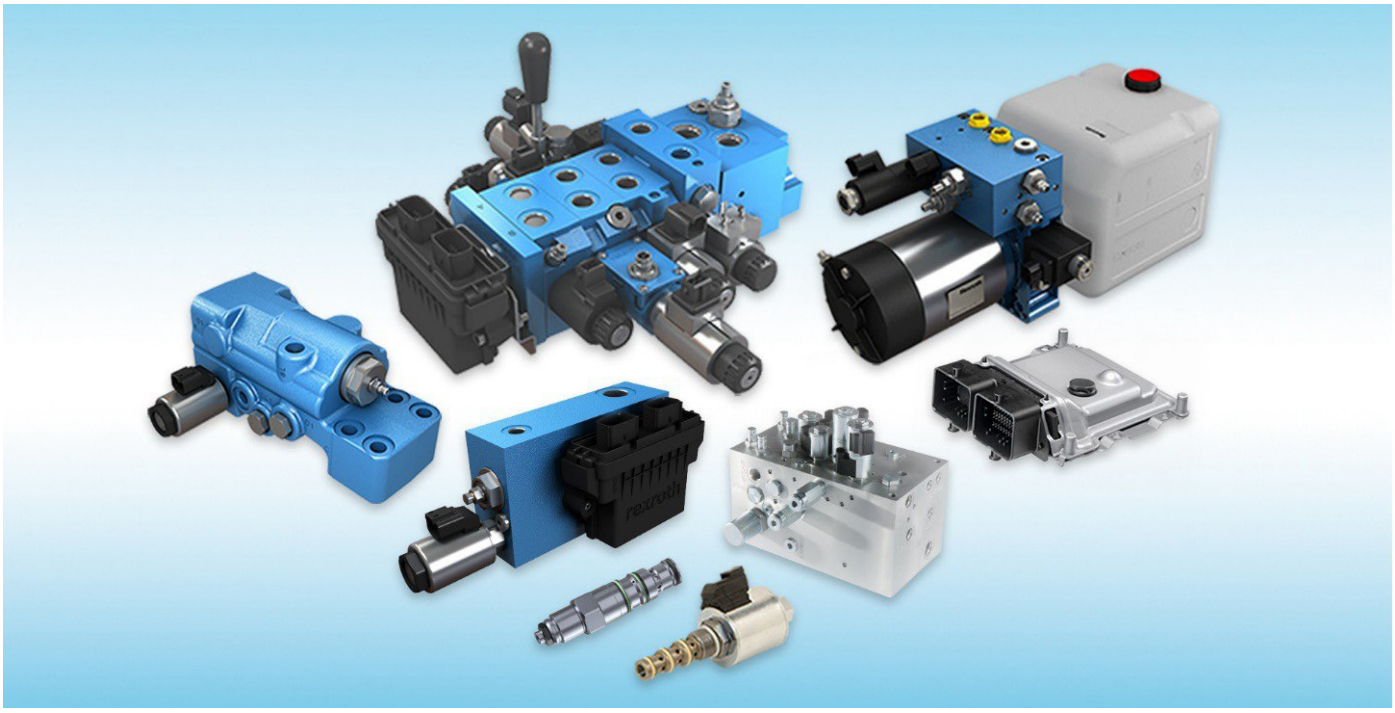
The eLION product line manages thermal output and delivers optimal conditions for critical battery and electronic components. **(Image: Bosch Rexroth)**

One of the key questions engineers face in agriculture applications today is whether or not to move to electrification or stay with traditional technologies.

tank on the machine, so navigating which types of machines, industries and use cases can benefit from electrification continues to be evaluated," Hershberger said.

Range anxiety, space limitations and modernizing old technology will continue to keep engineers up at night. How big a battery will you need to put in this equipment today especially if it's impossible and impractical to refuel when you're out in the field?

"What is being done differently today? Hershberger continued. "Do customers want to buy the machines or rent the machines? How experienced are the operators? How much automation is being considered? Do we move to electrification or stay with traditional technologies? We need to keep up with all the trends



With the acquisition of Hydroforce, Bosch Rexroth has expanded its range of compact hydraulic components and systems. **(Image: Bosch Rexroth)**

and keep the lines of communication open with our customers."

Smaller and lighter components continue to be an integral aspect of mobile hydraulics in overall optimization.

"For instance, the big valves control those large movements and functions but there are smaller flow demand functions that need to move at the same time that must be coordinated in the full system. We're providing *tomorrow's* system solutions today with our Simplified Solutions. The concept is really about providing the solutions—from a little support to a lot of support—that the customer decides. With the trend of more compact, energy efficient vehicles and the ability to provide technology in a smaller but effective package, the support is critical," Hershberger said.

The acquisition of Hydroforce in 2022 has also been beneficial for these markets. Bosch Rexroth offers a wider range of compact hydraulic components and systems, HydraForce focuses on mechanical and electrical cartridge valves and hydraulic integrated circuits (HIC).

Compact hydraulics is particularly valuable due to the high-power density. The world market for these systems has been growing continuously and this helped shape the Compact Hydraulics Business Unit. The move broadened the company's hydraulics offering for existing and new customers, expanding global reach and providing growth opportunities.

Market Needs

So, what are customers looking for today on mobile machines? Hershberger cites a growing plug-and-play market where torque factors into every conversation.

"We can continue to grow in these markets with the diverse line of products we're highlighting at trade shows like Con-Expo. It's still about function but more and more the ideal fit of the components within the system. This is very critical. When we place optimized components as part of the machine solution and provide new functionality, we'll continue to be successful."

Cybersecurity is another big ask in 2026. "The accuracy of the sensors is so critical in this equipment. Nobody wants a machine that can easily be hacked or be in a position where valuable machine data is stolen," he said.

Availability of chips used to be a greater challenge, but Bosch's history with its own chip production certainly makes it easier to address these issues.

"The ability to provide our own sensors and that deep engineering knowledge gained from similar applications has been good for us," he added. "You want to have sensors all over your machine because you're providing all the vital feedback."

Bosch Rexroth will continue to diversify its product portfolio by adding motor frame sizes, extending motor range and being flexible with the components they're releasing. In addition, Bosch Rexroth plans to expand and develop new technologies for electric actuators.

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Upgrading the Industrial Workflow

AMMEGA focuses on optimizing belt and belt driven systems

Matthew Jaster, Director, Editorial Content

***From polyurethane timing belts to high-performance power transmission solutions, Megadyne powers industries with innovative belting technology. (*All images: AMMEGA)**

The belt and chain market is heavily driven by intralogistics, automation and infrastructure growth in 2026. Manufacturers are looking at areas like electrification, sustainability and supply chain resilience to meet stricter performance expectations. *PTE* recently sat down with Kyo Oh, vice president and general manager at AMMEGA Group Power Transmission and Fluid Power Solutions, to discuss the U.S. belt market from a power transmission perspective.

Looking at the U.S. market today, Oh said the goal is to leverage the knowledge gained from R&D and manage the AMMEGA portfolio of products to determine what their U.S. customers need in terms of product specification.

"Belt doesn't work by itself. It requires an understanding of the motors, pulleys, and sprockets along with the drives and controllers. Then there's the regulatory requirements that need to be met. We're working with OEMs as well as distributors to hopefully exceed the expectations of our U.S. customers today by focusing on industrial workflow automation," Oh said.

Prior to the energy shortages and the tariff situation, AMMEGA had been focused on bringing a manufacturing renaissance back to the United States.

"We're looking at how we can distribute products and services in the quickest manner and this is really driven by Amazon's fulfillment center model. Do we have the right products at the right place at the right time? Supply chain management is so important today and bringing production closer to our customers from a geography point of view is pivotal for future success," Oh said.

The second thing that drives the supply chain is making sure the equipment is as efficient and reliable as possible. "Our components are designed to be maintained and serviced, and we really need to be flexible in case we need to expand a production line or increase the load on our motors, drives and belts," Oh said.

Product is flying across distribution center conveyors today and you're seeing faster moving parts and varying loads, so the belt drive system needs to be robust enough to handle larger requirements. "The drives, the torque, the horsepower, everything needs to perform at the highest level to maintain operational efficiency," he added.

AMMEGA has developed Quiet Self-Tracking (QST) profile belts, for example, that will automatically correct for any effects of pushing, pulling, side loading, or other actions that may result in mistracking. This results in less belt damage, low noise and reduces maintenance costs.

"The belts, however, can still generate some noise. How do we design drives and belts to achieve a quieter working environment? So, we're developing a profile that tracks to the center and drives the cancellation of tooth-engaging noise to a level that's quiet. And we're introducing softer materials into some of our product portfolios. Our goal is to reduce noise and provide sustainable, energy efficient solutions that meet the environmental needs of our customers today," Oh said.

Because reliability and performance are so imperative, Oh discussed the importance of collaborating with operation managers, engineers and MRO teams before, during and after product installation.

"It's critical to have an eye and an ear on making sure the system is optimized and running efficiently. This is where smart solutions come into play like scanning a QR code and receiving real time data on your smartphone, for example, letting personnel know when the last maintenance was performed on the belt drive," Oh said.

There are sensors everywhere in these environments today, monitoring the overall health and productivity of the power transmission components and providing data to support future maintenance needs.

"It's important to have a quick and easy way to understand the health and state of our belts and belt drives. Is the belt degrading faster than it should be? Why is a particular line no longer running efficiently? There's a lot of integration work that happens behind the scenes. Therefore, we have a clear understanding of the information and knowledge we're passing along to our customers, engineers, supervisors, etc., so everyone has a holistic view of the system," Oh said.

Manufacturing, automation, packaging, and robotics rely on Megadyne for timing belts, v-belts, and specialty drive solutions that enhance productivity.

The service of the belt system starts with asking the right questions. What products are riding on the belt? Why does it need to be replaced? What factors led to the downtime? Has this been an issue since installation?

This brings us back to the challenge of meeting automation demands with less floor space and less energy consumption. Globally, Oh said the industry is seeing a push to make everything more compact and come up with smaller solutions that can function as effectively as larger conveyor systems.

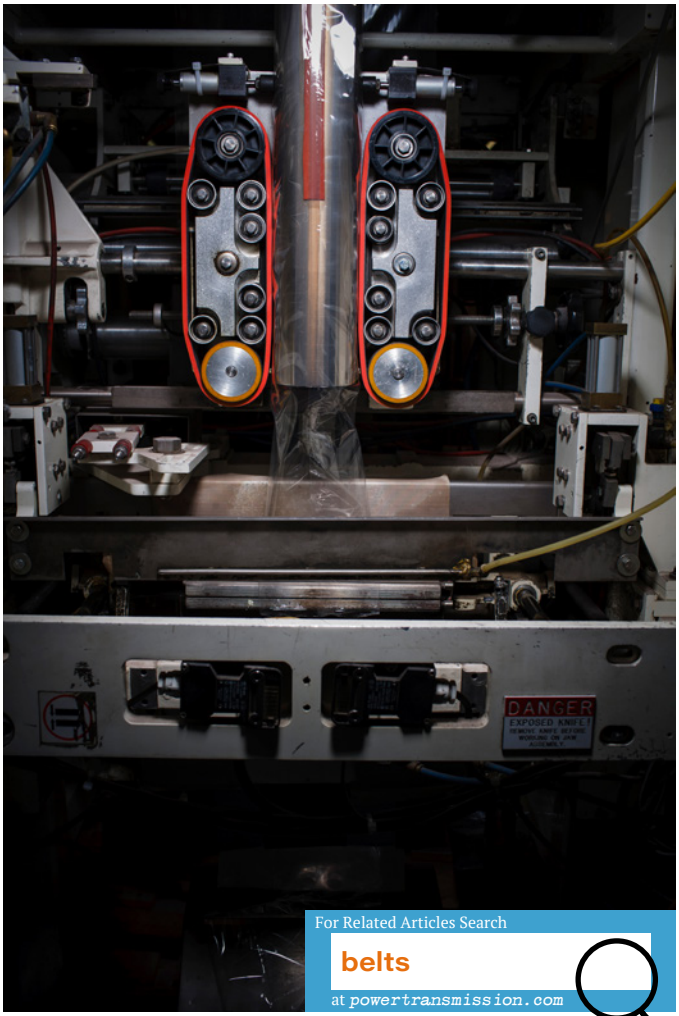
"If you look at Europe as an example, you're seeing fulfillment and distribution centers closer to where we all work and live and consume, right? So, you'll see a fulfillment center that was on the outskirts of the city is now downsizing to a smaller facility right in the city and the idea here is to get closer to customers and optimize production," Oh said.

Productivity in the belt market equals less downtime. This is the end game for power transmission components in the years to come. The objective is to design faster systems, provide not only predictive maintenance solutions but prescriptive solutions as well. Do you have the right personnel in place to accomplish these goals?

AI will play a large role in the coming years to sort through data and analytics and provide the customer with a blueprint for success.

"Time is of the essence and having the right product delivered to the factory floor in hours versus a few days will certainly move the needle," Oh said. "We'll see AI assist with crunching numbers, collecting data, etc., but it will also optimize the automation workflow. It will help MRO teams decrease downtime and allow them to focus on other work assignments. We're not too far off from a day when the belt will communicate directly with the customer, letting them know they're not functioning correctly, and they need to be replaced. Those days are coming."

Belting technologies in conveyors and power transmission will optimize performance across a wide variety of industries for years to come. Sustainability will not be



Megadyne belts resist wear, handle high torque, and maintain peak performance under intense conditions.

treated as a standalone initiative but integrated into the company's initiatives to reduce its environmental footprint, advance circular product design and strengthen responsible sourcing practices. AI and smart manufacturing will let customers know what products need to be maintained and provide the most efficient workflow system to get it done. These are just a few of the changes taking place in belt and belt drives in 2026.

Oh added that belts appear in such a diverse range of applications with technology that has been around for centuries and yet the industry continues to adapt to the changing needs of the customers.

"It's quite remarkable when you think about the innovation that has taken place throughout mechanical power transmission. We'll continue to adapt in the foreseeable future, all the things we talked about today including AI, smart factories, prescriptive maintenance, etc., it's amazing to step back and think about these belting solutions that are being adapted in new and exciting ways and the limit has yet to be achieved."

ammega.com

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Maximizing Machine Longevity

FST provides three advancements in lubrication and seal technology

Matthew Jaster, Director, Editorial Content

Freudenberg Sealing Technologies (FST) continues to expand its seal and lubrication technology platform by providing a range of solutions addressing critical issues such as friction, performance, power and material compatibility. The following article examines three recent additions to the company's broad range of system solutions.

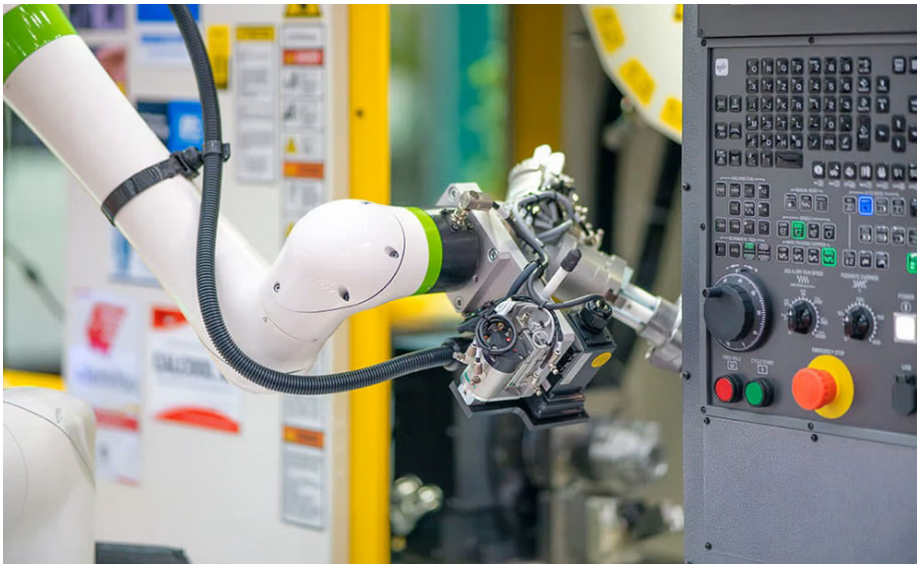
Ingress Protection Seals for Robots Highlight Automate 2026

The Automate Show in Chicago had its fair share of 6-axis, SCARA and Delta robots showing off how robotic technology is changing the industrial sector by providing solutions for physically demanding and monotonous tasks on the shop floor. These technologies need customized sealing solutions that offer long service life and reliability.

Collaborative robots, for example, are being used in difficult industrial environments or outdoors where water ingress can take place. Outdoor use—in particular—is a trend that will continue in the future.

FST has developed Ingress Protection Seals for Robots (IPSR) to ensure that AGVs, collaborative robots and humanoid robots' function reliably under extreme conditions. These seals for demanding robotic applications offer excellent protection against harmful environmental influences with low friction. High-quality, wear-resistant materials and the special surface design ensure a long service life even under poor lubrication conditions.

The challenges in the development of ingress protection (IP) seals for robot arms are diverse: robot arms consist of numerous joints that enable movements in different directions. Within these joints, there is only a very small installation space for the seal, which must be able to compensate for the tangential and axial displacements that occur there. A classic O-ring cannot do this. The sealing lip of the IPSR is designed in such a way that it can optimally adapt to these movements.



Thanks to the IP seals, cobots are optimally protected against harmful environmental influences such as dust and water ingress. **(All Images: FST)**

Thanks to the IP seals, cobots are optimally protected against harmful environmental influences such as dust and water ingress and depending on the installation space, surfaces, and tolerances, higher protection classes are possible.

Cobots have become a fundamental aspect of modern industry, marking a new era in industrial automation. Unlike other robot types, they can operate near humans without posing risks. Advanced sensor technology and sophisticated algorithms enable them to detect human presence, ensuring a safe working environment.

Due to their high flexibility, these machine helpers play a key role in streamlining automation tasks across diverse industries, ranging from automotive production to small-batch manufacturing. With quick setup and intuitive controls, they also pave the way for automated production in small and medium-sized enterprises (SMEs).

Cobots are widely used across industries due to their flexibility, ease of integration, and safe human interaction. To ensure safe and reliable operation across indoor and outdoor environments, advanced sealing solutions play a critical role.

The high flexibility of cobots, not only in adapting to changing tasks but especially in diverse working

environments, places stringent demands on the high-performance seals for articulated-arm robots. To guarantee operational reliability and long-term durability, it is crucial to protect the joints from dust, splash water, and other contaminants. Seals play a pivotal role in this context. FST's high-performance sealing solutions not only prevent leaks and potential failures but also enhance the efficiency of robotics applications by ensuring a long service life.

Lubrication Formula Targets Static Seals Including O-Rings

Freudenberg-NOK Sealing Technologies has also introduced FN Lube and FN Lube Plus, two purpose-designed lubricants formulated with the support of Klueber Lubrication. Klueber Lubrication is a full subsidiary of Freudenberg Chemical Specialties and has been part of the Freudenberg Group since 1966.

FN Lube and FN Lube Plus were developed specifically for static seals, especially O-rings, and were validated through laboratory testing to ensure material compatibility, reduce installation friction and minimize impact on elastomer properties.

The development of FN Lube and FN Lube Plus reflects a focus on ensuring consistency and reliability during seal installation. Klueber Lubrication's formulation expertise supports compatibility between lubricants and elastomer materials, helping to minimize installation risk and support stable sealing performance across a wide range of static sealing applications.

Designed for use with various elastomer types, FN Lube and FN Lube Plus demonstrated strong retention of tensile strength and elongation during internal testing. These results indicate that both lubricants help limit changes to material properties, reduce installation risks and support stable sealing performance over time. FN Lube and FN Lube Plus are available exclusively through Freudenberg-NOK Sealing Technologies' North American distributor network and are fully integrated into the company's digital catalog and PartnerHUB platform.

"Customers depend on us for static sealing solutions that perform reliably," said Paul Czajkowski, regional sales director, Freudenberg-NOK Sealing Technologies. "By combining our sealing expertise with Klueber Lubrication's lubricant formulation knowledge, FN Lube and FN Lube Plus offer a practical, application-focused option that helps protect O-rings during installation and supports long-term material stability."

"As part of Freudenberg's culture of Innovating Together, Klueber Lubrication was pleased to contribute its formulation expertise to help bring new O-ring and seal assembly lubricants to the market," said Steve Tompkins, business development manager, global industry team, Klueber Lubrication Components. "After reviewing the requirements, our engineers and R&D chemists quickly identified the appropriate chemistries to ensure compatibility with the selected elastomers and deliver reliable assembly performance. Helping OEM partners optimize lubrication solutions is at the core of what we do, and we look forward to supporting Freudenberg-NOK Sealing Technologies as they introduce FN Lube and FN Lube Plus to the market."

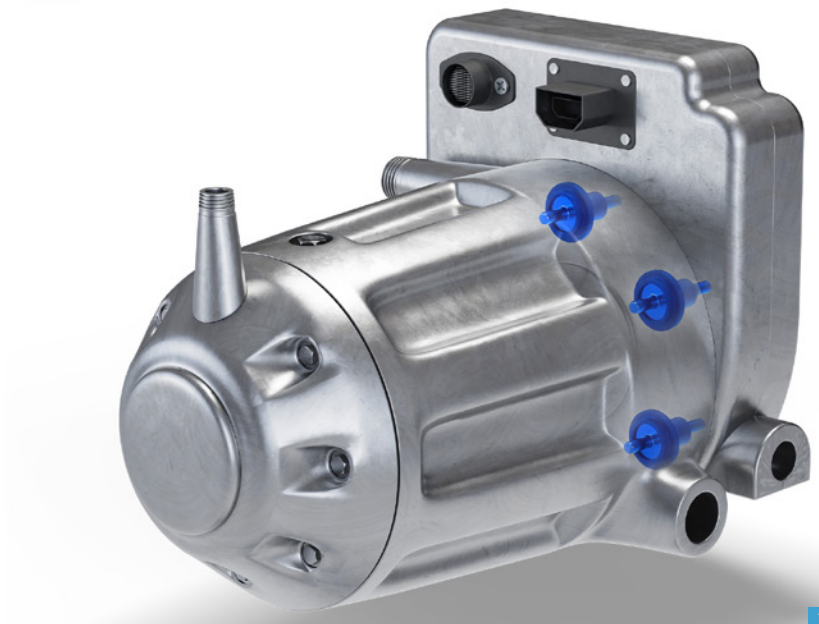
The introduction of FN Lube and FN Lube Plus reflects Freudenberg-NOK Sealing Technologies' approach to providing system-level sealing solutions. The lubricants support the company's holistic sealing system philosophy by complementing sealing materials with lubrication expertise from within the Freudenberg Group.

FN Lube and FN Lube Plus were developed specifically for static seals, especially O-rings, and were validated through laboratory testing.

FST Develops Sealing System for Vehicle Air-Conditioning Compressors

FST has recently developed a new sealing system for busbar sealing in vehicle air-conditioning compressors. This elastomer-based solution withstands test pressures of over 100 bar in leak tests and offers a cost-efficient alternative to conventional glass seals. Designed for CO_2 compressors (R744), it also works well with other refrigerants.

One of the key tasks in this environment is to reliably seal electrical feedthroughs—busbars or pins—in the compressor housing. The tiny CO_2 molecules can enter the elastomer material through permeation. In the event of a rapid pressure, the trapped gas molecules can then expand suddenly and destroy the seal from the inside out—a phenomenon known as explosive decompression. Furthermore, the seals must meet the strictest mechanical requirements.



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FST has specifically developed materials for use in CO2 compressors that resist explosive decompression and offer high media resistance to conventional refrigerants.

FST has the answer to these challenges: a new sealing system that uses a wide range of materials. With this solution, the company draws on its deep materials expertise: It specifically developed materials for use in CO_2 compressors that resist explosive decompression and offer high media resistance to conventional refrigerants. This also involves using elastomer variants that offer a high comparative tracking index (CTI), thus reliably preventing creep currents from arcing at the busbar feedthrough.

The sealing contour was created with an integrated development approach that precisely coordinates manufacturability, component design and functional safety. FST masters this balancing act across the entire value chain: from the development and processing of challenging materials to the design of the suitable seal construction. In leak tests, the sealing system reliably withstood test pressures of more than 100 bar.

"With this change in refrigerants, manufacturers of air-conditioning compressors are facing entirely new sealing requirements. We offer them not just a technical solution to this challenge, but a true development partnership—from the material selection to a sealing contour that is ready for series production," says Christian Jaschke, product manager at FST.

Compared with the glass seals that have frequently been used for this purpose, the new solution offers several advantages: The cost per sealed busbar/pin can be reduced by up to 30 percent, depending on the specific application. As there are typically three busbars per compressor, this creates significant potential savings. The compact design also helps optimize the installation space. This is a decisive factor in the densely packed compressor environment.

As a development partner, FST customizes the material, sealing contour and geometry to meet the requirements of the compressor manufacturer—offering high availability and short development cycles. The basis for this is a broad materials portfolio that covers a temperature range from –40 °C to more than 200 °C and offers high media resistance to a variety of refrigerants.

FST is currently working on concrete development projects with several vehicle compressor manufacturers. The first prototypes have already been validated. The technology is not limited to CO_2 refrigerant compressors. It can also be transferred to other high-pressure applications with different media—an advantage acquired during the intensive seal development for the particularly demanding refrigerant R744.

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Electrification Advancements

Helix delivers high-performance electric powertrains to a variety of industrial markets

Matthew Jaster, Director, Editorial Content

Helix worked on e-drive systems including areas like integration, thermal management and performance optimization. **(All Images: Helix)**

Helix develops motors, inverters, and e-powertrains for a diverse range of industries including automotive, marine, and aerospace. The company's expertise, founded in decades of elite engineering experience, provides a diverse range of engineering technologies from a single-source.

PTE recently caught up with Simon Mead, a member of the technical and business development team at Helix, to discuss the development and manufacturing ingenuity the company brings to the electrification market.

Ambitious Growth

The original company, Integral Powertrain Ltd., was founded in 1999 by former colleagues within the Cosworth Technology business. By 2005, the company had developed two compact permanent magnet motors and established an e-drive systems group. In 2022, the company launched an ambitious growth plan supporting the growing trend of electrification across multiple industrial sectors. The company rebranded as Helix that same year.

Mead has been very enthusiastic about the path various organizations are taking to develop electrification solutions today.

"I lead teams through all aspects of solution engineering—from initial proposals through to design, validation, and production—ensuring every product meets its technical specifications and operational requirements," Mead said. "I provide technical leadership across both motor and inverter projects, overseeing planning, execution, and critical decision-making. My role includes resolving technical challenges that may impact delivery, ensuring engineering excellence at every stage."

Mead's technical background is rooted in powertrain engineering, vehicle calibration, and control systems. He holds a First-Class BEng (Hons) from the University of Hertfordshire and started his career at Millbrook Proving Ground.

"Following a successful industrial placement with them, Millbrook sponsored me through my final year, and I returned to join their engine calibration team working on alternative fuel vehicles. This role gave me broad exposure to a variety of vehicle platforms and customers, laying a strong technical foundation and a 'can-do' mindset that I've carried throughout my career," Mead added.

Mead then joined Visteon as part of the Systems Implementation team, where he was involved in developing and validating ECU core software functions. This included extensive bench testing and environmental validation work—from hot and cold testing to international field trips—ensuring robust performance in all operating conditions.

"In 2008, I joined Helix (then named Integral Powertrain) as a senior engineer, focusing on global vehicle and engine calibration projects for OEMs. I later led the testing and development of SuperGen, our electro-mechanical boosting system. This involved customer development support, climatic testing, and establishing an in-house testing infrastructure. I also built and led a team of development engineers to scale our capabilities," Mead said.

As Helix grew, Mead became one of the first engineering managers, building a development department of 30 engineers covering electromechanical design, development testing, and running the emissions test facility. After successfully developing the team and handing over leadership to his successor, he stepped into the role of chief engineer. Today, he continues to lead multiple customer programs and support the development of e-drive systems.

Electric Hypercars

One of the key highlights of Mead's career has been serving as chief engineer for two iconic electric hypercar programs: the Lotus Evija and Czinger 21C. For these roles, Mead managed the technical delivery of the e-drive systems, working across system integration, thermal management, and performance optimization. Both programs required innovative engineering solutions and the highest standards of precision, pushing the boundaries of electric performance.

"For the Lotus Evija, we deployed a series of four Electric Propulsion Units (EPUs) that brought together a motor, inverter, and transmission. With one EPU behind every wheel, the car could output peak power of 1,500

kW and peak torque of 1,700 Nm, allowing acceleration from 0-60 mph in just three seconds and a top speed of 217mph. A lot of this performance does come down to the sheer power of each EPU, but a lot was also owed to the efficiencies we achieved owing to the system integration. In fact, we were able to achieve a full 20 percent mass saving over comparable e-powertrain layouts that were used in other hypercars," Mead said.

Each EPU brought together a Helix SPX242 motor and a MCU1200-640 silicon carbide inverter, and paired these with an ultra-efficient transmission from their partners at Xtrac. The four-EPU system allowed Helix to deliver precise torque-vectoring to maximize the efficiency of power delivered, all in a very lightweight package that had an efficiency of 98 percent.

"That sort of system integration and depth collaboration with best-in-breed partners is a big part of what makes us succeed in complex hypercar projects. This also rang true in our work on the Czinger 21C—there we paired two variants of our SPX177 motor platform with another Xtrac gearbox and a set of control systems from our friends at New Eagle in the United States. The efficiency, low mass, and sheer power of the EPU which followed was key to the Czinger 21C breaking major industry records—most notably setting the Laguna Seca production car lap record in December 2025.

Additional Projects

Mead works with senior management to identify opportunities for continuous improvement. He leads or supports the implementation of strategic changes aimed at improving engineering workflows, testing methodologies, and team capabilities. Because of the nature of the customers Helix is working with (early adopters of electrification) the company finds that many EPU and integrated e-powertrain projects vary considerably.

"Virtually all of them are underpinned by our motor technology," Mead added. "To deliver this our team draws on decades of experience in thermal and electrical management, along with our own winding and cooling technologies. However, along with the technology itself, we bring to the table a sophisticated simulation and modeling capability along with a great track record with collaborations and partnerships, allowing us to ensure our technology is used as effectively as possible in a vehicle.

The tendency towards integration into all-in-one electric powertrains is going to keep going in the coming years. In terms of reducing the number of parts, exposed connections, and finding ways to optimise cooling loops, EPU integration is going to be impossible to resist. Helix has embraced this, by finding ways to realize EPU solutions and contribute to these projects.

One project, for example, is where Helix has collaborated with high performance transmission specialist Zoerkler to develop and validate a geared EPU for advanced air mobility applications.

Designed to support demanding eVTOL applications, the new EPU can be installed to support propellers in lift, cruise, and tiltrotor configurations. Historically, these high-torque applications have required EPUs set out in a 'direct drive' layout, which demanded wider and higher-mass motors. Thanks to the seamless integration between Helix's motor and Zoerkler's lightweight transmission, however, this new EPU can deliver high torque in a package just 50 percent of the diameter of an equivalent direct drive unit.

Intended to be the first in a family of advanced air mobility EPUs, the initial Helix-Zoerkler collaboration has resulted in a 32.2 kg package, which can deliver 100 kw of power with up to 1,600 Nm of torque when used in a lift configuration. The Helix motor within the EPU can be significantly narrower and lighter than a direct-drive alternative. This unlocks significant packaging opportunities for the EPU, with the initial unit having a diameter of just 26 cm. Combined with the low mass of the package, this means the EPU can significantly reduce nacelle size and drag in eVTOL applications, enabling greater payloads and ranges.

Helix is also continuing to strengthen its position in the UK Defense sector through an extended collaboration with SDO Associates, focused on targeted business development and market engagement. This next phase focuses on turning that insight into meaningful market engagement and commercial progress.

Defense organizations are increasingly prioritizing high-efficiency, low-signature and high-reliability propulsion solutions. Helix's proven technologies, refined through demanding applications in motorsport, aerospace, automotive and industrial sectors, position the company uniquely to address these evolving defense requirements with strong engineering credibility and operational performance.

In the future, Mead plans to seek out new opportunities for the company across multiple industries involved in electrified powertrains.

"In my current role, I serve as the technical lead on multiple projects," Mead added. "I guide cross-functional engineering teams, ensuring robust and innovative solutions are developed and delivered on time."

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Helix has been involved in two electric hypercar programs.

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A Comparative Study of the Effect of Damping in the Dynamic Analysis of Drivetrains for NVH Performance Evaluation

Dr. Saeed Ebrahimi

Dynamic modeling of drivetrains is a highly required and indispensable task in the efficient and reliable design, development, and optimization of many engineering applications and modern vehicles. More recently, it provides a comprehensive framework in the context of NVH analysis for understanding, predicting, and mitigating vibrations and noise, ensuring optimal performance, passenger comfort, and regulatory compliance. As a determinative factor, damping is well known for its role in the design of structures to minimize noise, structural instability, and fatigue failure of components. Damping mechanisms dissipate energy, reducing the amplitude of vibrations and mitigating the risk of resonance. The internal damping of the elements including bearings and supports, shafts and gears represents different levels of energy dissipation under specific running conditions. Incorporating damping into the analysis, particularly in the gear meshes, shafts, and bearings, is essential for accurately predicting the dynamic response. The presence of damping in these components is crucial for enhancing the stability and longevity of the gearbox under varying torque conditions.

Damping in gear meshes primarily arises from three sources: internal hysteresis of gear teeth, lubricant film (oil squeeze), and surrounding structural contributions (Ref. 1). Gear mesh damping plays a critical role in attenuating dynamic responses, especially near resonance conditions. While damping has a minor effect on natural frequencies, it significantly reduces resonance amplitudes and mitigates nonlinear behaviors such as backlash and parametric excitation. Early modeling approaches employed constant viscous damping ratios to capture energy dissipation due to internal and lubricant-induced friction. However, time-varying and nonlinear damping models have been shown to yield more accurate dynamic predictions. For example, Amabili and Rivola (Ref. 2) introduced a single-DOF gear model with meshing damping proportional to time-varying stiffness, while others (Refs. 3, 4) incorporated backlash and impact effects in nonlinear damping frameworks. Li and Kahraman (Ref. 5) developed a viscous damping model derived from elastohydrodynamic lubrication (EHL) theory, linking damping behavior to shear stress and transient contact conditions. Their findings indicate that damping increases with torque and decreases with speed and temperature due to film thickness changes. Further studies (Refs. 6–8) quantified nonlinear damping under varying torque, speed, and lubrication regimes, showing damping ratios typically ranging between 5.3 percent and 8 percent. Yousfi et al. (Refs. 9,10) advanced this by formulating damping in the time-frequency domain using wavelet-based methods, incorporating operating condition variations and demonstrating that damping is inherently dependent on load, speed, and temperature.

This study investigates the influence of internal damping within drivetrain components under varying loading conditions, with a particular focus on its impact on NVH characteristics. A representative two-stage gearbox model is employed as the basis of analysis. Using *KISSsoft,* a forced response analysis is performed to evaluate the dynamic behavior of the gearbox when subjected to multiple excitation sources. This approach offers a comprehensive view of the system's vibrational response, identifying regions susceptible to elevated noise or vibration. The core of the study lies in isolating and examining the damping contributions of bearings, shafts, and gear meshes individually, thereby clarifying their specific roles in mitigating meshing contact forces and bearing reaction forces.

Damping in the NVH Studies

The evolution of damping strategies in drivetrain dynamics has significantly advanced the field of noise, vibration, and harshness (NVH) performance evaluation. From structural damping in EV components to torsional vibration mitigation in hybrid systems, damping strategies are integral to optimizing drivetrain design. Recent studies on this topic have mainly focused on developing advanced damping materials and techniques tailored to specific drivetrain configurations to further enhance NVH performance. From foundational studies to advanced methodologies utilized in simulations, research has continuously improved the understanding and application of damping mechanisms. The reviewed studies underscore the significant role of damping in enhancing NVH performance in vehicle drivetrains.

NVH performance is primarily governed by the interaction between meshing dynamics and the structural response of the drivetrain. Viscous mesh damping is therefore essential in dynamic models, particularly for polymer and lightweight gear applications. In the absence of adequate damping, dynamic excitations from gear meshing lead to increased noise emissions, elevated dynamic loads,

and accelerated wear of gears and bearings. A detailed modeling approach was presented in (Ref. 11), incorporating steady-state dynamics and radiated noise predictions. The influence of harmonic excitations, load torque, and rotational speed on noise and vibration was highlighted.

Bozca (Ref. 12) employed a meshing stiffness-proportional damping model to suppress rattle noise in automotive transmissions through transmission-error-based design optimization. Similarly, Zubik et al. (Ref. 13) quantified the effect of design variables—including torque, imbalance, backlash, and torsional stiffness—on gearbox noise, providing a useful diagnostic and design tool.

Material damping has also been studied extensively. O'Rourke and Grander (Ref. 14) analyzed how material selection impacts gear noise, while subsequent work (Ref. 15) compared the damping behavior of unreinforced, glass, and carbon fiber reinforced nylon 6/6 gears. Sharma et al. (Ref. 16) confirmed that glass fiber-reinforced plastic gears offer superior NVH performance under light-load conditions, making them viable alternatives to metal gears in automotive applications. Additional studies, such as those by Inoue et al. (Ref. 17) and Zhou et al. (Ref. 18) have explored advanced vibro-acoustic models that integrate time-varying damping with structural and acoustic coupling, showing improved prediction accuracy of gear noise radiation. Recent efforts also emphasize the role of variable damping in accounting for operational effects such as load-dependent contact damping and temperature-sensitive behavior in polymer gears (Ref. 19). More recently, the study in Ref. 20 presented some guidelines to properly adjust the gear mesh damping for achieving better NVH characteristics of a powertrain system. This goal was achieved by choosing the gear body material with higher damping properties within the required torque ratio specifications.

Model Setup

The electric axle analyzed in the following is a single-speed, two-stage gearbox powering the front wheels of an electric vehicle, as shown in Figure 1. The analysis is carried out for the nominal input torque of 320 Nm

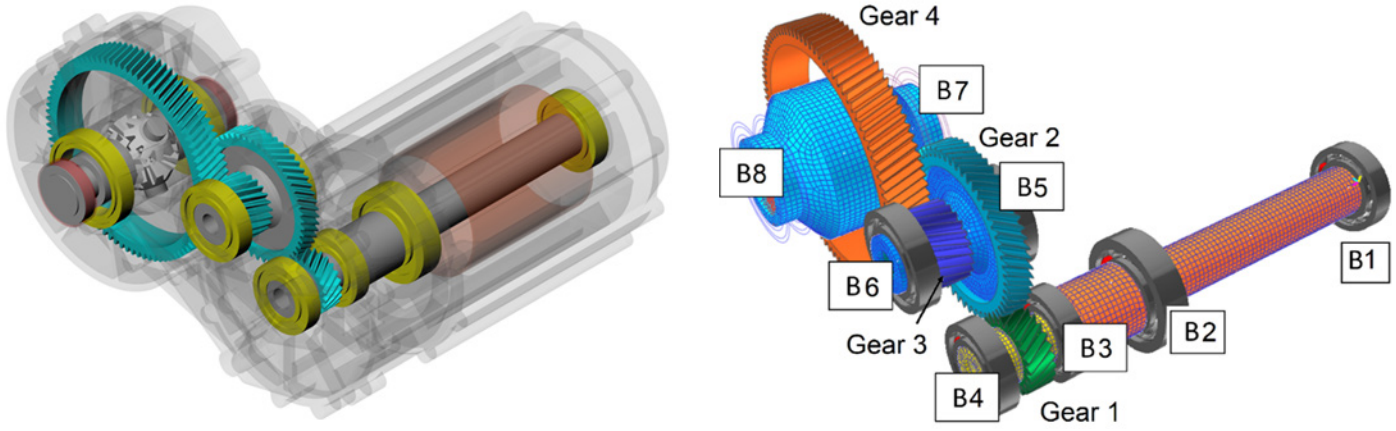

Figure 1—A two-stage gearbox model layout.

Gear parameters		Gear pair 1 (G1-G2)		Gear pair 2 (G3-G4)	
		Gear 1	Gear 2	Gear 3	Gear 4
Teeth number	z [-]	23	53	23	89
Face width	b [mm]	25	23	40	38
Center distance	a [mm]	107.99		150.22	
Normal module	m_n [mm]	2.5		2.6	
Pressure angle	α_n [°]	20		20	
Helix angle	β [°]	30		15	
Profile shift	x^* [-]	0.0163	-0.6682	0.4706	-0.6659
Excitation order	GMF	23		9.98	
Gear profile	$h^*_{fP}/\rho^*_{fP}/h^*_{ap}$	1.80/0.19/1.35		1.60/0.29/1.60	
Contact ratios	$\varepsilon_\alpha/\varepsilon_\beta/\varepsilon_\gamma$	2.048 /1.464/3.512		2.104 /1.204/3.308	
Safety factors	S_F/S_H	2.758/ 1.92	1.296/1.329	1.556/1.188	1.145/1.2890

Table 1—Gear mesh data of the gearbox model.

applied to the input shaft, which is considered here as the reference boundary with a nominal speed of 2,742 rpm. Table 1 specifies the gear mesh data of the gearbox. The microgeometry modifications (Table 2) are designed to optimize the tooth profile for reducing the excitations: helix angle modification and crowning are adopted to reduce the face load factor $K_{H\beta}$ under various load conditions, while tip relief and profile crowning are adopted to eliminate contact shock and reduce the peak-to-peak transmission error. For brevity, the depicted numbering shown in this figure for the bearings and gears is used from now on within the manuscript.

Furthermore, Table 3 shows the bearings specifications for the electric axle. In this Table, following parameters are specified: D_i: inner diameter, D_O: outer diameter, B: width, C: dynamic load rating, C_O: static load rating, P_{dO}: nominal diametral clearance, an P_{aO}: nominal axial clearance.

Contact Analysis

In this study, the gear meshing is considered as the only excitation source. In *KISSsoft,* the contact analysis is based on the Weber/Banaschek approach, which uses analytical formulations for quasistatic analysis by neglecting dynamic effects (Ref. 21). Shaft misalignment is taken into account to adopt more realistic conditions in calculating the excitation forces. As a result of the contact analysis, Figure 2 shows the stress distribution on the tooth flanks for the nominal input torque T=320 Nm. Depicted in Figure 3 illustrates the excitation force and its amplitude spectrum of both pairs. It can clearly be seen that for both pairs, the first two orders of the excitation force are dominant. Therefore, without significant loss of accuracy, only these harmonics are considered in calculating the excitation forces in the forced response analysis.

Modification type [µm]	Gear pair 1 (G1-G2)	Gear pair 2 (G3-G4)
Flank crowning C_β	8	6
Tip relief, arc like (Long) $C_{\alpha a}$	10 Gear 1: d_{Ca} = 69.20 [mm] Gear 2: d_{Ca} = 151.43 [mm]	4 Gear 3: d_{Ca} = 66.39 [mm] Gear 4: d_{Ca} = 241.43 [mm]
Profile crowning C_α	5	8

Table 2—Microgeometry modifications.

Bearing	D_i [mm]	D_O [mm]	B [mm]	C [kN]	C_O [kN]	P_{dO} [µm]	P_{aO} [µm]
B1 (Input shaft)	50	90	20	37.1	23.2	14.5	191.4
B2 (Input shaft)	50	110	27	65	38	14.5	234.6
B3, B4 (Input shaft)	45	85	19	35.1	21.6	14.5	188.3
B5, B6 (Intermediate shaft)	50	90	20	37.1	23.2	6	123.3
B7, B8 (Output shaft)	80	110	20	77	132	0	0

Table 3—Bearings dimensions of the gearbox model.

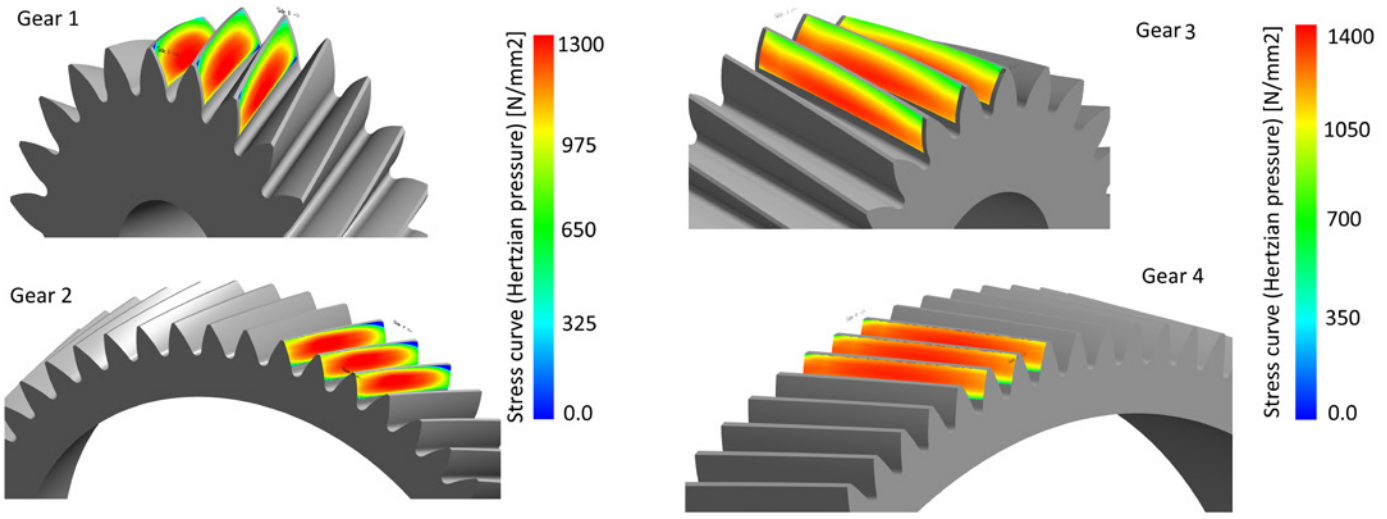

Figure 2—Stress distribution on the tooth flanks.

Modal Analysis

It is well-established in vibration theory that damping mechanisms in mechanical systems are particularly effective at mitigating resonant vibrations when the operating frequency aligns with the system's natural frequency. It is therefore imperative to identify the operating speeds that correspond to the system's natural frequencies, particularly those at which gear mesh excitations impose significant dynamic loads, potentially leading to resonance phenomena. As a result of this fact, it is required to perform a modal analysis to find the system's eigenfrequencies and their corresponding input-shaft speeds, which excite the system at those frequencies. Table 4 shows the results of this analysis in *KISSsoft*. The values of the input shaft speed resulting in the gear mesh frequency of the first gear pair equal to the eigenfrequencies are calculated.

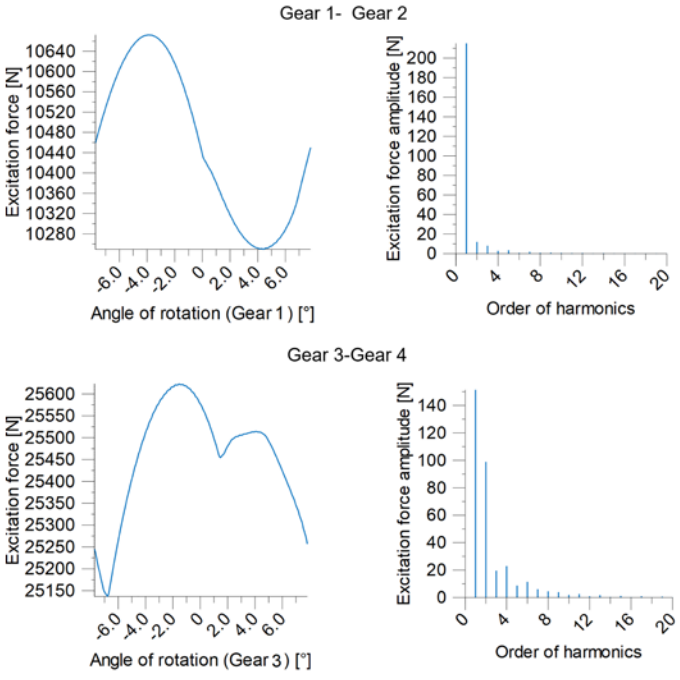

Figure 3—Excitation force.

Forced Response Analysis

In the forced response analysis of the system module, the dynamic response of the transmission subjected to the dynamic loads from different sources of excitations is calculated. Through this module, vibration characterization of the system under periodic excitations can be performed. In this current investigation, the harmonic excitation forces of the two gear meshes are calculated from the static transmission error multiplied by the tangent meshing stiffness. These are represented in the frequency domain and are applied to the system. By solving the linear system of governing dynamic equations for different excitation frequencies, the dynamic contact forces at meshing gear pairs and bearing reaction forces are calculated. As the approach is based on the analytical formulations for vibration analysis of continuous systems, the calculation process is very fast. This allows the engineers and designers to quickly evaluate the gears' properties with respect to the system dynamic excitations.

	Frequency [Hz]	**Speed** [1/min]	**Description**
1	400.9	1045.82	Axial: Intermediate shaft
2	721.3	1882.34	Axial: Intermediate shaft
3	934.6	2438.04	Axial: Intermediate shaft
4	1152.5	3006	Bending YZ: Output shaft
5	1158.7	3022.78	Bending YZ: Output shaft
6	1357.7	3541.7	Bending YZ: Output shaft
7	1712.5	4467.26	Bending XY: Intermediate shaft
8	1793.1	4677.70	Bending XY: Input shaft
9	1862.1	4857.64	Bending YZ: Output shaft
10	2013.9	5253.6	Bending YZ: Output shaft
11	2151.7	5613.16	Bending YZ: Output shaft
12	2454.3	6402.6	Bending XY: Output shaft
13	2468.2	6438.8	Bending XY: Output shaft
14	2870.7	7488.8	Bending YZ: Output shaft
15	2892.5	7545.6	Bending XY, YZ: Output shaft
16	3133.7	8174.86	Torsion: Input shaft
17	3275.0	8543.43	Bending XY: Intermediate shaft
18	3697.8	9646.3	Bending XY, YZ: Input shaft
19	4103.2	10704.11	Bending YZ: Input shaft

Table 4—Eigenfrequencies of the model.

Damping Model

In the forced response module, three different damping sources can be given: structural damping of shafts, gear mesh damping, and viscous damping of bearings and supports, which are defined in the shaft calculation module. The material damping of shafts in torsional, axial (tension/compression), and bending directions is specified with loss factors. The default value is 1×10^{-5} s. This type of damping is based on the Kelvin-Voigt model and is well-suited for the structural vibration analysis of continuous systems (Ref. 21):

$$\sigma = E(\varepsilon + k_w \dot{\varepsilon}) \tag{1}$$

where k_w is the damping coefficient, σ and ε, respectively, denote the stress and strain, and E is the Young's modulus. In this approach, damping is introduced in the equations of motion through complex-valued quantities with the underlying assumption that the vibrations are harmonic. Thus, this damping model can be used in the frequency domain analysis.

Gear mesh damping is known as an important determinative factor in the dynamic response of the system under certain running conditions. With the viscous damping, the effect of the lubricant film, as well as the internal damping of the gear teeth in dissipating the kinetic energy into frictional heat and constraining the motion amplitudes, is modeled. On the other hand, without damping, undesirable induced vibrations generate noise, increase dynamic loads, and potentially damage gears and bearings. Gear mesh damping can be defined as "Constant," "Proportional to average meshing stiffness," or "Proportional to nonlinear meshing stiffness." Typical values for the damping coefficient are between 10^2 and 10^4 Ns/m. In the proportional damping model, the damping coefficient C is calculated from:

$$C = 2\xi k \sqrt{\frac{J_p J_g}{(1/J_p r_p^2) + (1/J_g r_g^2)}} \tag{2}$$

where ξ is the damping ratio, k is the meshing stiffness, J_p and J_g are the mass moments of inertia of the pinion and gear, and r_p and r_g are the base circle radii of the pinion and gear, respectively.

The damping model of bearings in *KISSsoft* is based on the inclusion of separate viscous damping in translational and rotational directions. In this study, the same damping coefficients are used for all bearings. Typical values for the translational directions, C_{ux}=C_{uy}=C_{uz}=10 Ns/m, and for the rotational directions, C_{rx}=C_{ry}=C_{rz}=1 Nms/rad. A higher amount of damping will considerably dampen the vibrations and will lead to an unrealistic response of the system. Therefore, the selection of damping coefficients must be carried out with care.

Dynamic Factor

In the first step of the forced response analysis, the undamped response of the gearbox model to the first harmonics of the gear meshes' excitations under nominal input torque equal to 320 Nm is studied. The goal of this investigation is to check how the eigenmodes of the system contribute to the dynamic gear mesh forces. For this purpose, the speed range of the input shaft is considered from 100 to 10,000 rpm at 200 evenly spaced speeds. After running the forced response, the variation of the dynamic factor as a result of this analysis is shown in Figure 4.

At several speeds, the peak values of the dynamic factor are obvious. These points are associated with the excitation frequencies which are close to one of the eigenfrequencies governed by the gear pairs, see Table 4. For instance, this can be seen especially at S = 8,543.43 rpm, which is in fact the eigenmode No. 17. It is important to notice that two gear pairs have different gear mesh excitation frequencies. Furthermore, the influence level of the eigenfrequencies and their corresponding eigenmodes on the relative movement of the meshing contact points of two gear pairs can be significantly different. Therefore, special attention needs to be paid to finding the relation between the eigenfrequencies and the input-shaft speeds at which a peak value of the dynamic factor is observed. It is important to note that Figure 4 illustrates a qualitative variation of the dynamic factor rather than providing a quantitative representation. This implies that selecting different input parameter settings can lead to varying peak values of the dynamic factor. However, this is entirely reasonable, as the speeds at which these peak values occur remain consistent. This consistency arises because the system's response and, consequently, the maximum dynamic contact force are significantly influenced by the excitation frequencies.

Effect of Damping

In this section, the effect of damping in shafts, gear meshes, and bearings is separately investigated to provide more insight into to their individual effect on the reduction of the meshing contact forces and the bearing reaction forces. The investigation is carried out at the input torque 320 Nm for a wide range of running speeds and damping values. The analysis is followed by considering the case when the effect of damping in all elements is combined.

Damping in Shafts

In the first step, the dynamic factor of the gear pairs for different values of the shaft damping is checked. Figure 5 depicts the effect of torsion, axial, and bending damping on the reduction of the maximum dynamic contact force. The damping effect at higher excitation frequencies with D = 10^{-5} s is more obvious.

Damping in Gear Meshes

In the next step, the dynamic factor of the gear pairs for different values of the gear mesh damping is examined. According to Figure 6, the influence of the gear mesh damping becomes particularly evident when the excitation frequency coincides with one of the system's eigenfrequencies related to the gear mesh compliance, rather than the shaft deformations. This can be seen here again at S = 8,543.43 rpm, which is in fact the eigenmode No. 17, see Table 4.

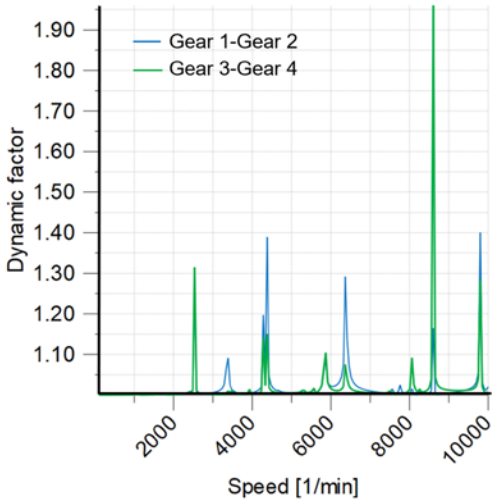

Figure 4—Dynamic factor of the gear pairs in the undamped case.

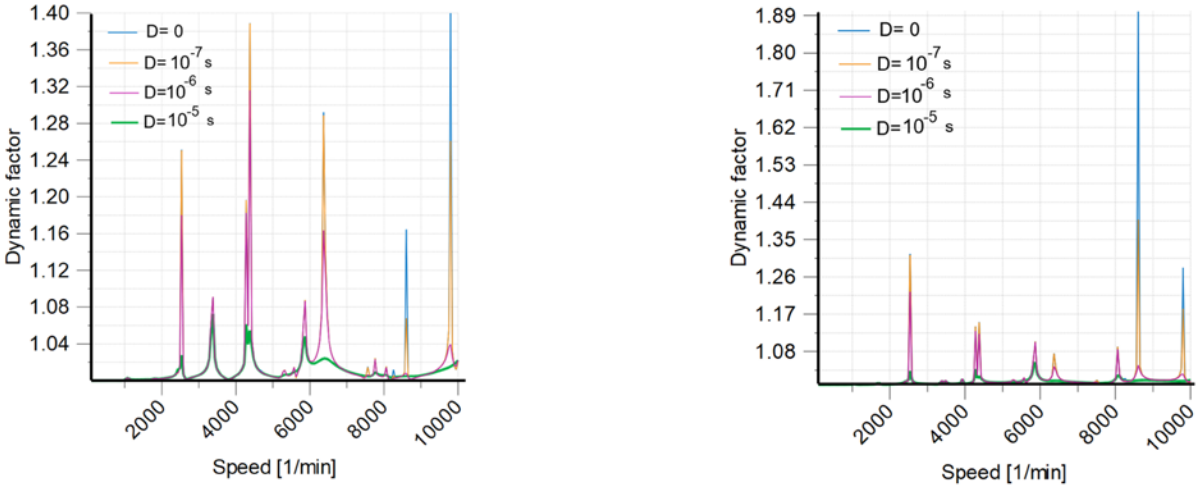

Figure 5—Dynamic factor of G1-G2 (left) and G3-G4 (right) for different shaft damping values.

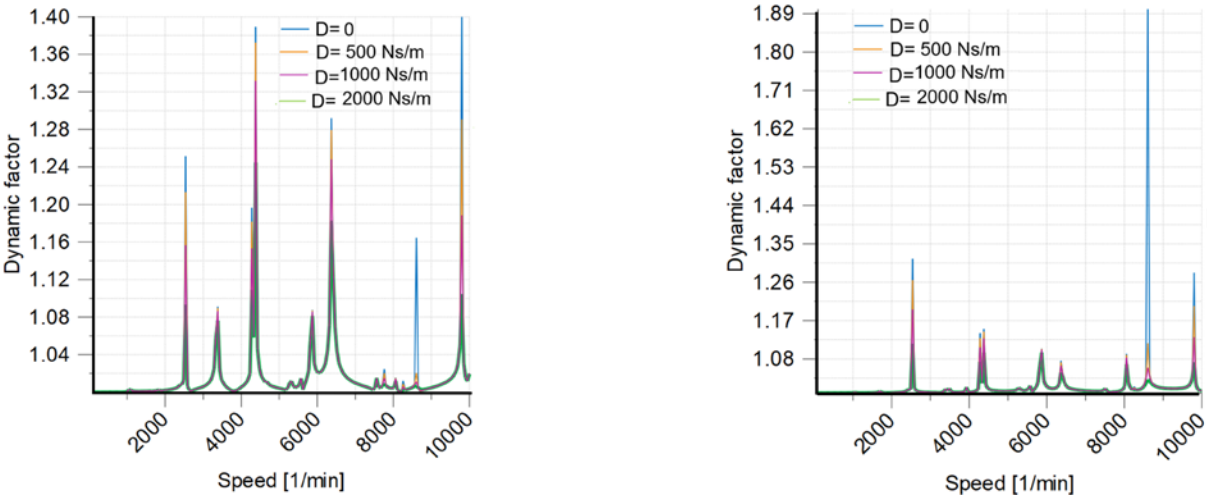

Figure 6—Dynamic factor of G1-G2 (left) and G3-G4 (right) for different gear mesh damping values.

Damping in Bearings

In this section, the effect of damping in bearings is investigated. For this purpose, four different cases, D1 to D4, with their six components of the damping values are considered as given in Table 5. As the result of this comparison, Fig. 7 shows the results. In contrast to the case of gear mesh damping, here the damping effect on the reduction of dynamic factor peaks is evident.

Damping in Different Input Torque Levels

The torque-induced variations in bearing stiffness and gear meshing stiffness significantly influence the system's modal frequencies and vibration modes. For instance, as torque increases, bearing reaction forces intensify, leading to greater bearing deformation. This results in a relative reduction in bearing misalignment, which can affect the dynamic response of the gearbox. Additionally, gear meshing stiffness plays a pivotal role in determining the system's natural frequencies and mode shapes. Studies have shown that variations in meshing stiffness can lead to abrupt changes in coupling frequencies and mode shapes, thereby influencing the dynamic behavior of the system.

Section 7 investigates the impact of damping in shafts, bearings, and gear meshes on the reduction of maximum dynamic gear mesh forces, initially assessed at a nominal input torque of 320 Nm. This section extends the analysis by varying the input torque from 40–320 Nm in 40 Nm increments. This incremental approach provides deeper insights into how torque levels influence the damping of undesired vibrations. A critical observation is that the eigenfrequencies of the gearbox model are torque-dependent, influenced by the torque ratio of the gear pairs. Changes in the input torque alter bearing stiffness values, which in turn affect the modal characteristics of the gearbox. Consequently, the peaks of the dynamic factor occur at different excitation frequencies compared to those observed in Figure 4. Therefore, in this section, the same increments in the damping values of the shafts, gear meshes, and bearings, as described in "Effect of Damping," are considered. The speed range of the input shaft is considered from 100–10,000 rpm at 200 evenly spaced speeds. To assess the effect of input torque variation, a damping measure is introduced here. To calculate this measure, the dynamic factor after applying damping is calculated and subtracted from the associated dynamic factor for the case of undamped case. Therefore, this damping measure is merely the difference between the dynamic factors of the undamped and damped systems. The results are shown in Figures 8–10.

According to Figure 8, at a low input torque of 40 Nm, all three damping levels show a high damping measure, with the highest value observed at $D = 10^{-5}$s, indicating a significant reduction in dynamic forces. As the input torque increases, the damping measure rapidly decreases, stabilizing at lower values beyond approximately 120 Nm. This suggests that at higher torques, changes in the dynamic behavior of the gearbox, likely due to increased bearing stiffness and altered modal properties, reduce the overall effectiveness of damping. A slight resurgence in damping effectiveness is observed between 200 Nm and 280 Nm,

Damping case	[Ns/m]			[Nms/rad]		
	D_{ux}	D_{uy}	D_{uz}	D_{rx}	D_{ry}	D_{rz}
D1	0.1	0.1	0.1	0.01	0.01	0.01
D2	1	1	1	0.1	0.1	0.1
D3	5	5	5	0.5	0.5	0.5
D4	10	10	10	1	1	1

Table 5—Bearings damping specifications.

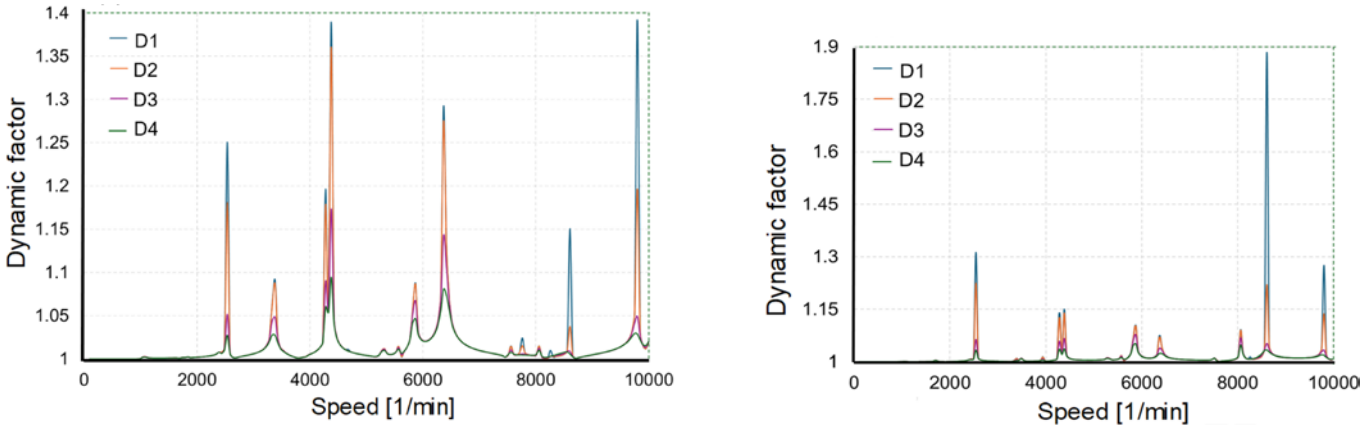

Figure 7—Dynamic factor of G1-G2 (left) and G3-G4 (right) for different bearing damping values.

where the damping measure temporarily increases before declining again at 320 Nm. This reflects the torque-dependent shift in eigenfrequencies, which causes the system to re-enter resonance-prone regions at specific operating conditions. Figure 9 illustrates the damping measure for both gear pairs under varying input torques, considering three levels of gear mesh damping: 500, 1,000, and 2,000 Ns/m. As with previous results, the damping measure quantifies the reduction in dynamic response due to energy loss. At low input torque, 40 Nm, higher mesh damping leads to significantly greater reductions in the dynamic factor, with diminishing returns as torque increases. Beyond 120 Nm, the damping effectiveness plateaus, with all three damping levels converging to similarly low values. A moderate increase in the damping measure occurs between 200–280 Nm, again highlighting the resonance sensitivity due to torque-dependent modal shifts. Finally, Figure 10 shows how varying bearing damping levels (D1–D4) affect the damping measure across increasing input torque. Higher damping values (D2–D4) yield significantly greater dynamic force reduction at low torque (40–80 Nm), while their influence diminishes and converges at higher torque levels. The lowest damping case (D1) remains consistently less effective across all torques.

Combined Damping Effect

Research shows that shaft, gear mesh, and bearing damping interact nonlinearly: an amount of damping that is beneficial in one component can amplify dynamic transmission error or shift critical speeds once the other two sources are active. As a further study, the three damping sources as independent factors are considered to explore their interaction across the whole operating input speed 100–10,000 rpm for the nominal input torque 320 Nm. Initially, the system is evaluated in an undamped state to identify critical speeds where gear meshing excitations

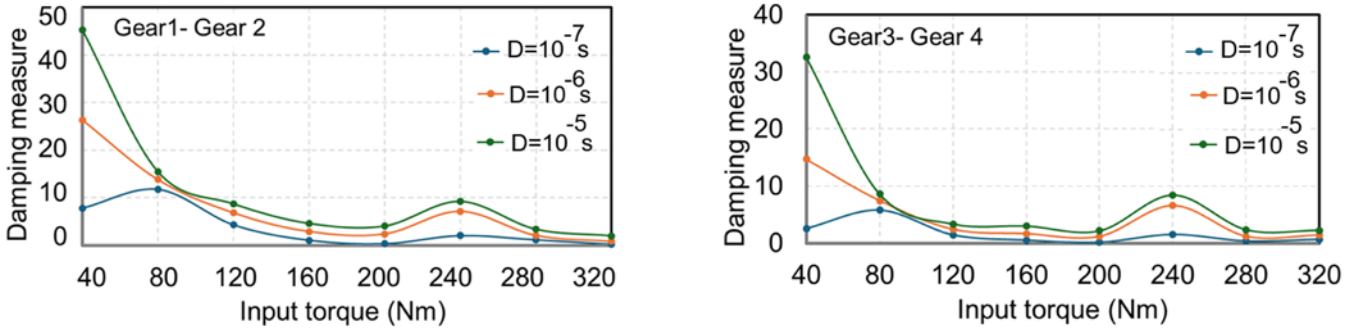

Figure 8—Damping measure for different values of the shaft damping versus input torque.

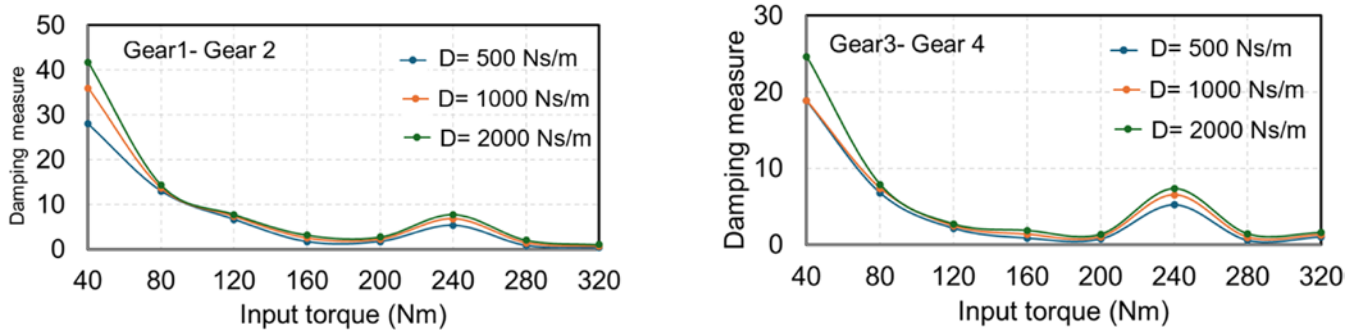

Figure 9—Damping measure for different values of gear mesh damping versus input torque.

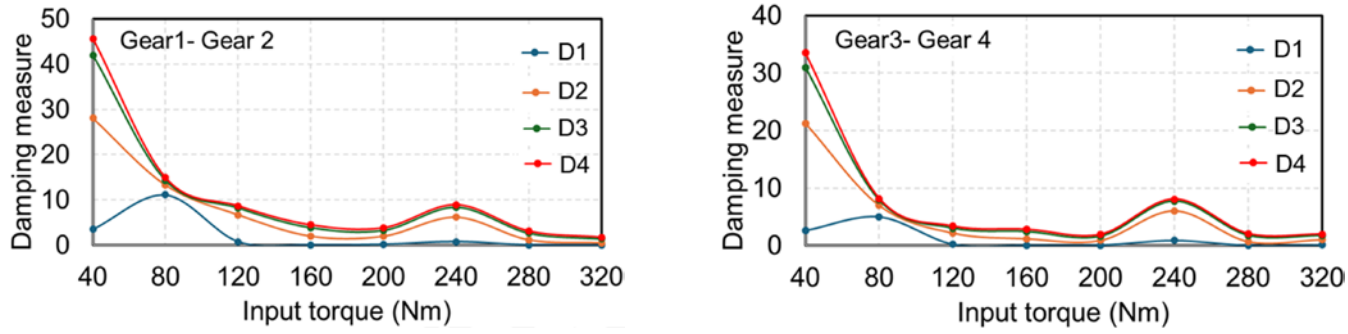

Figure 10—Damping measure for different values of the bearing damping versus input torque.

induce significant dynamic loads on the bearings. This step is crucial for pinpointing operational speeds that may lead to elevated noise emissions from the gearbox housing due to resonance phenomena. Subsequently, damping is introduced into the model with the following parameters: shaft damping coefficient of 10^{-5} s, gear mesh damping coefficient of 1,000 Ns/m, and bearing damping as specified in case D3 (refer to Table 5). The dynamic factor of both gear pairs is illustrated in Figure 11. The difference between the dynamic factors in the undamped (Figure 4) and damped (Figure 11) cases reveals the effect of damping with selected coefficients on the reduction of undesired vibrations at speeds that correspond to one of the eigenfrequencies.

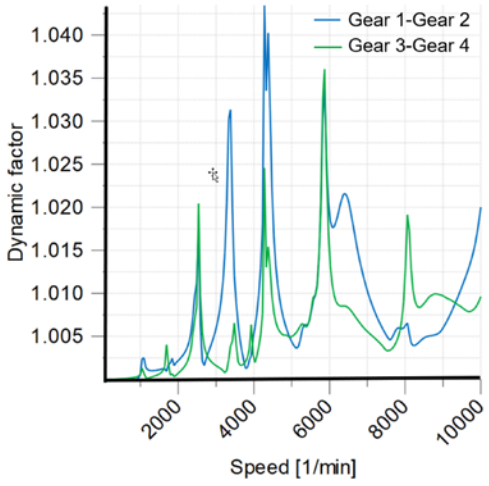

Figure 11—Dynamic factor of the gear pairs in the damped case.

The peak-to-peak amplitudes of the bearing reaction forces are illustrated in Figures 12 and 13, respectively. Comparative analysis reveals that incorporating damping significantly attenuates the peak-to-peak amplitudes, indicating a substantial reduction in dynamic loading. However, in the damped configuration, a pronounced peak in bearing reaction forces is observed at approximately 4,280 rpm, identifying this speed as a critical resonance point. To further assess the impact of this critical speed on the NVH characteristics, the corresponding bearing reaction force data at 4,280 rpm are exported to *RecurDyn*. This data serves as input for subsequent NVH simulations aimed at evaluating and mitigating potential noise emissions from the gearbox housing.

To quantitatively assess the influence of different damping sources on gearbox vibration, the maximum values of the dynamic factor were extracted from the simulation results for the undamped case and for each damping configuration (shaft, gear mesh, bearings, and combined damping). Table 6 provides a compact summary of these peak values for both gear pairs, together with the corresponding absolute and percentage reductions relative to the undamped baseline. This comparison highlights the relative effectiveness of each damping mechanism in reducing dynamic loads.

It can be further concluded from Table 6 that:

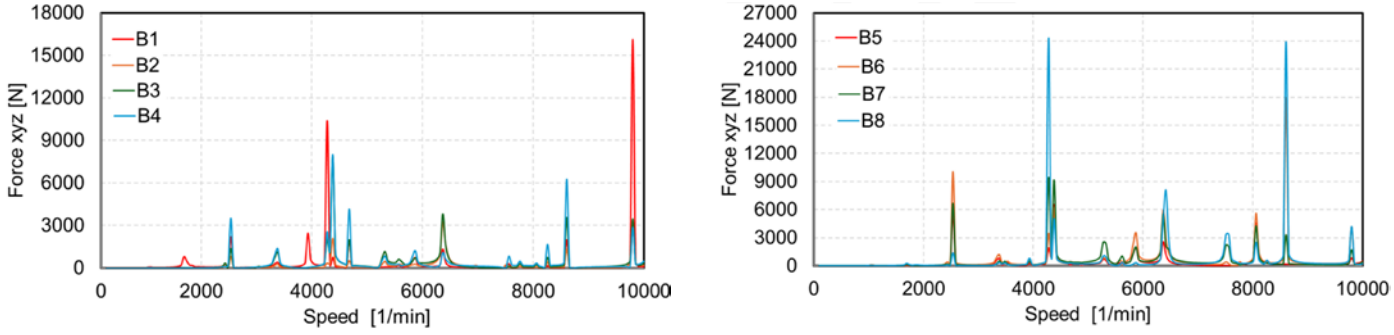

Figure 12—Peak-to-peak bearing reaction force of the undamped system.

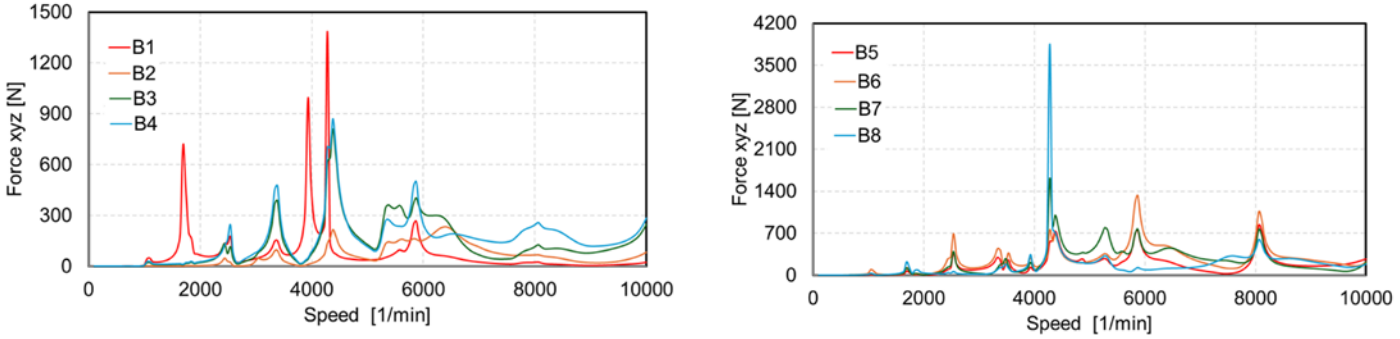

Figure 13—Peak-to-peak bearing reaction force of the damped system.

Gear3–Gear4 benefits most from damping: all three single-source damping strategies give large reductions (~36–44 percent), and combined damping gives the largest (~45 percent). This indicates the problematic peaks for G3–G4 are strongly dampable (likely mesh-related resonances and bearing-transmitted energy).

- Gear1–Gear2 shows moderate reductions:
  - Shaft damping (22.9 percent) and bearing damping (16.4 percent) perform similarly and significantly.
  - Gear-mesh damping has less effect on G1–G2 (5.0 percent), implying those peaks are driven less by mesh-compliance resonances and more by shaft/bearing dynamics.
  - Combined damping produces the best overall result for G1–G2 (25.4 percent), but the extra gain above the best single-source (shaft: 22.9 percent) is modest (~2.5 percent).
- These numbers imply that the bearing damping provides a broad and consistent reduction across the entire speed range, making it the most effective single-location damping strategy.
- Combined damping yields the largest reductions overall, but the interaction is not strongly synergistic, meaning that the combination gives modest extra reduction beyond the best single damping source (especially for G1–G2).

Beyond the quantitative comparison of peak dynamic factors, it is also important to highlight the qualitative differences in how each damping source influences system dynamics. While all mechanisms contribute to vibration mitigation, their effects differ in magnitude, frequency dependence, and consistency. Table 7 summarizes the typical characteristics of shaft, gear mesh, and bearing damping, as well as their combined action, indicating where each mechanism is most effective and how they interact within the drivetrain system.

Overall, the results confirm that shaft and bearing damping are the most effective individual mechanisms for mitigating dynamic loads, while the combined damping configuration provides the most significant overall reduction in dynamic factor, ensuring smoother operation across the entire speed range.

NVH analysis in *RecurDyn*

In the previous section, the forced response analysis of the gearbox model in the undamped and damped conditions was conducted. The analysis yielded the bearing reaction forces data. Subsequently, these bearing forces for both undamped and damped cases (corresponding to the input speed 4,280 rpm) are imported into RecurDyn and applied directly to the powertrain housing at the bearing locations, including the bearings, shafts, and gears from the model. The process commences with configuring the housing parameters and performing a modal analysis to

Damping	Gear pair	Undamped	Damped	Absolute reduction	Reduction
Shaft $D=10^{-5}$ [s]	G1G2	1.40	1.08	0.32	22.86 %
	G3G4	1.89	1.05	0.84	44.44%
Gear-mesh D=1000 [s]	G1G2	1.40	1.33	0.07	5.0%
	G3G4	1.89	1.20	0.69	36.50%
Bearing case D3	G1G2	1.40	1.17	0.23	16.40%
	G3G4	1.89	1.08	0.81	42.90%
Combined	G1G2	1.40	1.045	0.355	25.36%
	G3G4	1.89	1.035	0.855	45.24%

Table 6—Quantitative evaluation of damping effect on dynamic factor from different sources.

Damping	Typical effect	Most effective at
Shaft	**Minor** → **moderate** reduction only for highest D; otherwise small	Evident at *high* excitation frequencies; weak at mesh eigenfrequencies
Gear-mesh	**Strong but localized:** large reduction when excitation ≈ mesh eigenmode; little effect otherwise	Very effective at mesh-compliance eigenfrequencies
Bearing	**Broad and consistent** reduction of dynamic peaks across many speeds	Reduces transmitted bearing forces and housing excitation; best single-location benefit
Combined	**Most robust** overall reduction, but **nonlinear** interactions — possible peak shifts	Best for overall NVH once tuned together; beware of frequency shifts and new interactions

Table 7—Typical effect of damping on the dynamic factor from different sources.

extract a reduced-order flexible model, focusing on the first 200 eigenfrequencies. Time-dependent spline functions representing the bearing forces are then applied at the corresponding housing positions. Before executing the NVH analysis, a dynamic simulation is conducted to determine the housing's response. A critical kinematic parameter for the NVH assessment (the surface velocities at the nodes of the meshed geometry) is calculated. Finally, the equivalent radiated power (ERP), which quantifies the noise emitted from the housing surface to the environment, is computed as follows:

$$ERP = f_{RLF} \cdot \frac{1}{2} \cdot C \cdot \rho \cdot \sum (A_i \cdot v_i^2) \tag{3}$$

Where f_{RLF} is the radiation loss factor, C is sound velocity, ρ is the density of a target material which transfers the noise, e.g., air, A_i is the area on the i^{th} flexible panel of the meshed surface, and v_i is its face normal velocity. Further details can be found in Ref. 22. To clearly demonstrate which parts of the housing's surface emit higher noise, the contour plot of the ERP is very helpful. It can subsequently be used to address the design modifications demanded, such as local stiffening of the housing by means of the ribs, to reduce the noise.

Figure 14 shows ERP contours of both cases. T_{max} denotes the time at which the ERP reaches its maximum value. The maximum values of the color legends are adjusted to clearly show the noise distribution through the housing`s surface. It is noticeable to mention that the variation of the ERP depends on the simulation time and on the locally evaluated position on the housing. It is clearly seen that in the undamped model, the region of the housing close to the bearings of the output shaft has higher ERP values and consequently emits noise to the environment. In contrast, the housing of the damped model has a superior performance with respect to the noise emission. The difference between the ERP values of both models reveals this superiority.

To further clarify the performance of both models, the ERP in time domain is calculated for the surface next to the output shaft by considering the first 20 eigenfrequencies of the housing. The results are plotted in Fig. 15. These results characterize the improvement level of the noise emission from the housing surface based on the damping values selected for this purpose. This in fact implies that proper selection of damping properties leads to a lower level of noise emission by reducing the double amplitudes of the excitation forces and subsequently lower excitations to the powertrain system at critical speeds.

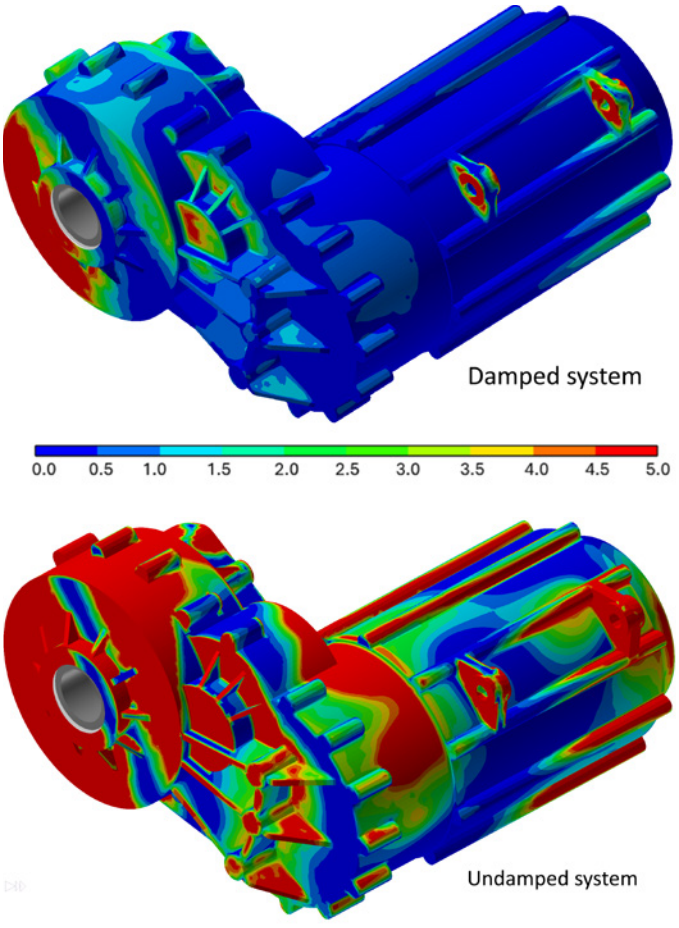

Figure 14—ERP contours at the time with maximum values.

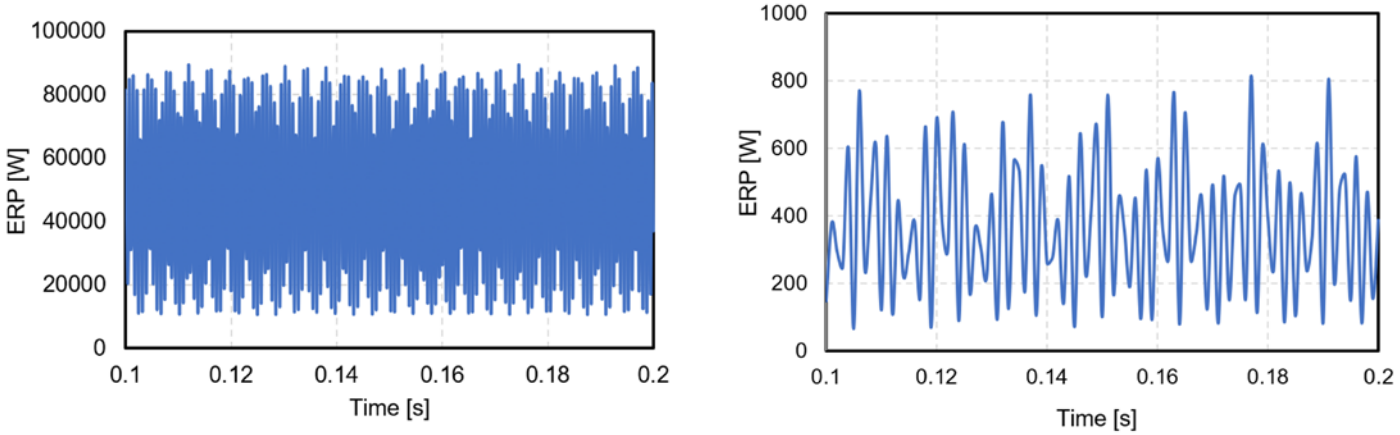

Figure 15—Magnitude of the ERP versus time: undamped case (left), damped case (right).

Conclusion

The effect of internal damping of the elements of a drivetrain under various loading conditions was compared. The forced response analysis of the model was carried out to calculate the dynamic behavior of the gearbox model subjected to dynamic loads from different excitation sources. The effect of damping in bearings, shafts, and gear meshes was separately investigated to provide more insight into to their individual effect on the reduction of the meshing contact forces and the bearing reaction forces. Then, the analysis was followed by considering the case when the effect of damping in all elements was combined. The results confirmed that the damping effectiveness is highly sensitive to input torque. While high damping values are most beneficial at lower torque levels, the system's dynamic response—and hence the benefit from damping—becomes less pronounced as torque increases. Damping is highly effective at low torque levels but becomes less influential as input torque rises. This highlights the need for adaptive damping strategies in gearbox systems that operate under wide torque ranges. The convergence of damping measures across damping levels at higher torques suggests that beyond a certain threshold, increasing gear mesh damping yields minimal additional benefits. This underlines the importance of optimizing damping parameters based on expected operating torque ranges. Future research should focus on developing advanced damping materials and techniques tailored to specific drivetrain configurations to further improve NVH outcomes.

PTE

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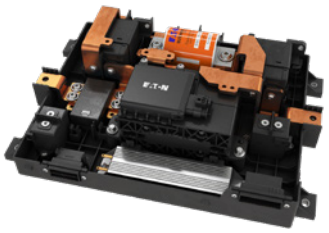
EATON
Combines Mobility Group with Dana Incorporated



Eaton has entered into a definitive agreement with Dana Incorporated under which Eaton will separate and combine its Mobility Group with Dana in a Reverse Morris Trust (RMT) transaction creating a combined company valued at over $10 billion.

The separation of the Mobility Group marks the next step in Eaton's ongoing portfolio transformation and positions Eaton to execute on the Company's 2030 growth strategy. Upon closing of the transaction, Eaton will operate a more focused portfolio concentrated on its Electrical and Aerospace businesses, which are directly aligned to secular growth themes in electrification, digitalization, AI-driven data center buildout, infrastructure modernization, aerospace aftermarket, and defense spending. The recent acquisitions of Ultra PCS and Boyd Thermal further strengthen the Company's strategic positioning, extending Eaton's capabilities in aerospace electronic controls and liquid cooling for data centers.

The separation is expected to be immediately accretive to Eaton's organic growth rate and operating margins upon closing. Eaton expects to deploy approximately $1.1 billion cash distribution from the transaction consistent with its existing capital allocation framework and priorities, including repayment of outstanding indebtedness.

Paulo Ruiz, Eaton chief executive officer, said, "We are pleased to have reached this agreement, which delivers significant value to Eaton and its shareholders, and represents a major milestone in Eaton's 2030 growth strategy to lead, invest, and execute for growth. Eaton shareholders will benefit from the meaningful upside created by the combined company, and the transaction will provide substantial cash value for Eaton to deploy to our highest-growth and highest-margin opportunities. Looking ahead, our portfolio will be closely aligned with the powerful megatrends driving generational growth in our Electrical and Aerospace businesses, and we look forward to continuing our momentum to drive meaningful value for our customers and shareholders."

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SKF
Invests in Startup Anferra to Solve Waste Challenges

Pictured left to right: Thomas Ottink, Max Lumetzberger, Ebba Adolfsson and Mikael Krook. **(Image: SKF)**

SKF has announced a strategic investment, together with Stephen Industries and Chalmers Ventures, in startup Anferra AB to tackle one of the industrial sector's most persistent waste challenges – hazardous steel grinding sludge.

Grinding sludge is a finely powdered mixture of metal particles, abrasives, and contaminated grinding emulsion generated during metal grinding operations. It is commonly classified as hazardous waste with most non-recycled volumes handled through incineration or landfill. Globally, around 12 million tons are produced each year, creating both environmental risks and significant costs for industry. Additionally, variability in sludge composition makes standardized recycling difficult.

Anferra's innovative process converts steel grinding sludge into ferric chloride which is a common chemical agent used for wastewater and water treatment. Another by-product is hydrogen gas which can be further used as an energy carrier, contributing to green energy solutions. This enables a potential net climate benefit of negative 470 kg CO_2-equivalents per ton of sludge (equal to driving an electric car for 7,500 km) compared to conventional disposal.

The process achieves up to 90 percent iron recovery with significantly lower energy demand, effectively transforming a costly waste problem into a valuable resource stream. Most importantly, the technology has the potential to shift grinding sludge from being treated as hazardous waste towards becoming a secondary raw material, aligning with the EU's efforts to harmonize waste regulations and build a stronger market for secondary raw materials.

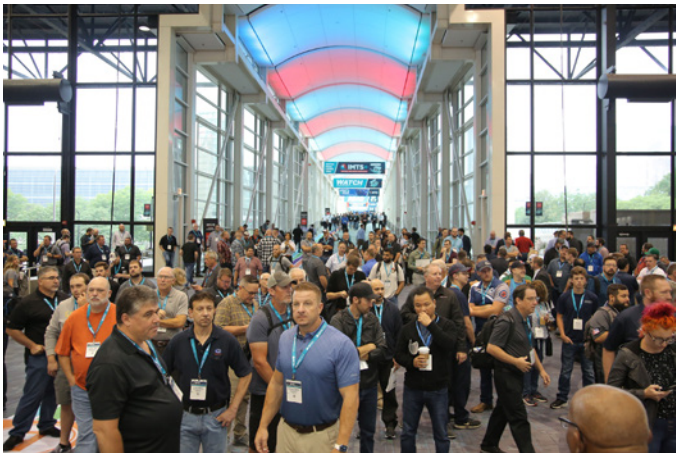
"Grinding sludge is one of the toughest recycling challenges in the steel and bearing industry. Anferra's approach represents a smarter way forward and positions us well to drive circularity and decarbonization. This investment, which is the first initiative coming out of SKF Ventures – SKF's initiative to accelerate new innovations, enables us to influence solution development, positioning SKF as a first mover in circular recycling innovations and creating new value from waste streams," says Mikael Krook, director, SKF Ventures.

"We are very happy to deepen our collaboration with SKF through this investment. SKF has been an important partner since the early stages of Anferra's development and with their support and close collaboration, we can accelerate our journey toward industrial implementation around the world. Our ambition is to significantly reduce the landfilling of grinding sludge while increasing circularity and resource efficiency on a global scale," says Ebba Adolfsson, CEO and co-founder, Anferra.

skf.com

September 14–19

IMTS 2026



The largest manufacturing technology trade show in the Western Hemisphere and among the largest in the world. IMTS (Chicago) attracts nearly 90,000-130,000 attendees from over 112 countries. Pavilions include Gear Generation, Additive Manufacturing, Machine Components, Metal Cutting & Machining Centers, Tooling & Workholding Systems, Controls & CAD-CAM and Quality Assurance. From quality and inspection to process optimization, downtime reduction, cybersecurity, ergonomics, safety, and demand forecasting, the Industrial AI Arena showcases breakthrough tools, prototypes, and platforms – real solutions that redefine what's possible on the manufacturing floor.

powertransmission.com/events/imts-2026

September 22–24

TPS 2026

TPS (Houston) is a vital industry event, offering a forum for the exchange of ideas between rotating equipment engineers and technicians worldwide. Now surpassing 54 years, TPS is known for its impact on turbomachinery, pump, oil & gas, petrochemical, power, aerospace, chemical and water industries through two pathways: an exhibition and a technical program. The TPS technical program is hand-selected by advisory committees made up of key industry players and led by highly respected practitioners and leaders in their fields. Topics cover maintenance, reliability, troubleshooting, instruction on emerging designs, technology, and best practices that include case studies with real-world relevance on problems solved and lessons learned.

powertransmission.com/events/tps-turbomachinery-pump-symposia-2026

September 22–23

RPM Symposium 2026

The RPM (Reliability Process & Maintenance) Symposium (Kalamazoo, MI) is a conference event where end users can network and learn about industrial facilities, reliability, maintenance best practices, electric motor driven powertrains, and IIoT. Topics include pumps, gearboxes, vibration analysis, drives, bearings, motors, couplings, condition monitoring, controls, automation and more. A keynote presentation will examine monitoring, maintenance and repairs. Additional sessions will focus on VFDs, managing critical equipment, AI, gearbox validation and pump failure.

powertransmission.com/events/rpm-symposium-2026

October 18–21

Pack Expo International 2026

Pack Expo International 2026 (Chicago) is where 48,000 attendees from over 40 vertical markets come together with more than 2,600 suppliers to shape the future of packaging and processing. It's the industry's global hub for innovation, collaboration and growth. Attendees represent a wide range of industries, including consumer packaged goods (CPG), life sciences, retail and industrial sectors. Education topics include robotics, cybersecurity, sustainability, digital transformation and more.

powertransmission.com/events/pack-expo-international-2026

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Menacing Drivetrain

Aaron Fagan, Senior Editor

Most power transmission engineers spend their careers making sure mechanisms run quietly, efficiently, and invisibly inside a housing, but Mark Setrakian built one that punches demons on camera. A recent episode of Adam Savage's *Tested*, the YouTube channel run by the former *MythBusters* host, features Setrakian with the original animatronic hand built for Mr. Wink, the cave troll who serves as muscle for the villain of Guillermo del Toro's *Hellboy II: The Golden Army* (2008). Wink's right hand is a giant mechanical fist, a weapon he can launch on a chain, use to grapple or strike a target, and retract into his forearm. Del Toro, who prefers practical effects to CGI whenever physics will cooperate, wanted a prop that actually did all of that on set. The job went to Setrakian, mechanical department chief at Spectral Motion, the Glendale, CA, creature effects studio run by Mike Elizalde. The segment has drawn close to a million views, and anyone who watches it will understand why.

What Setrakian built is a complete, self-contained drivetrain. Servo motors actuate the finger joints through bevel gear sets, which let him turn motion through right angles inside the cramped interior volume of fingers scaled for a troll. Each finger curls, grips, and gestures independently under remote control. Motors, gearing, the chain deployment system, and the retraction hardware all live inside the fist. Nothing is tethered. The design brief, though, inverted the priorities this magazine usually covers. Nobody cared much about efficiency or rated load. The gearing had to be expressive. It had to translate fine servo inputs into believable finger movement at several times human scale, without lurching or stalling, because on film the mechanism is the performance.

The chain drive is the showpiece. Setrakian has called it the chain nozzle: a spinning gear and winding assembly that pays the chain out through an opening in the wrist when the fist deploys as a projectile, then reels it back in. He has recalled that people who saw it assumed he had sourced some existing piece of industrial equipment. Readers here may take that as a compliment. The scariest object in the movie passes for something out of a power transmission catalog.

The fabrication story holds its own interest. The structural and mechanical components were printed on a Stratasys Titan, a large-format FDM machine that in the mid-2000s cost about as much as a house, back when industrial additive manufacturing was still a niche and expensive proposition. Printing bought Setrakian geometric complexity that would have been miserable to machine conventionally, but the parts came off the platter looking like printed parts, layer lines and all. So the team finished them by hand, working every surface with Dremel rotary tools to carve in the battle-worn industrial texture del Toro's creature designs demand.

And the prop still works. Nearly twenty years after fabrication, the servos respond, the fingers articulate, and the chain mechanism runs as designed. For a one-off built under deadline pressure, that longevity says something about the quality of the design and assembly, and it confirms what power transmission professionals already know. Electronics age out through obsolescence and capacitor decay, but a properly meshing gear set just keeps turning.

The full segment (*youtu.be/qKMFdbspHZ4*) is on the Adam Savage's Tested YouTube channel under the title "Adam Savage Shocked by This Practical Effects Prop From Hellboy!" For anyone who has ever wanted to see a bevel gear set and a chain drive get a standing ovation, it is twelve minutes well spent.

spectralmotionfx.com

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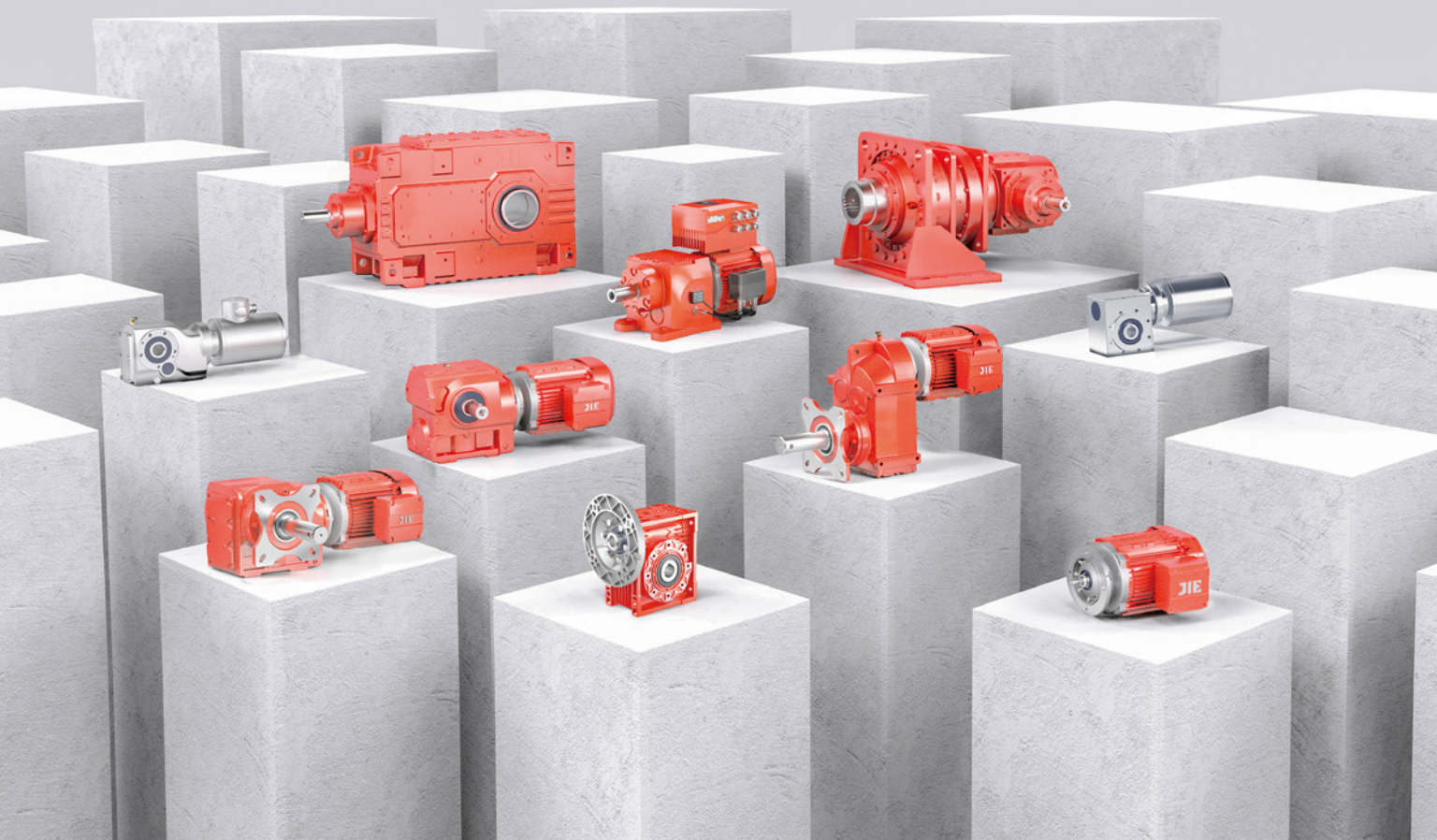

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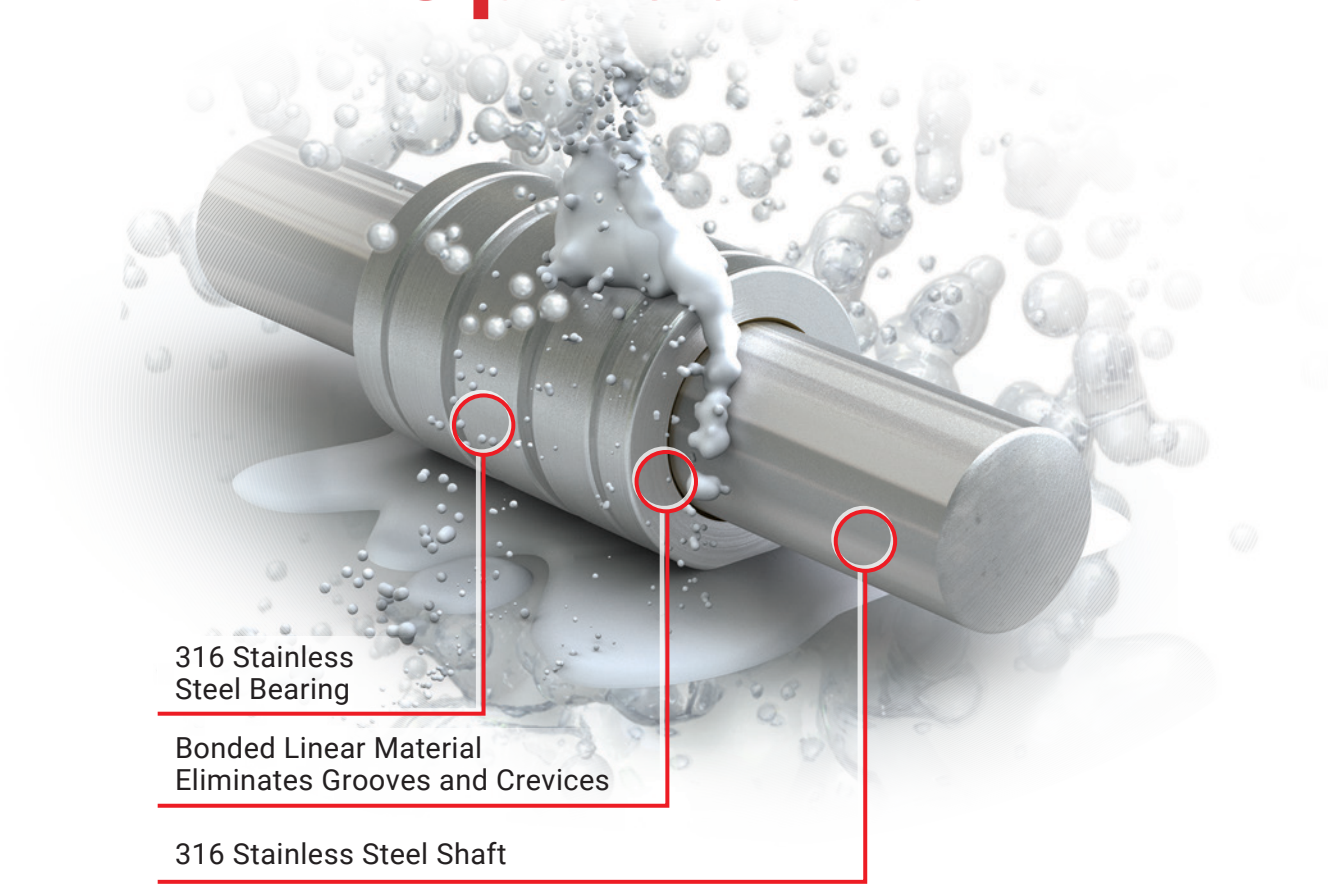

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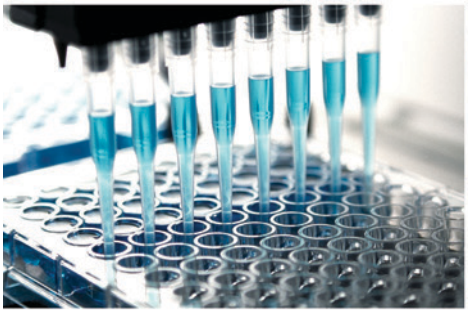

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