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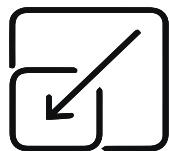
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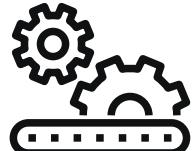
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SEPTEMBER 2024

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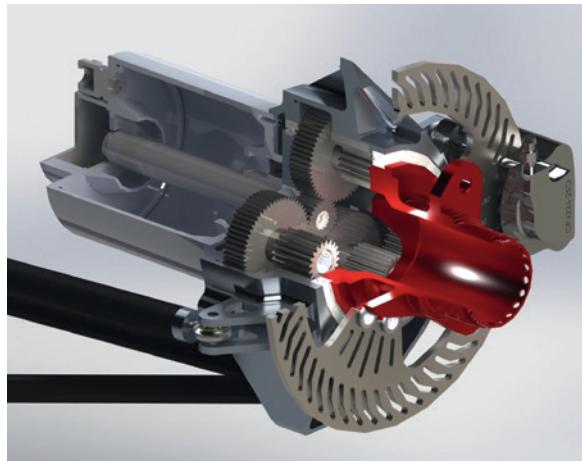
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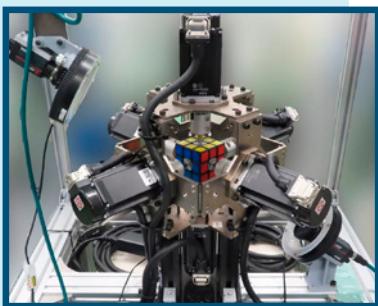
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## PTE REVOLUTIONS

### Purpose-Built Problem-Solving Skills

Mitsubishi Electric Corporation recently announced that it had been awarded a Guinness World Records title on May 21, 2024, for the fastest robot to solve a puzzle cube using the TOKUI Fast Accurate Synchronized Motion Testing Robot (TOKUFASTbot). The previous record of 0.38 seconds was trumped by TOKUFASTbot's time of 0.305 seconds.



[powertransmission.com/blogs/l-revolutions/post/9932-purpose-built-problem-solving-skills](http://powertransmission.com/blogs/l-revolutions/post/9932-purpose-built-problem-solving-skills)

### Hexagon Report Highlights Data, Collaboration and Automation



Every industry faces unique challenges, yet all can benefit from manufacturing's approach to data, collaboration and automation. The Advanced Manufacturing Report, a commissioned study conducted by Forrester Consulting on behalf of Hexagon, offers critical insights that can guide various sectors through their digital transformation journey.

[powertransmission.com/blogs/l-revolutions/post/9927-hexagon-report-highlights-data-collaboration-and-automation](http://powertransmission.com/blogs/l-revolutions/post/9927-hexagon-report-highlights-data-collaboration-and-automation)

## PTE VIDEOS

### Schaeffler Optime Makes Condition Monitoring Easy

Does Schaeffler really help prevent unplanned downtime? In this video, five of their customers from different industries share their experience with the company's industrial maintenance solutions. Optime from Schaeffler allows for comprehensive condition monitoring that is both easy and affordable. Thanks to its simple plug & play installation, Optime allows you to start monitoring hundreds of rotating machines in just a few hours.



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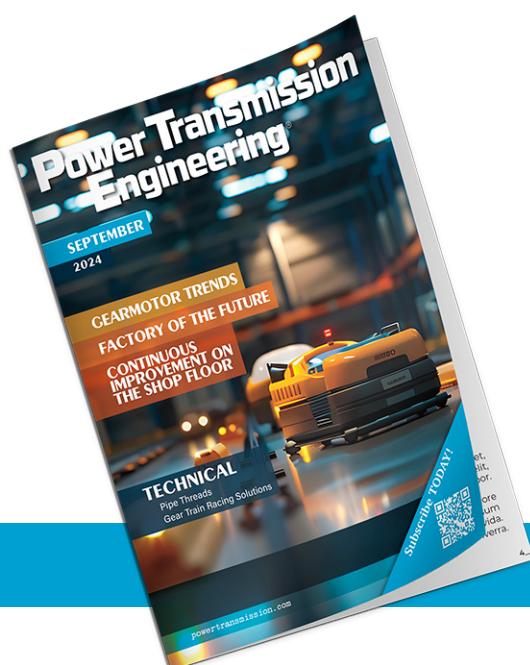
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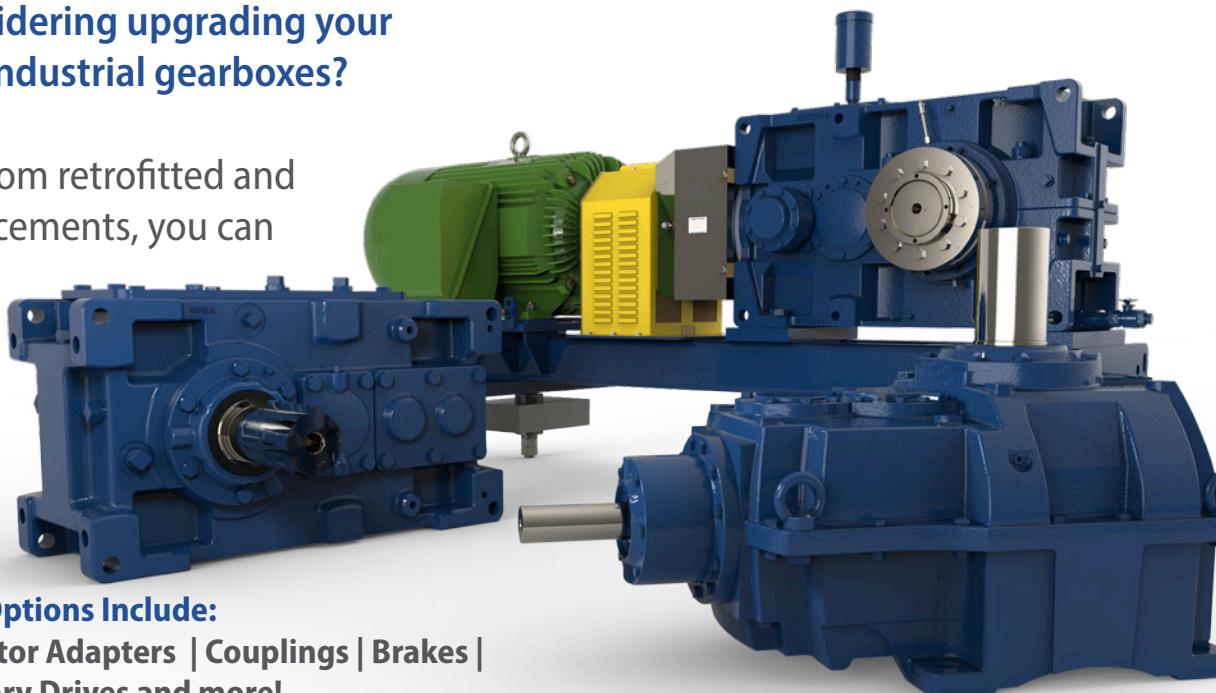
Michael Goldstein founded *Gear Technology* in 1984 and *Power Transmission Engineering* in 2007, and he served as Publisher and Editor-in-Chief from 1984 through 2019. Michael continues working with both magazines in a consulting role and can be reached via e-mail at [mgw42@hotmail.com](mailto:mgw42@hotmail.com).



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# It Feels Like Flying

Today's pace of technological change defies description. I keep hearing that we're in the middle of the next transformative leap in manufacturing, and with all the advances in robotics, automation, condition monitoring and artificial intelligence (AI), it's hard to argue that we're not. But it seems to me the pace of change is too fast for mere leaps and bounds. Industry 4.0 used to be a new thing, but we seemed to have skipped Industry 5.0 and are now talking about Industry 6.0 and beyond. By the time we stop long enough to define where we are, we're no longer there.

Today, it seems our feet can hardly touch the ground. Strap in, because we're headed toward the future, and we're headed there fast.

For example, robotics has long been a staple in manufacturing, but its role expands every day. Robots are no longer just for repetitive tasks and heavy lifting. Today's robots are designed to be more adaptable and intelligent, equipped with advanced sensors and AI capabilities, allowing them to perform complex operations with unprecedented precision and flexibility, often working hand-in-hand (or gripper) with their human counterparts.

Over the past few decades, automation has revolutionized manufacturing by improving speed, consistency, and reliability. But it's becoming far more sophisticated every day, incorporating advances like autonomous vehicles and robotic process automation (RPA). Autonomous guided vehicles (AGVs) and drones are taking over material transportation within factories, minimizing human intervention and reducing logistical bottlenecks.

Additionally, advanced automation systems are becoming integrated seamlessly with AI, enabling real-time adjustments to production processes. This integration allows for dynamic optimization, where production lines can adapt to changing demands or detect and rectify inefficiencies almost instantaneously. As a result, factories will achieve higher throughput and reduced waste, leading to more sustainable manufacturing practices.

In fact, AI is fast becoming the cornerstone of the modern factory, driving intelligent decision-making across all levels of manufacturing, starting with product design and continuing through a product's end-of-life. AI can analyze vast amounts of data generated by sales and ERP systems along with robotics, automation systems, and condition monitoring tools to provide actionable insights. These insights are being used to inform production planning, quality control and supply chain management.

Moreover, AI is facilitating advanced simulations and digital twins, virtual replicas of physical assets that can be used to model and optimize manufacturing processes. By running simulations, manufacturers can explore different scenarios and make data-driven decisions to enhance efficiency and reduce costs.

Go to IMTS in Chicago September 9–14. You'll see all this and more.

But if you can't make it there, all you have to do is read through this issue of *Power Transmission Engineering* to realize that the factory of the future, is not, in fact, in the future. It's here today.

If you're interested in staying informed about the transformative technologies that continue to shape our industry, don't wait for the next giant leap. If you're still thinking about Industry 4.0, you're already way behind. Join us by becoming a subscriber (or renewing if you've already signed up). It's fast, it's easy and it's free. Come fly with us at [powertransmission.com/subscriptions](http://powertransmission.com/subscriptions)

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# RULAND MANUFACTURING

Introduces new bellows couplings with enhanced misalignment capabilities



Ruland Manufacturing continues to expand its motion control coupling product line by introducing bellows couplings with increased misalignment capabilities. These new bellows couplings complement Ruland's existing high-stiffness line by offering equivalent torque with greater misalignment flexibility.

Ruland's bellows couplings are lightweight, have low inertia, and can reach speeds up to 10,000 rpm due to the combination of anodized aluminum hubs and stainless-steel bellows. The thin walls of the bellows flex easily while remaining rigid under torsional loads, allowing the coupling to accommodate all forms of misalignment. The new increased misalignment style features more convolutions than the high-stiffness style, meeting the desired misalignment requirements.

"Designers who require a high-torque, high-misalignment coupling can now come to Ruland if a bellows coupling is their preferred choice," says Bill Hewitson, president of Ruland Manufacturing. "Our rigorous design and physical testing process ensures these couplings exceed market standards. This marks the second expansion of our bellows coupling line in 2024 and reinforces why Ruland is the first choice for OEM coupling designers and our distribution partners."

The new bellows couplings with increased misalignment are available

in clamp style designs, with or without keyways, in bore sizes from 3/16 in. (4 mm) to 3/4 in. (20 mm). A planned increase to 1-1/4 in. (32 mm) will be available before the end of 2024. Ruland manufactures bellows couplings from meticulously selected North American bar stock in the ISO 9001:2015 certified advanced manufacturing facility in Marlborough, MA. The couplings are RoHS3, REACH, and Conflict Minerals compliant.

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

## MESYS

### Version 06/2024 Now Available

A new version of the MESYS shaft and rolling bearing analysis software including new functionality is available. The bearing analysis software allows the calculation of the load distribution within the bearing and bearing life according to ISO/TS 16281 and it is integrated in a shaft system calculation with additional possibilities like modal analysis, strength calculation for shafts and interfaces to gear calculations. Currently the software is used by customers in 32 countries on four continents.

#### General Extensions

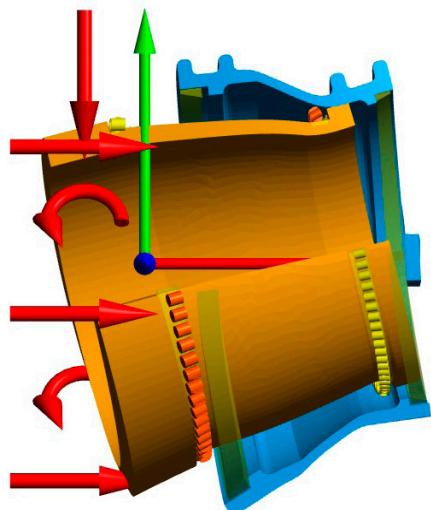
Visualization of 3D-Graphics is now done using OpenGL 4 which allows to draw curves shapes. Cylinders for

shafts or 3D-meshes with quadratic elements can now be shown including the curves shapes.

The bearing databases from SKF and NSK are updated. They include only catalog data. A new bearing database from Napoleon Engineering Services is added and includes encrypted internal geometry for split inner ring three-point bearings. The databases from CSC and HQW/Barden containing internal geometry are unchanged to the previous version. Additional encrypted databases containing internal geometry are available from GMN, IBC, SPL and GRW, but must be requested from the manufacturer.

In the status bar of the software a new switch showing "M" or "A" was added, which allows an automatic run of the calculation after each change of inputs. All results, including graphics are updated. This allows to see quickly what effect variations have on the results.

In the statistical parameter variations in addition to the diagrams for probability distributions now also cumulative distributions are shown.



#### Extensions in the Bearing Calculation

The bearing databases can now include values for preload forces for up to four preload classes for

angular contact bearings. Several new diagrams are added like for contact dimension showing half axes and areas for contact ellipses and for film parameter and lubricant film thickness. The multi-layer interference fit now also includes tolerances instead of a single value for interference.

Until now the profiles for rollers and races had to be defined over the same effective roller length. Now the profiles for rollers and races can be defined over different lengths between effective and total roller length. This allows to take undercut into account on one raceway and a longer contact length on the second raceway.

### Extensions in the Shaft Calculation

In the shaft calculation now several load spectra can be defined and easily selected for the calculation.

The line load distribution of cylindrical gears is dependent on misalignments in the system. It can be flank-line deviations of the gears or parallelism errors of the shafts. These errors can be defined in the system and evaluated with the full system. This is also the most accurate approach. A simplified approach can be used like ISO 6336 method B for face load factor, where the misalignments are only considered in the gear contact and not on the shaft deflections. The line load is calculated with an additional misalignment 'fma' considering only the gear mesh stiffness with constant tilting angles of the gears.

A shaft is stiffened by a gear body and the gear body geometry also affects the line load distribution in the gear contact. The two options for stiffening of the shaft by the gear are extended to five options now and can use a 3D-FEA mesh to consider the gear body stiffness. A simple rotation symmetric gear body geometry can now be defined at the load element, for complex geometries still the 3D-elastic parts option can be used.

For sections on the shaft previously six stiffness values were provided for the three displacements and three rotations. Now full stiffness and compliance matrices are available in the result tables. In addition to cut views with a quarter cut-out now also a 180° cut-out is possible and custom cut directions can be defined for imported housings. A cut-view of imported 3D-elastic parts is now also shown in the 3D-views.

The CAD-Import for 3D-elastic parts now saves the imported STEP file within the calculation. It will then be used for remeshing and for 3D-export of the system. To reduce the file size or to avoid sharing the CAD file, the saved CAD file can be removed under settings of the 3D-elastic part.

The surface mesh can be generated as a second order mesh on the CAD import now. This improves the accuracy if a second order mesh is selected for calculation afterwards. All nodes will then be on a cylinder, not only the corner nodes of the elements. The disadvantage is the increased file size. A second order mesh requires four times the size of a linear mesh. For large element sizes the outside geometry still looks like a circle instead of a polygon in case of a second order mesh generated on the import.

A 3D-elastic part can now be connected to an 1D-shaft using elastic surfaces instead of just using connections by central nodes. For bearings with elastic rings on a 3D-elastic parts also additional axial contacts are considered using elastic faces instead of central nodes.

[mesys.ag](http://mesys.ag)

## SCHAFFLER Optimizes wind turbines using closed-loop engineering

Wind turbines have a decisive role to play in the expansion of renewable energy. Schaeffler is leveraging closed loop engineering to play a key role that goes far beyond the pro-

vision of bearing solutions for on- and offshore wind. Working in close partnership with turbine and gearbox manufacturers, the company supports wind turbine development through state-of-the art system simulation, realistic test-bench testing, and field measurement campaigns.

"This closed loop engineering approach enables us to play a decisive role in further developing wind turbines and making them more cost-effective and efficient," explains Bernd Endres, vice president regional business unit wind at Schaeffler. "As the term 'closed loop' suggests, the insights gained through simulation, testing and measurement are fed back into the product development process."

Schaeffler is presenting its closed loop engineering approach along with various other solutions and services for the wind energy industry under the motto "Driving Wind Energy Together. Innovative. Reliable. Cost-effective." at the WindEnergy Hamburg trade show from September 24–27, 2024 (Hall B5, Booth #333).

### System Optimization Through Advanced Simulation Programs

Optimized bearing design is fundamental to maximizing wind turbine reliability and cost-effectiveness in operation. Hence, Schaeffler's closed loop engineering approach starts with state-of-the-art calculation and simulation programs. These are specialized multi-body simulation programs that generate highly realistic dynamic models of individual rolling bearings, adjacent structures, and even entire drivelines. The simulations use machine learning and cloud computing to optimize both the mechanics and the dynamics of wind turbine bearings. As well as classic rolling bearings, Schaeffler can run calculations and simulations for the new hydrodynamic plain bearings that it developed for wind turbine gearboxes and that are now in series production.



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## Powerful Test Facilities for Bearing Systems

As the next step in its closed loop approach, Schaeffler subjects its wind turbine bearing systems to comprehensive testing, to ensure reliability. Since 2011, it has been using its "Astraios" test bench for large-size bearings to gain important insights into the loads and moments affecting wind turbine drivetrains. This facility enables the company to rapidly test and validate newly developed products under realistic conditions.

Schaeffler is currently engaged in a major expansion of its bearing testing capacity. To this end, a new test facility for wind turbine main bearings is currently being built in Lindø, Denmark, in cooperation with LORC (Lindø Offshore Renewables Center) and R&D Test Systems. The facility should be ready to run its first test programs by the end of 2025. Schaeffler played a major part in defining the specifications of the test facility and will use it to test its main shaft bearings in cooperation with turbine OEMs.

## Data from Field Measurements Fed Back into Simulation

The third step in Schaeffler's closed loop engineering approach, alongside simulation and testing, is field monitoring. This involves Schaeffler experts monitoring prototype turbines in field mea-

surement campaigns. The results of these measurements are then used either to validate the original design parameters from the simulation process or to initiate further optimizations. The focus here is on the drivetrain, particularly the main shaft bearing system, as this is where all the forces exerted on the turbine add up. These early, design phase measures enable Schaeffler to minimize system failures and the associated costs while maximizing system robustness.

The closed loop approach also means that Schaeffler undertakes its bearing optimization work in partnership with its customers. In this way, Schaeffler is helping to lower the levelized cost of electricity and drive the expansion of renewable energies.

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

## SKF Provides components for telescope system

SKF is providing key components for the next generation Very Large Array (ngVLA), a \$2 billion telescope system that aims to peer deeper into the universe than ever before.

The U.S. National Radio Astronomy Observatory (NRAO) is planning the ngVLA to replace the highly successful Very Large Array, a group of 28 radio telescopes that have been operating in the New Mexico desert for more than 40 years. The

new, more advanced and ambitious project will include 244 antennas arranged in a series of spiral arms on the current VLA site. Another 30 dishes will extend these arms more than 1,000 km across the Southwest, with additional dishes positioned across the continental United States, Hawaii and Puerto Rico to create a truly continental virtual telescope.

SKF technology will be integrated into the elevation control system of the prototype ngVLA antenna currently under construction by mtex antenna technology gmbH, a specialist in advanced radio telescope projects based in Germany.

SKF and mtex have worked together for more than two years and defined a bearing solution that could meet the telescope's requirements for high load capacity, low friction and extreme precision. In use, the system must be able to point the antenna with an accuracy of less than one thousandth of a degree, while continuously adjusting its position to compensate for the effects of wind and the Earth's rotation.



The prototype elevation control system includes two 720 mm SKF spherical roller bearings manufactured to unusually high accuracy to minimize thickness variations that could cause the antenna to wobble during motion. The bearings are mounted on tapered sleeves that allow the final clearance to be precisely adjusted during assembly to further reduce radial runout during operation. Finally, an SKF automatic lubrication system will minimize stick-slip and reduce friction and wear during telescope operation.

The prototype antenna will be installed at a test site in New Mexico later this year, before undergoing extensive testing over the next 18 months. If all goes according to plan, the NRAO will begin large-scale production of antennas for the ngVLA project in 2027, supporting a construction process that is expected to take a decade.

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

## THOMSON INDUSTRIES

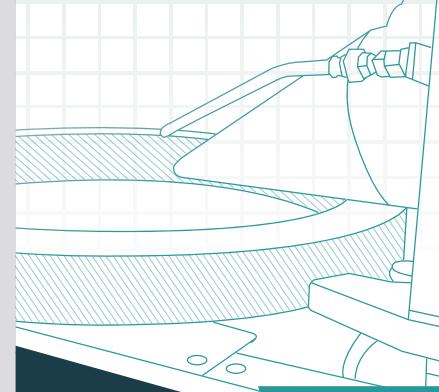
Adds controllability to long-life electric actuators

Thomson Industries, Inc. has added advanced controllability options to its Electrak LL line of long-life electric linear actuators. In addition to the 600 km of maintenance-free life and 100 percent duty cycle performance inherent to all the Electrak LL models, machine designers can now get absolute position feedback, CAN bus integration, reduced current flow and higher speeds.

"OEM designers using our long-life actuators in applications that might otherwise require hydraulic or pneumatic systems can now also get more control over the position, load and speed. Our new configuration options enable them to move actuators into position more smoothly, know instantly where they are and use that data in motion profiles," said Travis Gilmer, product manager—linear actuators at Thomson.

Key to the Electrak LL's long-life architecture is a brushless motor, a high-load ball screw assembly, a brake solution that does not wear, and IP69K (static) and IP66 (dynamic) compliant sealing. This combination enables duty cycles of up to 100 percent, up to 600 km of travel life, and up to one million cycles—more than ten times that of electromechanical actuators without these features. The new configuration options for the Electrak LL augment its industry leading

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durability with advanced control, integration, higher voltage and higher speed options.

Instead of calculating position from sensors and encoders, users of Electrak LL actuators can get direct absolute position information by programming its embedded microprocessor to count mechanical turns within the gearbox. This enables an instantaneous, exact reading of position for the use of advanced control logic. A design engineer might, for example, use it to synchronize movements of multiple cylinders to defined positions at designated speeds.

Another advantage of absolute position feedback is that it will be calibrated during assembly and does not need to be recalibrated. This improves efficiency

in applications such as railway and agricultural controls where actuators are usually shut down for extended periods of time when the vehicles are not in use. If the position is not absolute, the actuator will need recalibration on restart. Also, the Electrak LL absolute position measurement does not require mechanical contact, which minimizes wear to the system.

Advanced control sequences need a way to share exchange instructions and data, and Thomson long-life actuators provide this as well. Electrak LL users can build applications around either CANopen or SAE J1939 communications. This provides maximum flexibility to integrate actuators with other components or productivity and business applications.

High-duty-cycle applications, such as mobile robots, are usually battery powered as low current draw can be an advantage. Electrak LL users can now meet application power requirements by configuring their systems with a 48 V power supply. In comparison to the 24 V version, the 48 V will reduce resistive power losses, which enables thinner, less expensive wiring.

Thomson also has added a 2 kN (450 lbs.) load option to the Electrak LL. This optimizes the actuator to handle higher speeds with longer service life.

Thomson Electrak LL long-life actuators with new controllability, CAN bus, 48 V voltage and 2 kN load options are available immediately.

[thomsonlinear.com/electrak-ll](http://thomsonlinear.com/electrak-ll)

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Siemens Digital Industries Software offers *Zel X* software, a next generation browser-based engineering app for streamlining manufacturing and shop-floor operations. *Zel X* consolidates software for manufacturing, operations, col-



laboration, design and simulation into a comprehensive, yet lightweight browser-based solution.

"The manufacturing industry is demanding open, flexible toolsets that are not only laser focused on their needs but are instant on and accessible anywhere they need them," said John Miller, senior vice president, mainstream engineering software for Siemens Digital Industries Software. "Zel X combines Siemens' expertise and technology leadership across the manufacturing, operations, design, simulation and collaboration domains to deliver next generational capabilities through the browser that our customers are demanding. Zel X supports their rapidly changing businesses with instant-on toolsets that offer them the whole process coverage they need to innovate and gain competitive advantage."

Sharing a common architecture with NX, and delivered as part of the *Siemens Xcelerator* platform, Zel X delivers real-time monitoring and tracking of project and job statuses with interactive dashboards, and shop floor specific instructions with notifications available on any device. Zel X also includes tools to help with automated request-for-quote (RFQ), both inbound from customers and outbound to suppliers.

[newsroom.sw.siemens.com/en-US/siemens-rl24-zel-x/](http://newsroom.sw.siemens.com/en-US/siemens-rl24-zel-x/)



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# Massive Machinery and Innovation at MINExpo International 2024

## All aspects of mining industry converge in Las Vegas

Matthew Jaster, Senior Editor

MINExpo boasts 1,900+ companies involved in the global mining industry. Opening sessions allow the industry to come together to debate global challenges, market fluctuations and the future of mining. Resources include exploration, mine site development, open pit mining, underground mining, smelting and refining, processing and preparation and reclamation. Here's a sample of the companies exhibiting and the products/technologies they will be featuring in Las Vegas from September 24–26, 2024.

### Ferry-Capitain (Booth #5517)

Ferry-Capitain is a key contributor to the AGMA Mill Gearing Committee responsible for the development of design rating standards for open gearing used in rotating (cylindrical shell and trunnion supported) equipment applications. With direct experience in the casting of alloyed steel and ductile iron gear materials, Ferry-Capitain developed through extensive metallurgical research what quickly became the most recognizable open gearing material grade: FerryNod



*FerryNod offers an open gearing material grade for large-scale, industrial applications such as ring gears for horizontal mills and kilns.*

FerryNod is a high-performance alloy engineered for durability, strength, and reliability in heavy machinery applications across the mining, cement, and power generation industries. With hardness levels spanning from 180 to 340 BHN, FerryNod meets and exceeds ANSI/AGMA6014-B15 standards for allowable contact and bending stresses.

Thanks to the presence of graphite nodules, FerryNod exhibits inherent lubricity, reducing friction and wear. Unlike steel, where cracks propagate freely, FerryNod allows for serviceable repairs with minimal fatigue strength loss.

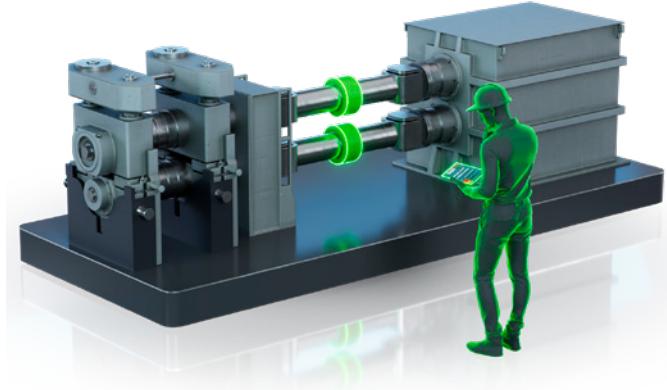
Widely recognized by OEMs and end users for being cost advantageous and for its shorter manufacturing cycle time, FerryNod is the ideal choice for large-scale, demanding industrial applications such as ring gears for horizontal mills and kilns, where reliability and performance are critical.

[ferrycapitain.fr](http://ferrycapitain.fr)

### Regal Rexnord (Booth #10437)

The toughest applications deserve the toughest solutions. Regal Rexnord brands have over 125 years of experience customizing the power transmission solutions for surface and underground mining applications and equipment such as conveyors, electric rope shovels, draglines, grinding mills, slurry pumps, and other mining applications. Proven and reliable components and powertrain solutions keep extraction, transportation, and processing operations efficient and profitable. Carefully designed to withstand vibra-

tion and overload, Regal Rexnord's power transmission components include a wide variety of torque limiters, backstops, couplings, caliper and thruster brakes, clutches, geared motors, gear drives, mounted and unmounted bearings, roller and steel chain, belts, sheaves, and more.



**Perceptiv** offers next generation solutions for condition monitoring and predictive maintenance.

Regal Rexnord's engineering and supporting services aim to reduce downtime and lower total cost of ownership. The powertrain solutions team will meet customers on-site to custom build end-to-end systems optimized to meet an application's unique needs. Regal Rexnord's Perceptiv portfolio of IIoT sensors and systems track oil, grease, and hydraulics on heavy-duty brakes and backstops, while vibration monitoring catches potential clogs on shaker screens. For commissioning and beyond, Regal Rexnord industrial services teams keep critical equipment functioning properly. Coupling recertifications, gear reducer repairs and rebuilds, and on-site walkthrough gap analyses are just a few of the services offered.

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

### **Bosch Rexroth Corp. (Booth #10347)**

Bosch Rexroth will demonstrate a diverse offering of mobile hydraulic solutions at MINExpo this year, including advanced valves, controllers, sensing joysticks, and piston pumps that are critical components in electrifying the future of large mobile machinery like excavators, drills, and cranes. Many of these solutions are part of Rexroth's electronic open circuit system (eOC) and can be integrated with our advanced telematics monitoring system, BODAS.

Additionally, Hägglunds, a brand of Rexroth, will showcase its newest direct drive motor, Quantum Power. The most compact motor within the Hägglunds portfolio, Quantum Power boasts an efficiency up to 170 rpm and 350 kNm of torque. The applications for this



**Hägglunds** Quantum motors are suitable for both mining and mobile applications.

solution are extensive, including brakes, valves, speed sensors, and shaft adapters. Come by the booth for an in-person demonstration of this product, along with the full line of Hägglunds and Bosch Rexroth solutions.

[boschrexroth-us.com](http://boschrexroth-us.com)

### **SEW-Eurodrive (Booth #8695)**

SEW-Eurodrive announces the launch of XMiner Industrial Gear Units, specifically designed for the rigorous demands of mining and aggregates applications including conveyor systems, crushers, and apron feeders. Built on the trusted X.e series platform, the XMiner units are now available with local engineering, stocking, and assembly in Wellford, South Carolina, ensuring quick and reliable support for North American customers. The XMiner Industrial Gear Units are tailored to meet the high-performance requirements of mining operations.

The alignment-free plug-and-play design simplifies installation, while the Taconite heavy-duty sealing system for abrasive environments like mining and cement, features grease purge-able labyrinth seals and laminar rings to prevent debris from entering the gear unit.

"We designed our XMiner Industrial Gear Units to reduce the hassle of machine design, installation, operation, and maintenance of heavy-duty conveyors. The XMiner's design ensures a quick and flexible setup, significantly reducing downtime. This product meets the mining industry's rigorous demands while enhancing operational efficiency," said Austin Burdette, product and business development manager – industrial gearing, SEW-Eurodrive.

The XMiner features gear ratios ranging from 6.3–450 in 2, 3, and 4-stage configurations with output torque to 1,637,389 lb-in in multiple finely-stepped frame sizes.



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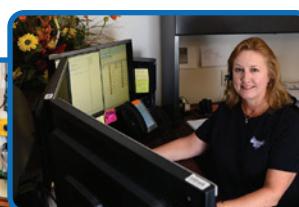
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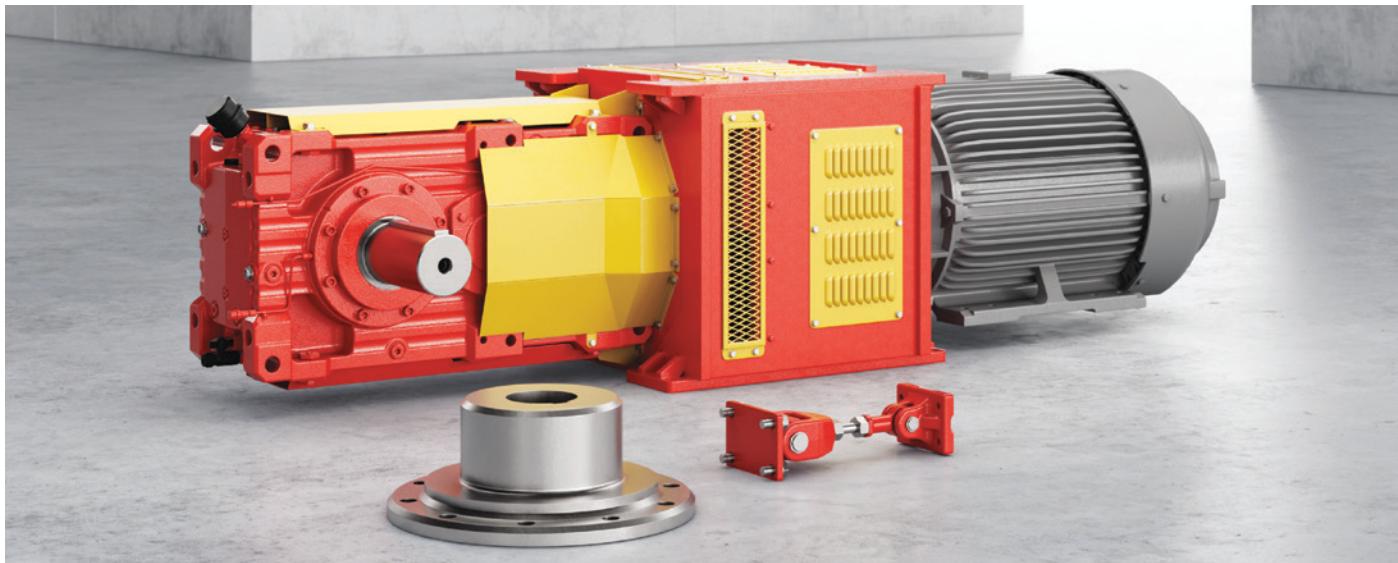


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# Technology and Reports Help Optimize Operations

## Real-Time Alarms and Historical Data Drive Better Processes

Cody P. Bann and David Nolan,  
SmartSights



**HMI is a highly visible and critical component of the SCADA system. Over time, HMI has shifted from individual machine interfaces to higher level views visualizing information from SCADA for the entire plant or even multiple operations.**

Digital Transformation. IIoT. Industry 4.0. While they may seem like trending buzzwords, the technologies are critical to operations being efficient and competitive, and reducing unplanned downtime. Every industry strives for maximum efficiency; be that manufacturing, oil & gas, or water/waste-water. For capturing production data, the days of the clipboard and manual data analysis are gone.

Digital technology and interconnectivity are driving influential technologies like advanced computing solutions; cloud and remote computing; IoT and connected devices; smart and real-time data sensors; data capture, software analytics and processing; and the adoption of AI and machine learning. To remain competitive—particularly in light of worker shortages—and increase productivity, Industry 4.0 and complementary technology must be embraced.

Operators are being asked to do more work than ever before as myriad advanced control features are incorporated for process optimization and improved safety. Fortunately, there are many systems and technologies to aid in this.

Metric	Target	As Found	Evaluation
Announced alarms per hour per operator console (average)	~6	~12	5.8 <span style="color: green;">Acceptable</span>
Announced alarms per 10 minutes per operator console (average)	~1	~2	0.9 <span style="color: green;">Acceptable</span>
Percentage of 10-minute periods containing more than 10 alarms	~<1%	6.20%	<span style="color: red;">Critical</span>
Maximum number of alarms in a 10 minute period	≤10	157	<span style="color: red;">Critical</span>
Percentage of time the alarm system is in a flood condition	~<1%	22.30%	<span style="color: red;">Critical</span>
Percentage contribution of the top 10 most frequent alarms to the overall alarm load	~<1% to 5% maximum	4.70%	<span style="color: yellow;">Manageable</span>
Quantity of chattering and fleeting alarms	Zero.	132	<span style="color: red;">Critical</span>
Stale alarms	Less than 5 present on any day	2	<span style="color: green;">Acceptable</span>
Announced Priority - % of Highest Priority Alarms	~<1%	0.75%	<span style="color: green;">Acceptable</span>
Announced Priority - % of High Priority Alarms	~5%	9.19%	<span style="color: red;">Critical</span>
Announced Priority - % of Medium Priority Alarms	~15%	15.00%	<span style="color: yellow;">Manageable</span>
Announced Priority - % of Low Priority Alarms	~80%	75.06%	<span style="color: green;">Acceptable</span>

*Research has shown that a well-managed alarm system results in production efficiency, product quality and operator effectiveness. Alarm prioritization provides a mechanism for placing a qualitative value of importance on an alarm. The priority usually signifies how quickly the operator should respond to an alarm.*

## Operations and Technology

The ultimate goal of adopting modern systems is to have a wholly efficient, maybe even an autonomous process that cuts out excess fat, ballooning costs and wasteful operations. Focus should be on end-to-end process improvement, which will, in turn, help shape collaboration within the organization. That means investing in training and education, process automation, related hardware and new tools or software ([interestingengineering.com/innovation/how-manufacturing-plants-can-prepare-for-industry-40](http://interestingengineering.com/innovation/how-manufacturing-plants-can-prepare-for-industry-40)).

Continuous operational improvement starts with capturing data from machine assets. This data provides immediate insights for both people and systems, enabling them to make better, faster decisions and drive automation.

Let's take an example of a smart manufacturing plant using data. Characterized by increasing automation and the employment of smart machines and smart factories, informed data helps to produce goods more productively across the value chain. By collecting additional data from the factory floor and combining that with other enterprise operational data, a smart factory can achieve information transparency. ([ibm.com/topics/industry-4-0](http://ibm.com/topics/industry-4-0)).

Accurate, real-time production data is pivotal to shop floor operations and the effective operation of each machine asset.

Once real-time process information is gathered, the next logical step is to define conditions of concern on those process variables. For example, "Is an oven too hot or a motor spinning too slowly?" "Is a tank nearing empty or a pressure too high?" "Are there issues with the centrifugal pumps drawing liquid?" SCADA systems provide for such conditions to be defined and tracked, monitoring process variables and surfacing active conditions to HMI. These condition-based events and alarms add another level to optimizing the

process—they allow greater situational awareness for plant operators by calling attention to irregularities and suboptimalities. Real-time process variables and alarm conditions can then be captured over time, and calculations can be performed to improve planning and offer solutions to detect patterns in the data.

## Remote Alarm Notification Software

A key theme of Industry 4.0 is greater connectivity—increasing connectivity between devices, industrial networks, and physical assets and the cloud. Growing connectivity allows for greater process transparency and the added potential for predictive analytics and sentinel alarm conditions. Smart manufacturing allows potential issues to be addressed before they become problems, but only by extending that connectivity to the people who operate and optimize manufacturing assets. Connecting devices and getting the right information (with increased sophistication of modeling) to the right people at the right time is the strength of remote alarm notification software.

Remote monitoring and alarm management enables operators to take on more proactive, hands-on tasks in the field or on the plant floor, without hiring additional staff.

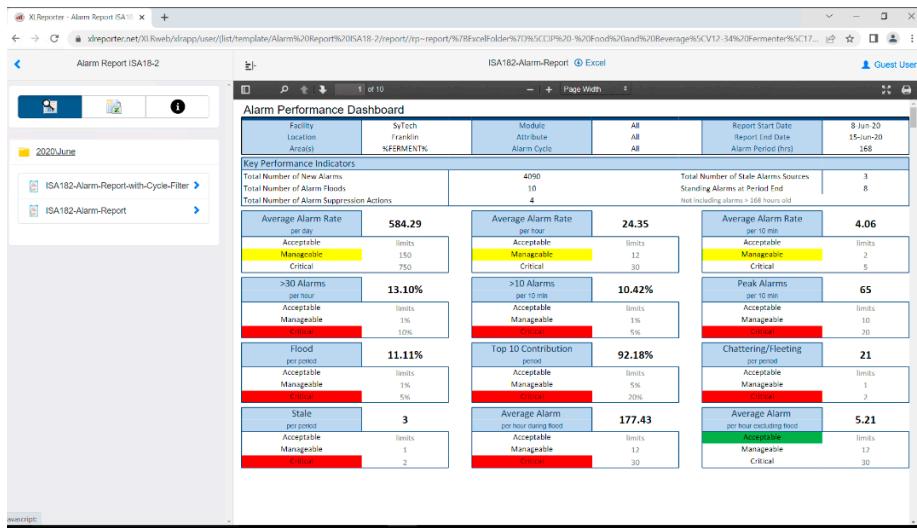
## Historization and Analytics

The convergence of advanced technologies and data-driven strategies has ushered in a new era of optimization, where historical data analysis plays a pivotal role in achieving accurate forecasting and scheduling. The ability to harness this data effectively can lead to smarter decision-making, improved processes, and a competitive edge. Analyzing historical data allows operations management to identify patterns, trends and anomalies that may otherwise go unnoticed. These insights serve as the foundation for creating accurate forecasts and efficient production schedules ([planettogether.com/blog/analyzing-historical-data-for-enhanced-forecasting-and-scheduling-in-pharmaceutical-manufacturing](http://planettogether.com/blog/analyzing-historical-data-for-enhanced-forecasting-and-scheduling-in-pharmaceutical-manufacturing)).

As the past three+ years have shown, supply chain disruptions and unexpected demand shifts make forecasting more challenging. However, historical data analytics can help plants transition from reactive to proactive planning and keep planning aligned with operations.

## Reporting

Reports provide a visualization of this historized process information and correlate related process variables, compute metrics on that data, and visually graph such data for eas-



*Any improvements to an alarm system starts by identifying problem areas. Third-party reporting software can provide filters that help reveal the unknown challenges.*

## ISA 18.2 Alarm Performance Indicators



A dashboard showing the Key Performance Indicators (KPI) uses configurable targets to show the health of the alarm system in an "at-a-glance" display.

ier pattern and anomaly detection. These reports are created through third-party software that seamlessly integrates with PLCs, SCADA and historian systems. Advanced reporting solutions can even pull information from remote alarm notification software, allowing further analysis and optimization of condition response times.

Reporting software enables organizations to turn raw process data into actionable information, thereby increasing efficiency and reducing costs. Furthermore, automated reporting solutions streamline regulatory compliance by collecting data from various sources like SCADA, LIMS, manual entry and others. As the data is collected it is summarized as key metrics—flow totals or turbidity threshold analysis. The final output is published into a formatted document accepted by regulatory agencies.

Leveraging aggregated data at the plant level offers economies of scale for managers. With a summation of performance across all machines, larger performance inefficiencies become evident, and managers can develop a deeper understanding of their machine performance, people performance and process

performance ([machinemetrics.com/production-monitoring](http://machinemetrics.com/production-monitoring)).

## Alarm Management

A robust alarm management system enhances operational efficiency and enables timely detection of failures. A comprehensive alarm system provides actionable information to the operator and helps in taking corrective action. Research has shown that a well-managed alarm system results in production efficiency, improved product quality and better operator effectiveness.

Since 1991, alarm management standards have been published and currently the ISA-18.2 and IEC 62682 are the most widely accepted. The standards define a seven-step Alarm Management Cycle program from identification to monitoring and assessment.

A cloud-connected alarm management system provides access to real-time alarms even when working remotely to decrease response times and help reduce unplanned downtime. Alarm audits and reporting provide an efficient means to document and track the history of individual alarms, consequences, response time and the action taken to mitigate the alarms. As this rationalization is

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condition monitoring

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performed, continued system-level monitoring and assessment reports validate that these efforts are driving real improvement.

An effective alarm management program can help the processes get closer to an optimal operating point resulting in lower production costs, higher quality, greater throughput and eventually safer operations ([sciedirect.com/science/article/abs/pii/S0950423017306320](http://sciedirect.com/science/article/abs/pii/S0950423017306320)).

## Continuous Improvement

The fourth industrial revolution, rapid globalization, technological advancements, changing consumer preferences and evolving government policies are reshaping industries. Trying to meet these challenges with manually intensive processes and outdated technology is difficult. However, by leveraging advanced technology such as real-time alarms and automated processes, operations can increase productivity and efficiency, and reduce costs.

Prioritizing operational excellence not only fosters growth but also positions organizations for continued success.



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# CCTY Tackles Humanoid and Industrial Robot Development

## Reimagining motion control one application at a time

Matthew Jaster, Senior Editor

CCTY (Lake Zurich, IL) is a manufacturer of high-performance motion control and assemblies including spherical plain bearings, rod ends, mast guide bearings, self-lubricating bearings, tie rods, ball joints and more. CCTY is a full-service global engineering and consulting partner that helps customers quickly turn new product ideas into reality. *PTE* recently discussed the company's evolution with Yaman Obaid, a mechanical engineer specializing in robotics for CCTY.

### Give us a brief history on CCTY. Where did you start as an organization and what do you hope to accomplish in the future?

CCTY specializes in the production of motion control products that include bearings, bearing assemblies and related components. The company was established in 1996 with a focus on research and development to provide individualized solutions for a range of industrial applications. Over the years, CCTY has expanded its expertise and product line to cater to additional sectors, including automotive, agriculture, and robotics.

The company's journey began with a commitment to quality and innovation, which remains at the core of its operations. CCTY is constantly investing in research and development to meet the customer's evolving demands.

Looking ahead, CCTY aims to continue its growth by advancing in the field of motion control technology. This includes contributing to the development of industrial and humanoid robots, which are becoming increasingly important in the modern world.

### Describe the variety of motion control solutions (components and assemblies) CCTY provides to humanoid and industrial robotic applications?

CCTY specializes in designing and manufacturing motion control solutions tailored for both humanoid and industrial robotic applications.



**Ball Bearing:** These include radial, 4-point contact, angular contact, and flexible ball bearings, ideal for precise rotation in linear and rotary actuators and humanoid robot fingers. They are characterized by high precision, low clearance, low friction and the ability to handle both radial and axial loads.

**Cross Roller Bearings:** Located in the rotary actuators of humanoid robots and industrial arms, these bearings support axial loads from both directions, radial loads, tilting moment loads, and any combinations of loads. They boast high load capacity, high stiffness, precision, compact design, long lifespan, and low maintenance requirements.

**Spherical Plain Bearings:** Suitable for applications requiring three-dimensional motion, these bearings accommodate self-lubrication, high misalignment angles and offer near zero torque and clearance, with high precision.

**Rod End & SPB Assemblies:** Used in the joints of humanoid robots, particularly in linear actuator ends, rod ends allow for rotational freedom about all axes while maintaining a fixed point of contact. They are compact, optionally maintenance free, easy to mount, and can accommodate high misalignment angles, enhancing the robot's efficiency and durability.

**RNN & Cage Needle Bearings:** These bearings are utilized in planetary rotary actuators and wheel side reduction gears. They transmit torque and support radial loads while maintaining a compact design, reducing friction in robot arms and improving rigidity.

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## **What role do the bearings play in these applications? Why is a customizable approach to bearing design critical for these robotic applications?**

Bearings are fundamental components in robotics, serving as the interface between moving parts. They transfer loads and facilitate smooth and controlled motion, allowing for precision in robotic applications. A customizable approach to bearing design is critical because each robotic application has unique requirements regarding load, speed, precision, and environmental conditions. Custom bearings can be tailored to meet these specific demands, ensuring optimal performance and longevity.

## **What are the benefits of samples?**

Manufacturing short, application-specific runs, which we refer to as samples, allows for greater flexibility and customization. Samples enable rapid iteration and improvement of designs, which is essential in the fast-paced field of robotics where technology and requirements can quickly evolve.

## **Elaborate on the role that torque and clearance play in these applications as well as other areas where precision and reliability are critical to success.**

Torque and clearance directly affect energy consumption and motion accuracy of robots. Torque or friction, the force needed to cause rotation, must be minimized to ensure efficient operation and reduce energy consumption. Clearance, the space between moving parts, must be carefully controlled to prevent excessive play, which can lead to imprecision, excessive wear and noise.

## **How does backlash fit into product design and the impact it has on humanoid movement?**

Backlash, the looseness or play between parts, can significantly impact the accuracy and smoothness of humanoid movement. Minimizing backlash is essential to maintain precise control over the robot's movements, which is particularly important for tasks requiring high levels of dexterity and coordination.

## **What role do lubrication and seals play in robotic applications?**

Lubrication and seals are crucial for the longevity and reliability of bearings in robotics. Lubrication reduces friction and wear, while seals protect against contaminants that can degrade the bearing's performance. Together, they ensure that the bearings operate smoothly and require less maintenance over time.

## **What challenges are manufacturers facing in the humanoid and industrial robot market segment and how can CCTY help solve many of these challenges?**

In the humanoid and industrial robot market, manufacturers encounter many challenges, including the demand

for precise motion control, increasing energy efficiency, and longevity. The bearings must meet stringent specifications, like near zero friction, minimal clearance, high accuracy, and long lifespan. CCTY is as much an engineering company as it is a manufacturer and is well equipped to tackle these issues. CCTY engineers work closely with customers, aiding in the design process to ensure optimal performance. Through specialized bearing design and sophisticated manufacturing processes, the company manufactures tailored solutions and conducts comprehensive on-site testing, ensuring that each bearing is perfectly suited to the unique demands of its application. This approach not only addresses the immediate challenges but also contributes to the longevity and reliability of robots.

## **How does CCTY's experience in bearing design help the organization develop full assemblies requested by the customer? What are the benefits of these full assembly solutions?**

CCTY's expertise in bearings is drawn from years of experience designing, developing, manufacturing, and testing a variety of linkages and high-precision rolling and sliding bearings. With the advantage of an in-house forging, machining, heat treating, assembling, and testing facility, CCTY guarantees exceptional quality control and expedited sample turnaround times.

When customers opt for full assemblies can expect a multitude of benefits, as follows:

- Design optimization for reduced weight and size
- Minimized tolerance stack-up for improved accuracy
- Reduced friction/torque for enhanced energy efficiency
- Minimized clearance for precise motion control
- Incorporate a seal and lubrication to prevent rust and contamination
- Integrate the bearing into surrounding components to facilitate cost reduction

Customers who request full assemblies can benefit from a more streamlined assembly process and supply chain, coupled with enhanced component performance. These full assembly solutions, meticulously optimized for performance, reflect CCTY's commitment to delivering superior, ready-to-integrate components that advance the capabilities of the robots into which they are incorporated.

## **How will humanoid and industrial robotic applications evolve in the coming years?**

The evolution of humanoid and industrial robotic applications is likely to focus on increased autonomy, adaptability, and integration into human-centric environments. Bearings will play a crucial role in this evolution, with ongoing advancements in materials and engineering contributing to more sophisticated and capable robotic systems.

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# Solving the Problems of Tomorrow, Today

## How Siemens' software will play a significant role in the factory of the future

Matthew Jaster, Senior Editor

Siemens' annual event Realize LIVE Americas never fails to disappoint on the technology front. Automation, AI, IIoT, the Industrial Metaverse, additive manufacturing—you name the technology—Siemens has it covered. The factory of the future is no different. The company spends a great deal of time discussing smart manufacturing, analytics and services examining what a typical shop floor might look like in 15–20 years.

How does the factory of the future apply towards mechanical power transmission? This is the question we raised with Rahul Garg, vice president industrial machinery a, Siemens Digital Industries Software.

In the virtual realm, a comprehensive digital twin represents every aspect of a product's life, from design all the way to in-use performance, including the processes employed to manufacture the product. The comprehensive digital twin is used to simulate, predict and optimize the product and production system before investing in physical prototypes and assets. It provides valuable foresight prior to production as well as insights that drive continuous manufacturing improvements. Having an accurate digital twin of your complete manufacturing process is essential. It not only helps you produce higher quality products at a lower cost today, but also forms the backbone for manufacturing technologies that are just around the corner.

"One of the things we are doing is we are taking our applications to the cloud. By taking our applications to the cloud you get many benefits. First off,



*Sony's XR head-mounted display is a fundamental part of the forthcoming NX Immersive Designer.*

we are enabling customers to use the latest technology with minimal company resources like IT staff and server hardware. You have instant access to software updates. We are enabling very easy collaboration between engineers inside the company and outside the company—in a secure way. As a component manufacturer, like a gear manufacturer, if they are using Siemens NX-X for the design application, we have many built-in libraries that are easy to use," Garg said. "By utilizing these libraries and wizards, you can further improve your product design's timing and efficiency. Users are no longer alone at the computer. They have the Siemens backed catalog and many customers who are building and using similar designs. It becomes a lot more powerful when you have many customers that are feeding into these libraries and you're able to leverage those capabilities."

### Optimizing Component Design

Siemens software such as NX-X and Teamcenter-X are updated regularly to improve component design, provide exceptional data and enhance Product Lifecycle Management (PLM). This analytical approach to product development is what the future of design will look like, according to Garg.

With NX X you can create, simulate, visualize and optimize 3D factory designs faster to improve factory logistics and material flow operations before full-volume production. Designers are planning and virtually simulating the smart factories of the future through digitalized processes. The virtual factory is created in 3D with layout and optimization tools, allowing us to design, layout and configure the factory environment and optimize factory operations. By allowing facility

planning and line design teams to see the outcome of plans virtually, costly expenses and wasted resources that occur when problems are discovered in actual, physical facilities can be easily avoided. During factory line design and planning the impact of equipment placement and access is difficult to realize using conventional factory layout tools. Understanding the throughput of individual lines of the factory is critical for manufacturers, as is understanding how material moves throughout the facility. Inefficiency can ripple throughout the factory and its production systems if you don't have the ability to optimize the factory layout based on the data obtained during the planning and analysis phases of production engineering. With *NX* solutions, you can quickly design and visualize production line layouts and associate them with manufacturing planning. You can easily optimize the process by specifying each production step down to managing a single manufacturing resource, such as a robot or fixture.

"As a company, Siemens is also a user of our own software applications in the design and manufacturing of the motors we sell to others," Garg added. "That's the most interesting part, where we not only sell the software applications to other companies, but we actually use these tools in-house for our own products.

"Our software applications are used all the way from the rotor design to the electromagnetic interference detections to the heat and thermal flow analysis and cost estimation" Garg said. "Our simulation applications can help design a motor effectively while also helping with the programming and evaluating the electrical power needs."

With these software tools, engineers can design the power input and output from the motors. They can also design the controls for the motor. They can help you get the maximum torque, define the speed-up/speed-down torque, etc. All this can be designed inside the software, which makes the process much more efficient.

"Siemens provides a whole set of sensors, gear and Industrial IoT applications that can help with gear noise reduction. The design

application software—within *NX*—can help get manufacturers to the lowest possible fidelity of movement. This is where gear ratios and other challenges can be addressed.

"What's unique about *NX* is how the software can be used from the design phase all the way to the finished product," Garg said. "Kapp Niles, for example, uses *NX* to make the machine tool itself. Then, they use *NX* to design the gears on that very same machine. Every step of the gear manufacturing process involves *NX* software."

Garg noted that within a gearbox, there's typically a lot of change in motion. The whole purpose of the gearbox is to change this motion, either step it up, step it down, change the direction, etc. *Simcenter* helps with this analysis. It determines if the gearbox will perform efficiently or not.

"Not only will it provide simulation and analysis, but it will also help you do a lot of load analysis, time dependent stress analysis, heat transfer, and more," Garg said. "What if you put a certain amount of load on the gear? What will happen in two hours? What will happen in two days? What will happen in 10 days? The software can also deep dive into friction analysis. What kind of friction are you generating and how can it be eliminated?"

If you've been paying attention to the markets, particularly consumer and industrial, you've noticed the consolidation of several vendors and suppliers. Post-COVID has laid the groundwork for "all-in-one" solutions. Software is no different.

The factory of the future demands that the design engineering process is streamlined and extremely focused. Modern industrial robotics systems play a crucial role in producing complex and smart products sought after by today's consumers, ranging from personal electronics to passenger vehicles. As advanced robotics, though adept at managing complex products, face hurdles in adoption due to the commissioning process.

Advanced robotics, especially with Virtual Commissioning will handle these changes without harming everyday operations. Technologies like AI

and ML will modernize manufacturing so tasks can be optimized through advanced robotics. Businesses can leverage Virtual Commissioning for identifying issues during simulations, facilitating early validation and achieve informed decision-making. Shifting development and planning processes to an earlier stage allows problems to surface in the simulated environment rather than on the shop floor.

"You can have one application that does it all, eliminating the need for any data translation. Every time you do a translation, there is the possibility of losing accuracy and fidelity in that data," Garg said. "By using the same data, you are ensured and guaranteed—the analysis, design work, machining, production—all of it is working off the same data set enabling simulation to be done through the design process—Simulate early and simulate often. "By simulating the whole production line, we can identify defects and problems in the design to make necessary corrections before real production." Garg added.

This also ensures that if you make any changes anywhere in your process, that change is accounted for along the entire process chain.

"It's important and becomes a lot more seamless to use all the applications within the software suite," Garg said. "Track any changes as well. This is the biggest value that we see today whether you're designing a gearbox or an airplane. You need to have the ability to see the impact of changes. Siemens' MES allows us to spread process improvements and eliminate legacy tools. The dual benefit helps improve product quality and process efficiency, while also reducing operational risk and setting the stage for future shared improvements."

## New Toys in the Toolbox

How would today's mechanical engineer want to conceptualize the products that they're trying to make—from the engineering phase to the manufacturing phase to the service, repair and maintenance? What's the best way to make sure that you're doing it in a sustainable way?



**Simulate highly automated manufacturing processes in the digital twin before investing in expensive equipment. (Images courtesy of Siemens)**

"For us, it's like the whole cradle to grave process of a product. This is where Siemens PLM software really shines. I think there are two important things that are coming into picture, two core technologies that have become more relevant today. One is Generative AI, and then the second is the Industrial Metaverse," Garg said.

Generative AI makes it very easy to leverage AI technologies to create and design new things without having the burden of starting from scratch, according to Garg. "It's much easier to take a piece of paper and edit versus writing anything from scratch, right? This can have a huge impact in terms of innovation and the speed of innovation. The testing, the validity, the various ways to attack a project, etc., now this can all be done using Generative AI tools."

The industrial metaverse is the concept of a digital world to mirror and simulate real machines and factories, buildings and cities, grids and transportation systems. By seamlessly integrating technologies like cloud and edge computing, industrial AI and digital twins, the industrial metaverse can optimize processes and drive sustainable practices, ultimately shaping the future beyond simulation.

The construction of the Industrial Metaverse relies on collaboration, openness, and strong ecosystems. Serving as a digital business platform, *Siemens Xcelerator*

brings together a strong ecosystem of partners and offers solutions that work easier, faster, and at scale to use, helping customers to accelerate their digital transformation and enable the industrial metaverse.

*Siemens Industrial Copilot* opens the language models and gives engineers the ability to have human-like conversations with the equipment. Garg said the *Siemens Industrial Copilot* gives designers real-time access to non-proprietary information (manuals or guides, for example), proprietary product information and those language models.

"We're giving our customers the ability to access all three pieces of information through *Siemens Industrial Copilot*. If someone has made a new design in Brazil, they can share it in real time with the company or share it with customers around the world," Garg said. "Someone said it took the internet 20 years to become pervasive. I think it was on a podcast with the CIO from Google. Many believe Generative AI is going to do the same thing in five years' time. Keep an eye on the pace in the coming months, it's going to explode at a mind-boggling rate!"

At the show, Siemens also unveiled its collaboration with Sony's XR technology. Sony's XR head-mounted display is a fundamental part of the forthcoming *NX Immersive Designer*, an integrated solution that combines

Siemens' NX, exclusively with Sony's breakthrough XR technology to deliver immersive design and collaborative product engineering capabilities. The head-mounted display and dedicated controllers let designers create more intuitively in a fully immersive environment, allowing you to move freely between the virtual and real worlds. It will allow designers to play around in the virtual environment without ever having to build a physical prototype. Siemens' *NX Immersive Designer* is expected to launch at the end of 2024.

"Lastly, we are looking at new ways to make our more accessible. Through a token-based approach and subscription models, small- and medium-size enterprises can now have easy access to applications that in the past were only in the reach of larger enterprises. "Instead of investing in a large upfront payment or managing a large IT system to support the software, there are many other options available. Now you can pay as you go, you can leave the application support to Siemens. There is much more flexibility," Garg added.

As a society, we take for granted how quickly technology is changing. Manufacturing production can slim down from months to weeks to days—even hours in certain circumstances. We can build things faster and more efficiently thanks to these new software tools.

*Siemens Xcelerator* is a comprehensive, integrated portfolio of software and services. It is designed to form a software foundation for digital business transformation—helping companies accelerate their evolution into digital enterprises, enabling them to be poised for ongoing success.

The factory of the future will allow designers to test, research and validate hundreds of "what-if scenarios" in real-time. They will no longer feel the restraints from budgets, time or resources. Creativity and innovation will play as big a role as the design execution itself in areas such as energy, e-mobility, packaging and aerospace.

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# Power and Potential



# Eaton and BAE Systems collaborate on 3:1 solution for medium and heavy-duty trucks

Matthew Jaster, Senior Editor



The assignment was simple: compare a CL7 Freightliner M2 retrofit—with a BAE Systems propulsion solution and an Eaton MD 4-speed EV transmission—to a similar sized truck with an ICE. Sure, you can pop the hood, examine the interior, and ask a few questions—which we did during a June 2024 event at Eaton's Proving Grounds located in Marshall, MI—but the fun part came when we took both vehicles out on the test track to see how the EV truck handled on turns, inclines and at top speeds versus its ICE counterpart.

"We see an exciting opportunity here to reduce complexity, cost, and improve reliability and efficiency of next-gen EV trucks with this solution," said Justin Hopkins, product director, e-powertrain at Eaton.

## Experience Matters

BAE Systems has more than +25 years commercial vehicle experience including the development of a power-dense electric motor and advanced silicon carbide/gallium nitride power electronics suite as well as two decades of experience developing and integrating electric propulsion systems. If that's not enough the company provides some of the world's most advanced defense, aerospace and security solutions.

Tom Webb, director of business development and strategy at BAE Systems described the collaboration as "focusing on simplification, serviceability and an effort to meet EV goals now and in the future."

"When I first started, we had about 12 people working on pilot orders at BAE Systems and now we have 350+



*Eaton's heavy-duty 4-speed EV transmission was named a 2024 Automotive News PACEpilot Innovation to Watch winner.*



*Brian Kovalchick, senior technician at BAE Systems, reveals the space savings available under the hood of the test vehicle.*

## Notes from the Eaton/BAE Systems Test Drive Event

### Integrated motor/gearbox

- Easy to install
- 4 speed AMT for CL5-8
- Superior performance
- Power-dense e-motor
- High torque for gradeability and top speed
- Industry leading electronics SiC/GaN
- Improved efficiency and more range
- High power density reduces size and weight
- Multi-functionality
- Charging and battery interface
- E-ancillaries and ePTO

Truck retrofit: CL7 Freightliner M2; BAE Systems propulsion solution; Eaton MD 4-speed EV transmission; Forsee Zen 77 Plus batteries; Meritor rear-axle with 3.9:1 ratio.

Key metrics: 33,000 lb. Gross Vehicle Weight Rating (GVWR); Payload capacity of >18,000 lbs.; 230 kWh of electrical energy storage; top speed of 70 mph (electronically limited); starting grade at GVWR of >21 percent; Efficiency at GVWR of 1.1 kWh/mile.

Performance vs. ICE: Improves 0-20 mph acceleration rate by 2x; Reduces 0-50 mph acceleration time by >20 seconds; Curb-weight increase of only 1,400 lbs.

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people and have been profitable for over two decades. We have shipped (and support) roughly 18,000 systems—99 percent are in city buses not trucks, but to give a little respect to city buses, particularly in New York City, for example, they have a pretty severe duty cycles."

Eaton is an intelligent power management company dedicated to improving the quality of life and protecting the environment. They offer heavy duty and medium duty 4-speed EV transmissions that deliver class-leading performance, superior acceleration and gradeability with advanced efficiency for the EV system.

Together, they provide +125 years combined experience in commercial vehicle technology with more than 5 billion revenue miles in electrified commercial vehicle products. Engineers from both organizations examined Gen 1 EV trucks and determined they have a high part count, many interconnects and lots of wiring. "This not only adds expenses, but also compromises efficiency," Hopkins said during the event.

## EV Evolution

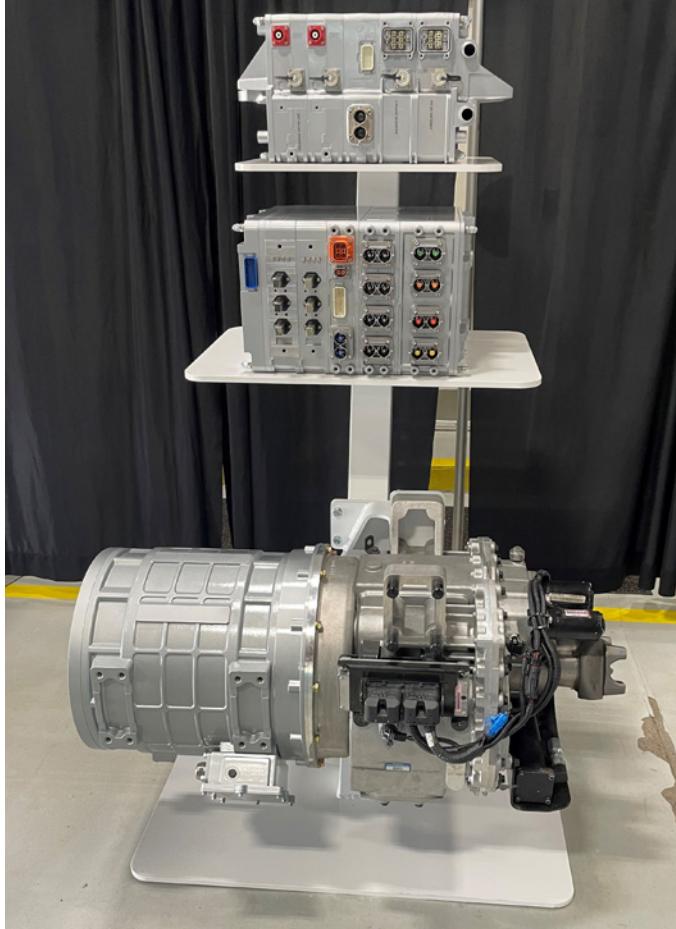
Eaton and BAE Systems engineers were tasked with reducing the cost, size, weight and complexity of the EV truck while increasing its reliability. The solution uses a multi-speed EV gearbox coupled with a compact high efficiency motor to deliver both speed on highway and speed on grade—most commercial EVs cannot deliver both. Bill of Material is significantly reduced from typical EV solutions by highly integrating all major EV drive and auxiliary functions. Potential applications for this solution include pickup and delivery, bus, municipal, port drayage, yard tractor and regional logistics.

"While Eaton's electrical experience is wide and robust it's of interest to note that the company is now offering charging solutions that complement our on-vehicle powertrain solutions," Hopkins said. "We're not doing electric motors or any accessory power electronics like BAE does, so this collaboration makes a lot of sense."

Developed to aid efficiency, Eaton's purpose-built medium-duty and heavy-duty EV transmission helps to increase range, grade capability and acceleration for commercial electric vehicles. Leveraging decades of experience, this EV transmission is based on proven, robust and efficient layshaft architecture and allows for use of a smaller motor.

Eaton's new 4-speed transmissions provide superior performance on grades and acceleration for electrified commercial vehicles while offering more flexible gear ratios compared to competitive technologies. The compact 4-speed transmissions also improve system efficiency, enabling longer vehicle range and battery life.

"These transmissions were developed based on existing Eaton ICE technology that we adapted to the EV market," Hopkins said. "Our goal was to make the shift smooth and quick, but there's tradeoffs, right? If you make it too quick, it could be jerky. We want to make sure we're doing the right thing for the application."



BAE Systems provided the electric motor and power electronics for the test vehicle.

A 4-speed transmission is unique for both commercial and light vehicles but Hopkins stated that because the motor has a larger range of operation, you don't need as many speeds.

Additionally, the heavy-duty 4-speed EV transmission was named a 2024 *Automotive News PACE*pilot Innovation to Watch at an awards ceremony in April. This recognition acknowledges post-pilot, pre-commercial innovations in the automotive and future mobility space.

### Ride and Drive

The Class 7 demonstration vehicle checked all the boxes for simplifying electric drive systems.

First impressions? It's uncanny how much room there was under the hood. By emphasizing size and weight reduction and moving the battery pack toward the back of the truck, there's so much empty space up front. I've never seen fewer components in a vehicle or less high voltage orange cables running amok.

The handling and acceleration on the test track were significantly better in the EV vs. the ICE commercial vehicle. It took turns and shifted smoothly, accelerated generously and was an absolute comfort between 60 and 70 mph.

With a hill holding function on the powertrain, I was able to take my foot off the accelerator on steep inclines and the EV truck would hold on to the grade. I imagine this would be an extremely beneficial feature for a delivery driver in heavy traffic in Pittsburgh or San Francisco.

The ICE counterpart performed as expected.



*The empty space under the hood was noteworthy in the EV test vehicle compared to the ICE truck.*

The steering wheel shook harder during acceleration and the overall handling whilst taking curves was nowhere near as comfortable as the EV. Honestly, it felt like driving an old truck as opposed to a shiny, spectacular new EV vehicle fresh off the lot.

As my first drive in an EV commercial vehicle, I was impressed by all the bells and whistles on the inclines as well as the shifting architecture on the test track. Eaton and BAE Systems have delivered on simplifying and reducing the weight of the motor and battery packs. This test vehicle hints at what fleet vehicles could look like moving forward. I thoroughly enjoyed my time behind the wheel.

### What We Learned

It's one thing to debate about the differences between electrical and ICE vehicles, but I believe if more people had an opportunity to drive an EV and its ICE equivalent back-to-back, you'd see how far the technology has come and what the future *actually* holds for the transportation industry.

I circle back to discussions at the CTI Symposium earlier this year. Many experts in the automotive, truck, construction and off-highway sectors understand the push-back when it comes to meeting sustainability and CO<sub>2</sub> requirements. They realize the infrastructure challenges, the costs, and the market fluctuations. Everyone hears all the noise in politics as well as the media. Regardless, these engineers continue to roll up their sleeves and find the best EV solution for the application.

"Buses—city and school—are doing really well in the EV space," Webb added. "We hope to see similar results in commercial vehicles and material handling. There are challenges to overcome, but it's an exciting time to be a part of the electrification movement."

[eaton.com/us/en-us/products/emobility.html](http://eaton.com/us/en-us/products/emobility.html)

# Industrial Automation Integrity

## Gearmotor Trends and Topics 2024

Matthew Jaster, Senior Editor

Truth be told, there are few components as versatile as the gearmotor. We find them in AGVs, AMRs, and robotics. They can also be found in automation equipment, industrial drive solutions and material handling applications. Four key trends involving gearmotors today include the simplification in design and installation, quiet and energy efficient performance, predictive maintenance and condition monitoring—and lastly—the ability to perform at the highest levels in hazardous and demanding applications.

### Streamlined Operations

Bonfiglioli's AxiaVert is a series of frequency inverters offering integrated functional safety, precision and control for any industry and process. Highly dynamic and extremely performing, AxiaVert ensures complete flexibility and supports a wide range of Ethernet fieldbuses. At SPS Italy 2024, AxiaVert was featured in two hybrid systems. In the first one it was combined with a BMD servomotor, in the second one with a BMS servo gearmotor, both characterized by the innovative single-cable technology

and both managed in PTP or Master/Slave operating mode. The high resolution of the encoders used on BMD/BMS motors allows to achieve an infinitesimal precision positioning and therefore, it represents the best choice for challenging applications, above all in motion, labelling and filling fields. The most important innovation is represented by the shielded single cable applied to the servomotors, which represents a huge advantage in terms of simplification during installation and space saving: one single cable means one single connector, i.e. one single attachment point upstream with the drive and downstream with the servomotor.

In the field of mobile robotics applications, Bonfiglioli displayed BlueRoll: the high-performance, wheel-mounted gearmotor platform for AGVs and AMRs, featuring an ultra-compact and energy-efficient design for a long operating cycle. The modular drive system is available in three configurations, basic, advanced and compact, with a customizable single gearbox load ranging from 360 to 1,020 kg and a maximum speed of 2 m/s. A

*Bonfiglioli displayed its latest gear technology during SPS Italy 2024.*



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compact servo gearmotor of the BMS Series, together with a combined solution composed of a TQ high precision planetary inline gearbox of the Performance Line and a BMD permanent magnet AC low voltage synchronous motor, were also showcased at the booth.

The BMS Series' main advantages are excellent compactness, high torsional stiffness and low moment of inertia, making it the ideal solution for applications that require highly precise positioning, accuracy and efficiency. Thanks to its space-saving machine design, along with a wide range of options, the BMS Series enhances performance through the synergy between permanent magnets, synchronous motors and precision planetary gearbox technologies. According to the application requirements, in terms of speed torque and operation cycle, it is also possible to select the suitable gearmotor choosing between the base, medium or high overspeed variants.

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

### Quiet Performance

BLDC (electronically commutated) hypoid gearmotors from Bodine Electric Company are designed to be high-performance, maintenance-free alternatives to gearmotors with standard worm gearing. The gearmotors are available with gear ratios from 5:1 to 240:1, provide up to 2,370 lb-in (268 Nm) of continuous torque, and speeds of up to 400 rpm. The unique hypoid gearheads are permanently lubricated and feature hardened steel gears for long-life and quiet operation. They can be face-mounted in any orientation via four tapped holes or through-bolts.

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Driven by a maintenance-free, totally enclosed non-ventilated (TENV), 1/2 hp (368 Watts), brushless DC (130 VDC) motor, the type 42B-25H2 and 42B-30H3 gearmotors are ideal for applications that require continuous operation and minimal downtime. These new brushless DC motors feature a built-in 256 PPR, magnetic encoder with commutation track, and are rated IP-66 for protection from dust and water.

[bodine-electric.com](http://bodine-electric.com)

## Preventive Measures

Servo gearmotors benefit from regular check-ups according to Sumitomo Drive Technologies. Scheduled maintenance ensures early detection of potential issues.

Ensuring that your servo gearmotors are in peak condition will undeniably translate into tangible benefits for your manufacturing processes, product quality, and bottom line. Maintenance checks prevent minor issues from escalating into major problems, reducing costly downtime. MRO personnel suggest scheduling periodic inspections, document findings, and promptly addressing identified issues.

Lubrication reduces friction and wear between moving parts, ensuring smoother operations.

Consistent lubrication reduces the risk of premature wear, overheating, and associated damage. It's important to use manufacturer-recommended lubricants, check lubrication levels frequently, and re-lubricate as necessary.

Another guideline is to keep staff up to date on training and communication. Well-informed employees contribute to machinery longevity and operational efficiency. Offer regular training sessions, circulate informational material, and encourage open communication about observed abnormalities.

Lastly, installation is the foundation of a gearmotor's operational lifespan. Proper alignment and installation prevent undue stresses and imbalances in the system. Follow manufacturer guidelines, seek assistance if unsure, and verify installation with diagnostic tools.



*Gearmotors are tasked with operating in hazardous environments and providing functional safety solutions.*

By proactively maintaining and monitoring your equipment, not only do you safeguard your investment, but you also ensure seamless production, minimizing costly downtimes and disruptions.

[us.sumitomodrive.com](http://us.sumitomodrive.com)

## Heavy Industrial Expertise

Nord Drivesystems gear units are used for a variety of heavy-duty applications such as bucket elevators, mixers, agitators, cranes, conveyor belt drives, bulk material handling, steel production, manufacturing, and more. These units provide high output torques, long service life with minimal maintenance, and offer extensive input, output, and mounting designs to ensure versatility over a wide range of applications. When combined with high efficiency motors and dynamic variable frequency drives, high performance and smooth operation is achieved.

In the grain industry, it is important that drive systems increase productivity, improve reliability, and reduce downtimes. Drive solutions in this sector often include functional safety and hazardous environment protection due to dust and fibers that are generated during processing. For high-capacity applications like bucket elevators that are used for vertical transport of bulk materials, Nord offers MaxxDrive XC parallel industrial gear units and MaxxDrive XC right-angle industrial gear units. These industrial gear units deliver immense output torques up to 2,495,900 lb-in and feature a wide

range of additional options ideal for bucket elevator applications. These include a backstop to prevent material flow back, an auxiliary drive with an overrunning clutch, a base frame for reinforced alignment between components and easy installation, taconite seals to prevent shaft damage from the dusty atmosphere, and axial fans for high cooling power.

In order for cranes and hoists to pick up loads and set them down gently at precise locations, they require special drives with integrated brakes and variable frequency drive technology for soft starts and braking via defined adjustable ramps. MaxxDrive XD industrial gear units are engineered with hoist applications in mind and feature an extended housing center distance to accommodate a U-shaped drive design, allowing the cable drum and the motor to be arranged on the same side of the gear unit. The Unicase housing is also FEA-optimized for overhung load, especially downwards forces, and offers additional options such as brake attachment via input flange or brake console and various output shaft designs. Together with intelligent Nord VFDs like the decentralized Nordac Flex and cabinet mounted Nordac Pro SK 500P, high positioning accuracy, efficient automation, and smooth operation are achieved. These variable frequency drives can also be synchronized for gear units to work in tandem to hoist and move loads for trolley or travel drive applications.

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# UGRacing's Gear Train Solutions from Combustion to Electric

Jordan Pitt

UGRacing is the University of Glasgow's Formula Student team. Since its inception in 2005, the team has been working to compete at Formula Student UK (FSUK). Over the last decade, the team has grown to over 150 members across ten disciplines. With a strong focus on knowledge transfer and iterative design, the team has worked year after year to develop new technologies and a more refined package. In 2022, the team saw a culmination of all their hard work when they placed first overall in FSUK with their final internal combustion vehicle. The following switch to an electric powertrain brought new challenges. Through the constraint of a new powertrain architecture, the team has explored and innovated drivetrain concepts which, in future years, will improve vehicle performance.

## Technical Problem

The drivetrain team faced an important technical challenge in designing an appropriate gear train that will be used when they transition to hub motors. Hub motors refer to electric motors being mounted within each wheel assembly, and the motors provide drive to the vehicle's hubs via a gear train, avoiding the conventional drivetrain setup, which involves driveshafts.

With the electric motor and gear train being constrained to fit within the ten-inch magnesium wheels that they currently use, a compound planetary gear train was required and modeled within *KISSsoft*, as shown in Figure 1. Due to each planet gear consisting of two stages that are constrained in terms of the center distance for each stage, the macrogeometry tool within *KISSsoft* allowed them to obtain appropriate gear sizes according to the ISO 6336 standard whilst meeting our desired gear ratio. By defining the required safety factors followed by the specific conditions, the macrogeometry tool provided ear sizes that minimized and balanced the specific sliding of the gear mesh and provided hunting tooth ratios to improve wear distribution and minimize gear vibration. For their first electric vehicle entry last year, the drivetrain sub-team designed a custom planetary gearbox using *KISSsoft*. Following this design, they had a specific oil supplied by one of their sponsors in terms of yellow metal protection and viscosity. For the design of this new gear train, they wanted to incorporate the properties of this oil into the gear calculations. Within *KISSsoft*, they were able to add their own oil data into the software through the "own input" function which allowed them to alter the gear design to ensure their contact, bending and scuffing safety factors were met. Figure 2 shows the list of gear sizes obtained for the first stage of the planetary gear train.

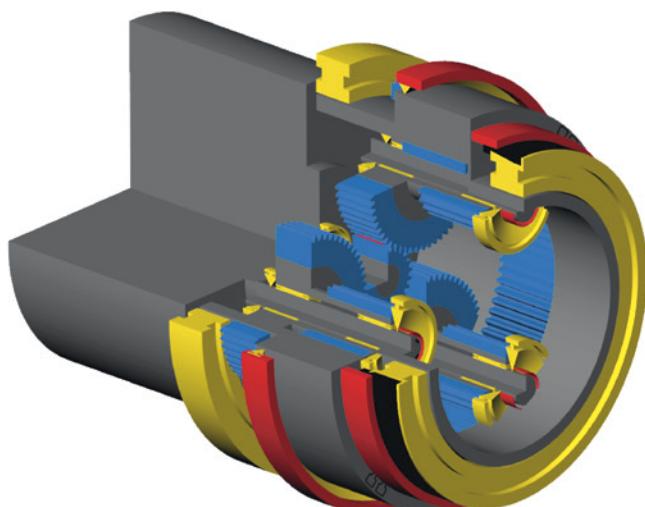


Figure 1—Compound planetary gear train within *KISSsoft*.



K Fine sizing macrogeometry									
Conditions I		Conditions II		Conditions III		Summary	Results	Graphic	
a [mm]	z <sub>1</sub>	z <sub>2</sub>	x <sub>1</sub>	x <sub>2</sub>	$\varepsilon_0$	$\zeta_1$	$\zeta_2$	Hunting	
34.0000	24	59	0.5127	0.5715	1.4575	-0.8846	-0.8845	Yes	
34.0000	24	58	0.7061	0.9789	1.4609	-0.8091	-0.8090	No	
34.0000	24	59	0.3127	0.7715	1.4790	-1.2793	-0.7212	Yes	
34.0000	24	59	0.4127	0.6715	1.4699	-1.0675	-0.8020	Yes	
34.0000	24	59	0.5127	0.5715	1.4575	-0.8846	-0.8845	Yes	
34.0000	24	60	0.1512	0.3704	1.5115	-1.5356	-0.8212	No	
34.0000	24	60	0.2512	0.2704	1.4991	-1.2500	-0.9155	No	
34.0000	24	60	0.3512	0.1704	1.4855	-1.0120	-1.0120	No	
34.0000	25	61	-0.0745	-0.4025	1.7171	-2.8474	-1.2856	Yes	
34.0000	25	61	0.0255	-0.5025	1.6981	-2.1158	-1.4340	Yes	

Figure 2. Fine sizing results from KISSsoft.

Being able to model most assembly components within *KISSsoft* allowed them to define and adjust shaft and bearing sizes during the gear sizing process before creating the full model within *SolidWorks*. This can be seen in Figure 3, with it closely representing the *KISSsoft* model shown in Figure 1. Being able to do this within *KISSsoft* allowed them to save valuable design time with them limiting the iterative process of moving between *KISSsoft* and *SolidWorks*.

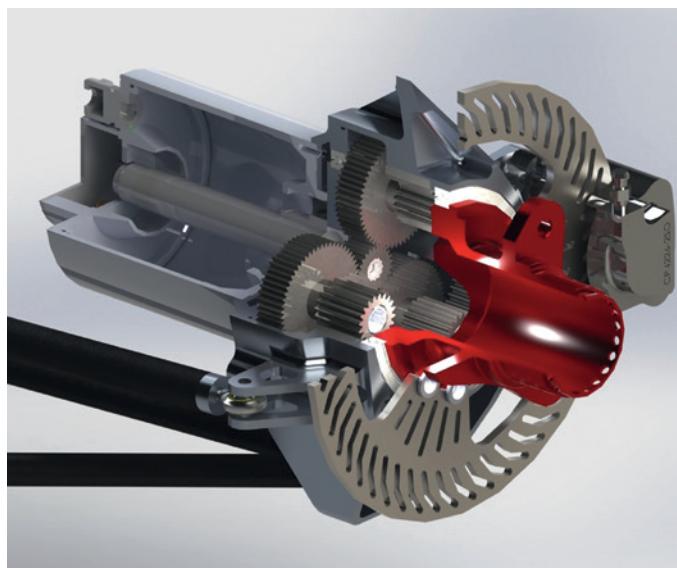


Figure 3—Full wheel assembly model within SolidWorks.

Another major advantage of modeling the whole system accurately within *KISSsoft* was the ability to apply tip and root relief to the gear profile design based on shaft deflection under loading. Using the microgeometry tool, tip and root relief were applied to the gear profile, which removed contact shocks as shown in Figure 4.

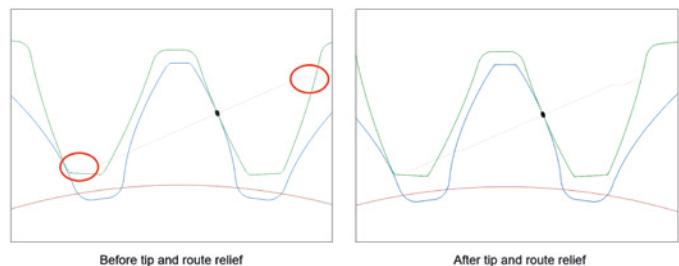


Figure 4—Tip and root relief added to remove contact shocks (circled in red).

Being able to implement tip and root relief into the gear design within *KISSsoft* is advantageous for them based on their manufacturing capabilities which are restricted to wire-EDM. Given their limitation to wire-EDM for manufacturing, they heavily depend on the accuracy of the gear involute model. *KISSsoft*'s capability to provide precise DXF files of the involute profile, including flank modifications, allows them to confidently send their designs for manufacture. This has been proven by the successful implementation of their first planetary gearbox in their electric vehicle. The support provided by *KISSsoft* had been crucial for the team to design highly refined gear train solutions.

PTE



**Jordan Pitt** graduated with a Master's in Mechanical Engineering from the University of Glasgow. He led the Unsprung Mass & Drivetrain sub-team within UGRacing, the University of Glasgow's Formula Student race team, and worked extensively on the design and development of drivetrain solutions for their electric vehicle.

# Pipe Threads: Standards and Compatibility

Tyler Sorenson

Have you ever been confused about pipe thread nomenclature? Have you wondered what is the difference between NPT and PT? What about BSPT? If you have asked these questions or similar ones, you're not alone and this paper is for you! Several different pipe thread designations are used around the world, and some are equivalent or compatible while others are not. A few of the most common types of pipe thread are listed below:

## American National Standard (ASME)

- NPT
- NPSC

## International Standard (ISO)

- G
- R
- Rp
- Rc

## Historical British Standard (BS)

- BSPP
- BSPT

## Historical Japanese Industrial Standard (JIS)

- PT
- PS
- PF



Figure 1—Typical threaded pipe connection with thread sealant.

In the U.S., American National Standard pipe thread is the most common, but other designations are also used. This is especially true of overseas companies (or their U.S. subsidiaries), where ISO, British Standard, and JIS pipe threads are often much more prevalent. Certain pipe thread

designations are equivalent and compatible, some are not equivalent but partially compatible, and others are neither equivalent nor compatible. It can be confusing to determine what is true of a particular designation. This paper aims to eliminate this confusion.

## Background

Regarding American National Standard pipe, ASME B1.20.1 covers the following series: NPT, NPSC, NPTR, NPSM and NPSL. All of these thread series specify threads with a 60° angle between the flanks (see Figure 2). Among these, NPT is the most common and indicates a tapered thread for both internal and external threads. NPT threads are designed to be fitted together wrench-tight and require a sealant for a pressure-tight seal (Ref. 10). NPSC threads are parallel internal threads, which are designed to be fitted wrench-tight with an external NPT thread. As with NPT/NPT connections, a sealant is required for a pressure-tight seal (Ref. 9). NPTR (tapered threads for railing joints), NPSM (straight threads for mechanical joints), and NPSL (straight threads for mechanical joints with locknuts) have the same thread profile dimensions as NPT or NPSC, but have certain modifications for specific applications (Ref. 10).

A separate standard, ASME B1.20.3, covers inch Dryseal pipe threads, which can create a pressure-tight connection without a sealant. The series covered by this standard are NPTF, PTF-SAE SHORT, NPSF and NPSI (Ref. 11).

ISO, British Standard, and JIS pipe threads are commonly used outside of the US. These thread standards all specify a 55° flank angle and specify two families of pipe threads: those for pressure-tight joints and those for non-pressure-tight joints. Pipe threads where pressure-tight joints are made on the threads are defined in ISO 7-1, BS EN 10226-1, BS EN 10226-2, and JIS B 0203. These standards all define identical thread series which are designated with R for external tapered thread, Rp for internal parallel thread, and Rc for internal tapered thread. For these connections, thread sealant is required to achieve a pressure-tight seal (Refs. 1, 2, 5, 7). ISO 228-1, BS EN ISO 228-1, and JIS B 0202 define pipe threads where pressure-tight joints are NOT made on the threads. These standards define identical thread series which are parallel for both internal and external threads and are designated with G. If a pressure-tight joint is required with these threads, then an external seal or gasket is required (Refs. 3, 6, 8).

With the latest standards listed in the previous paragraph, BS and JIS have adopted the same symbols as the ISO standard (namely R, Rp, Rc and G), but the historical symbols previously specified in the standards are still frequently used. In the British Standard, the historical symbols are BSPT and BSPP (Ref. 4). In the Japanese Industrial Standard, the historical symbols are PT, PS and PF (Refs. 7, 8). The characteristics of these series are shown in Table 1, which also defines the equivalent ISO thread series for each.

Standard(s)	Thread Designation	Thread Profile	Internal/External	Flank Angle (deg)	Equivalent ISO Designation(s)	
ASME B1.20.1	NPT	Tapered	Both	60	N/A	
	NPSC	Parallel	Internal			
ISO 7-1 BS EN 10226-1 BS EN 10226-2 JIS B 0203	R	Tapered	External	55		
	Rp	Parallel	Internal			
	Rc	Tapered	Internal			
ISO 228-1 BS EN ISO 228-1 JIS B 0202	G	Parallel	Both			
BS (Historical)	BSPT	Tapered/Parallel	Both	55	R, Rp, Rc	
	BSPP	Parallel	Both		G	
JIS (Historical)	PT	Tapered	Both		R, Rc	
	PS	Parallel	Internal		Rp	
	PF	Parallel	Both		G	

Table 1—High-level overview and comparison of relevant pipe thread series. The series shaded grey are historical designations that are still in use.

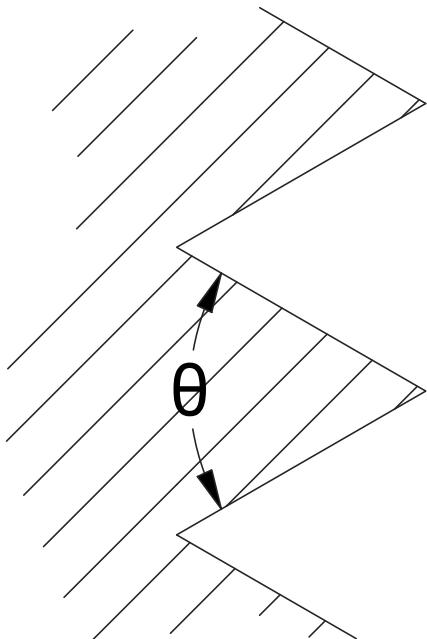


Figure 2—Diagram depicting flank angle, represented by  $\theta$ .

To begin to address the confusion regarding pipe threads, it is helpful to take a step back and investigate some of the reasons for this confusion, some of which are listed below:

Different designations use the same nominal sizes (e.g., 1/2), even though they may have different thread profiles, dimensions, and tolerances.

Some of the designations have similar letters in the nomenclature but are not necessarily equivalent (NPT, BSPT, PT).

Certain historical designations are still extensively used, such as BSPP and BSPT.

Certain sizes of different thread standards can be screwed together, but not in a leak-proof manner. This means that physically fitting two threads together does not guarantee proper fit and leak prevention.

Different thread types require different sealing methods (sealant, O-ring, etc.).

Within each standard, the relationships between thread series are clear. Problems mainly arise from attempts to combine threads from different standards. The next section will address some of these problems and clarify which thread series are equivalent and compatible, and which are not.

## Thread Compatibility

A compatibility chart of selected thread series is shown below in Table 2.

The cases of partial compatibility listed in Table 2 are mainly attributable to the tolerance difference between Rp and internal G threads, as shown in Figure 3. These two thread series have identical nominal dimensions but have different tolerances on the pitch diameter. The internal G thread has a  $+/0$  tolerance above the nominal value while the Rp thread has a  $\pm$  tolerance (Refs. 5, 6).

For the Partial<sub>1</sub> case, this means that there will not be issues threading parts together, but the use of a thread sealant is especially critical.

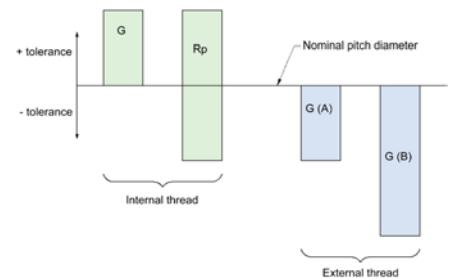


Figure 3—Comparison between pitch diameter tolerance of G and Rp series.

The bigger issue arises in the Partial<sub>2</sub> case. External G threads come in two classes (A and B), which both have a 0/- tolerance, and therefore there is no interference risk when threading into an internal G thread. However, when attempting to thread into an Rp internal thread, it is possible that the external thread pitch diameter will be larger than the internal thread pitch diameter. In this situation, it would be extremely difficult, if not impossible, to physically thread the external thread in.

		Internal Thread					
		NPT	NPSC	Rp, PS	Rc, PT	G, BSPP, PF	BSPT
External Thread	NPT	Yes	Yes	No	No	No	No
	R, BSPT, PT	No	No	Yes	Yes	Partial <sub>1</sub>	Yes
	G, BSPP, PF	No	No	Partial <sub>2</sub>	No	Yes	No

Table 2—Compatibility between selected thread series, with equivalent series grouped together.

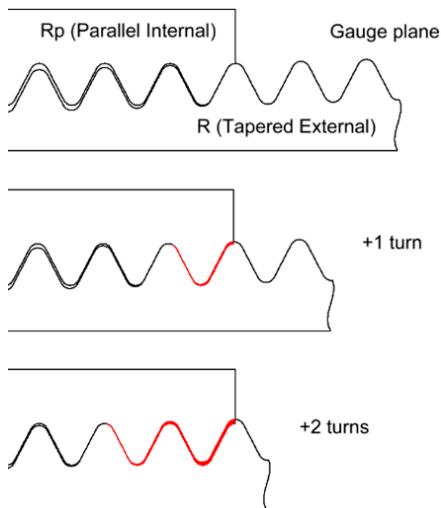


Figure 4—Diagram showing the connection between R 1/2 and Rp 1/2. The red area indicates where plastic deformation leading to a seal occurs.

Another important topic is the relationship between NPT and the ISO thread series. These two families of threads have different flank angles and root shapes and are not compatible with one another (see Table 2). However, it is sometimes possible to physically thread these two series together due to similar thread pitch and pitch diameters. This is especially true of the sizes designated 1/2 and

3/4 because the thread pitches of these sizes are exactly the same for both standards (Ref. 9). Although it may be possible in certain circumstances to physically thread these two series together, a pressure-tight seal is unlikely and certainly not guaranteed.

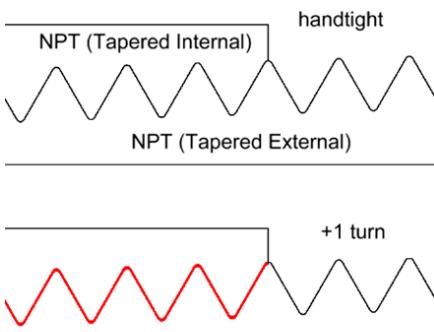


Figure 5—Diagram showing a 1/2-14 NPT connection. The red area indicates where plastic deformation leading to a seal occurs.

Figure 4 shows an engagement between an R thread and Rp thread (which are designed to mate with each other). As the external thread is tightened beyond the gauge plane with a wrench, plastic deformation leads to sealing. Similarly, a

complete seal on the threads occurs with an NPT connection, as shown in Figure 5. Remember that both connections require a sealant to guarantee a pressure-tight seal.

When an R external thread is threaded into an NPT internal thread (see Figure 6), problems begin to arise. In this case, the difference in flank angle and root/crest shape mean that portions of the threads will begin to experience excessive plastic deformation while other areas (mainly at the roots of the internal thread) will still have clearance between the threads. This can lead to a phenomenon known as “spiral leakage” (Ref. 4).

The situation is even worse when an external NPT thread is threaded into an internal Rp tapped hole or fitting, as shown in Figure 7. In this case, the gaps remaining between portions of the two threads are even more pronounced despite excessive interference in other areas. Whatever the combination may be, a connection between an American National Standard thread (e.g., NPT) and an ISO thread (e.g., Rp or G) is not recommended and should not be used.

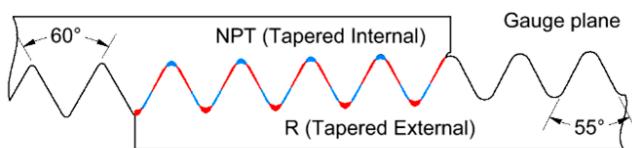


Figure 6—Diagram showing a connection between R 1/2 and 1/2-14 NPT. The red areas indicate where plastic deformation occurs and the blue areas indicate where clearance is present in between areas of interference. Note the small regions of clearance in the roots of the NPT thread at +1 turn.

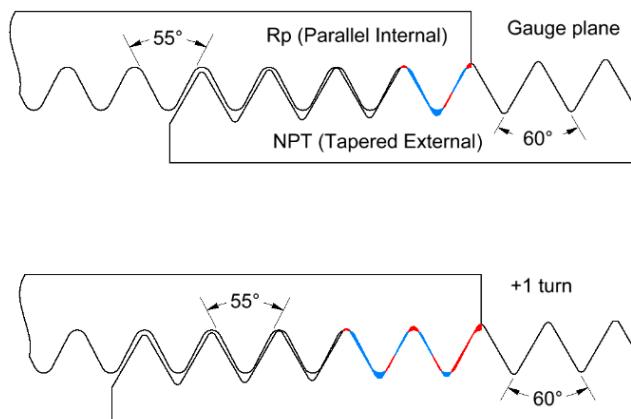


Figure 7—Diagram showing a connection between 1/2-14 NPT and Rp 1/2. The red areas indicate where plastic deformation occurs, and the blue areas indicate where clearance is present in between areas of interference.

## Conclusion

The preceding information on pipe thread compatibility is critical for anyone who is designing, inspecting, or assembling a threaded connection. For applications where maintaining pressure or sealing is necessary, one must ensure that the correct threads are being used. It is not safe to assume that a connection is adequate just because the threads can be screwed together. For this reason, controlling plug and fitting inventory is crucial because different thread series often cannot be easily distinguished from one another.

When using 55° flank angle threads (i.e., ISO, BS, and JIS thread designations), the best approach is to specify the G or R series instead of BSPP/BSPT or PT/PF/PS. The G and R designations are not only the correct designations according to the latest ISO, BS, and JIS standards, but also help to eliminate confusion and misinterpretation. In particular, extreme caution must be taken

when working with the old British Standard designations. “BSP” is often used to indicate BSPP, but this is not always the case. Similarly, BSPT on an internal thread would most likely indicate a tapered internal thread (i.e., Rc) but may actually refer to a parallel internal thread (i.e., Rp). Be sure to clarify with vendors exactly what thread series is being supplied and use the G and R designations on all new designs wherever possible.

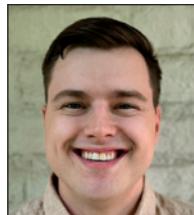
In addition to the items brought up in this paper, there are a variety of other variables to consider when designing, inspecting, and assembling pipe threads. The material of both parts, the internal pressure, the sealant used, the type of fluid inside, and other factors can all have a substantial impact on the threaded connection. That being said, this paper will equip you with the basic knowledge you need to handle threaded connections with confidence.

**PTE**

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**Tyler Sorenson** has been working as an R&D Engineer at Sumitomo Machinery Corp. of America for three years. He has a B.S. degree in Mechanical Engineering from Brigham Young University.

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to our core values," states Bob Mainz, president of Zero-Max.

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## STLE Releases Sustainability Report

Published July 2024

**Sustainability Opportunities for Tribology**

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The Society of Tribologists and Lubrication Engineers (STLE) is pleased to announce the release of its new free digital special report, *Sustainability Opportunities for Tribology*.

This special report summarizes key findings discussed at the Sustainability Forum during the 2024 STLE Annual Meeting & Exhibition. It explores views on sustainability in the lubricants community, sustainability of electric vehicles, the value of sustainability in manufacturing and more.

"Regarding sustainability, it is crucial to acknowledge the long-term advantages of saving energy, lowering emissions and eventually reducing operating costs," said STLE President Jack McKenna, Sea-Land Chemical Company. "This special report acknowledges that as more organizations implement sustainability using proper tribology practices, the benefits will become apparent leading to acceptance that lubricant use is a critical part of the move toward sustainability."

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October 5-9

## WEFTEC 2024

WEFTEC - Where the water community comes to connect. No matter the obstacles, through changes and challenges, water professionals keep going, learning, and doing what's necessary to provide safe, clean water. At WEFTEC, (New Orleans) the full breadth of the water sector comes together, in one place, for attendees to explore, learn, network, grow professionally, and strengthen their connection to the water community. The show offers water quality education, leading experts and the latest technology and trends. Exhibitors include ABB, Eaton, Emerson, Nidec, WEG and more.

[powertransmission.com/events/902-weftec-2024](http://powertransmission.com/events/902-weftec-2024)

November 3-6

## Pack Expo International 2024



Pack Expo International (Chicago) is produced by PMMI, the Association for Packaging and Processing Technologies. North America's largest packaging event will bring together the solutions needed to launch new products and solve production issues. Corporate managers, engineers, sales managers, plant managers, manufacturers and production supervisors, brand and marketing managers, quality controllers, purchasers, research/development and package designers from a wide variety of consumer-packaged goods companies (CPGs) will be in attendance. Exhibitors will display state-of-the-art technologies, equipment and materials.

[powertransmission.com/events/988-pack-expo-international-2024](http://powertransmission.com/events/988-pack-expo-international-2024)

November 19-22

## Formnext 2024



Formnext (Frankfurt, Germany) is an entire platform for companies from the world of additive manufacturing. Here, design and product development, industrial tooling, production solutions, quality management, and measurement technology comes together with leading providers in basic materials and component construction. The show will explore clever ways in which AM can be integrated into process chains in industrial production. In addition, top international speakers and other experts will be on hand to engage conference attendees. A permanent fixture on the international AM calendar, Formnext has been providing an AM platform for businesses to present themselves to customers, partners, and potential investors for eight years.

[powertransmission.com/events/908-formnext-2024](http://powertransmission.com/events/908-formnext-2024)

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# The AI Up There

## In our data-driven future, Maverick won't need a wingman

Matthew Jaster, Senior Editor



There's no such thing as "Too Much Information" when it comes to warfare. Lockheed Martin believes it's critical in today's global landscape for a warfighter to act on information as soon as it is available. Leveraging the strengths of manned/unmanned teaming enables rapid action during combat situations. With the assistance of AI, this has the potential to increase situational awareness and improve combat efficiency and effectiveness for any warfighter.

The U.S. Air Force partnered with Lockheed Martin Skunk Works to tackle an experiment known as "Have Raider." This project was designed to demonstrate the technologies required for an unmanned vehicle to fly as a teammate with a manned vehicle in a battlespace.

Using an experimental F-16 as a surrogate unmanned aircraft, the demonstration proved the ability to autonomously plan and execute air-to-ground strike missions, fly in formation with a manned aircraft and react to changing threat environments. This is an AI-based case study that might force *Microsoft Copilot* to consider a name change.

The research demonstrated that effective manned/unmanned teaming in fighter jets reduces the high cognitive workload, allowing the warfighter to focus on creative and complex planning and management. Autonomous systems also can access hazardous mission environments, react more quickly, and provide persistent capabilities without fatigue. They consider the "Have Raider" program a critical step to enabling future loyal wingman technology development and operational transition programs—cue the Kenny Loggins soundtrack.

Lockheed Martin Skunk Works also recently partnered with the University of Iowa's Operator Performance Laboratory (OPL) to demonstrate the use of AI in air-to-air intercept scenarios.

The successful flights are a significant milestone for Skunk Works' Tactical AI team, in which AI directly flew and conducted tactical exercises with a full-scale, live aircraft—one of OPL's L-29 Delfin jets—using heading, speed and altitude commands. The team executed simulated-to-real transfer test objectives against a virtual adversary in offensive and defensive risk postures.

Eight test cases were conducted per flight to exercise the AI agent in a variety of situations, from standard head-to-head fights to off-aspect encounters, missile support and missile defeat scenarios. The team was encouraged to see clean sim-to-real transfer of learned behaviors and that the AI agent appeared intentional and decisive in its actions.

"This was the first live exercise of the new flight interface; it's thrilling to see the separate components successfully integrate on the L-29 to demonstrate new capabilities. The complete system performed even better in live flight than in simulation," said Dr. Tom "Mach" Schnell, OPL professor at Iowa Technology Institute.

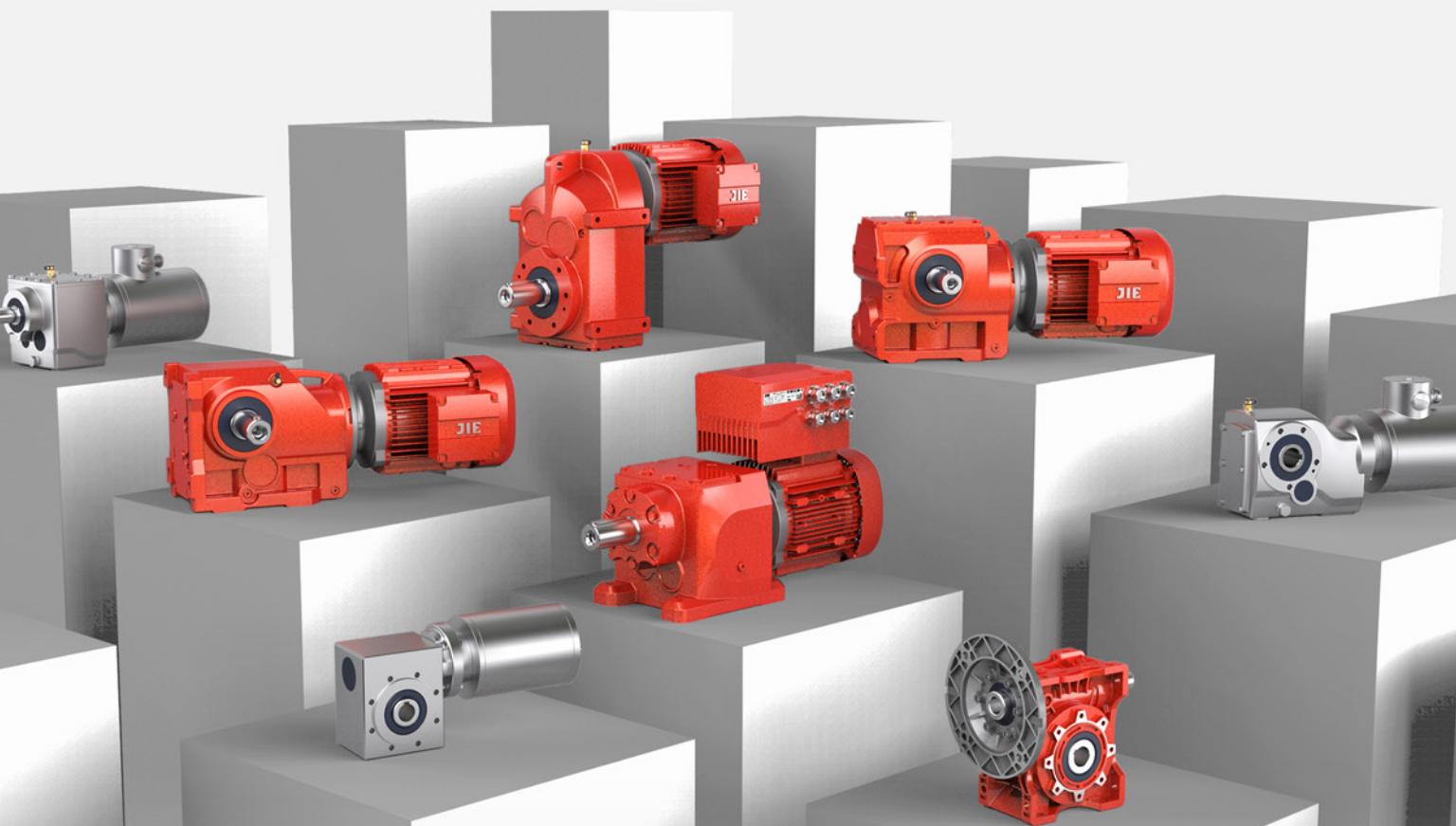
"Live flight tests are a crucial aspect of advancing our expertise in AI and autonomy. These flights are powerful demonstrations of our ability to quickly and affordably develop and test operationally relevant AI capabilities," said Matthew "Gabe" Beard, Lockheed Martin Skunk Works autonomy/AI and machine learning engineering manager.

These flight tests are part of a broader initiative to rapidly develop and test AI-driven autonomy for air-to-air missions. Several other flight tests are planned for this year, building on these achievements, and increasing the complexity by introducing additional aircraft into offensive counter air and battle management scenarios.

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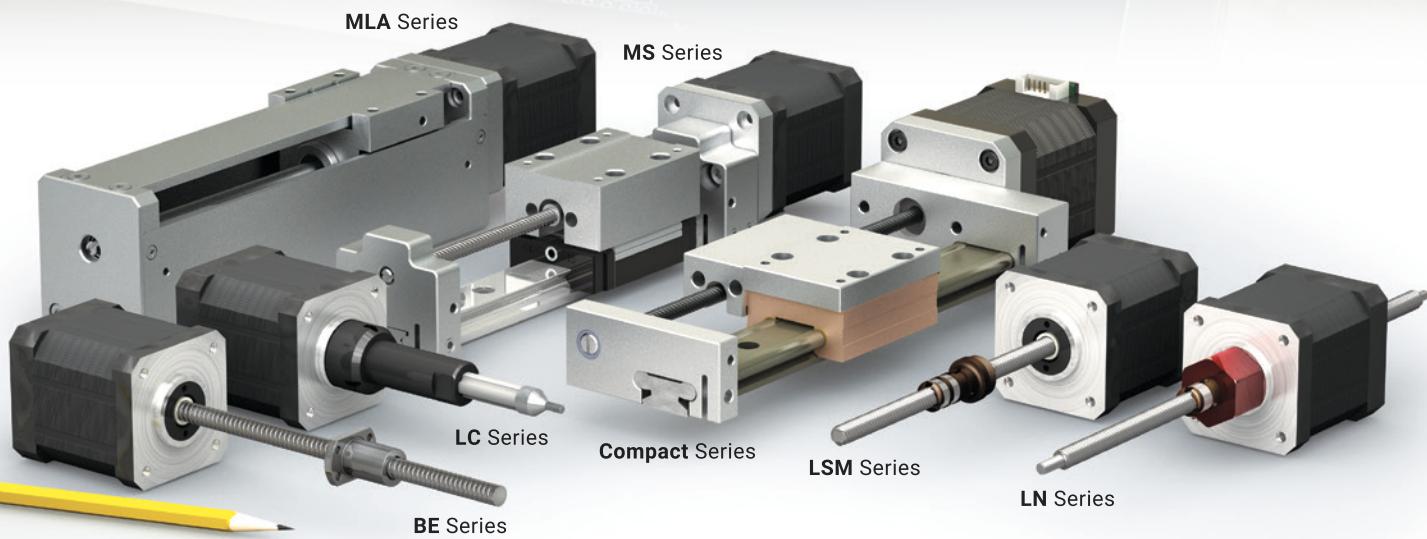
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