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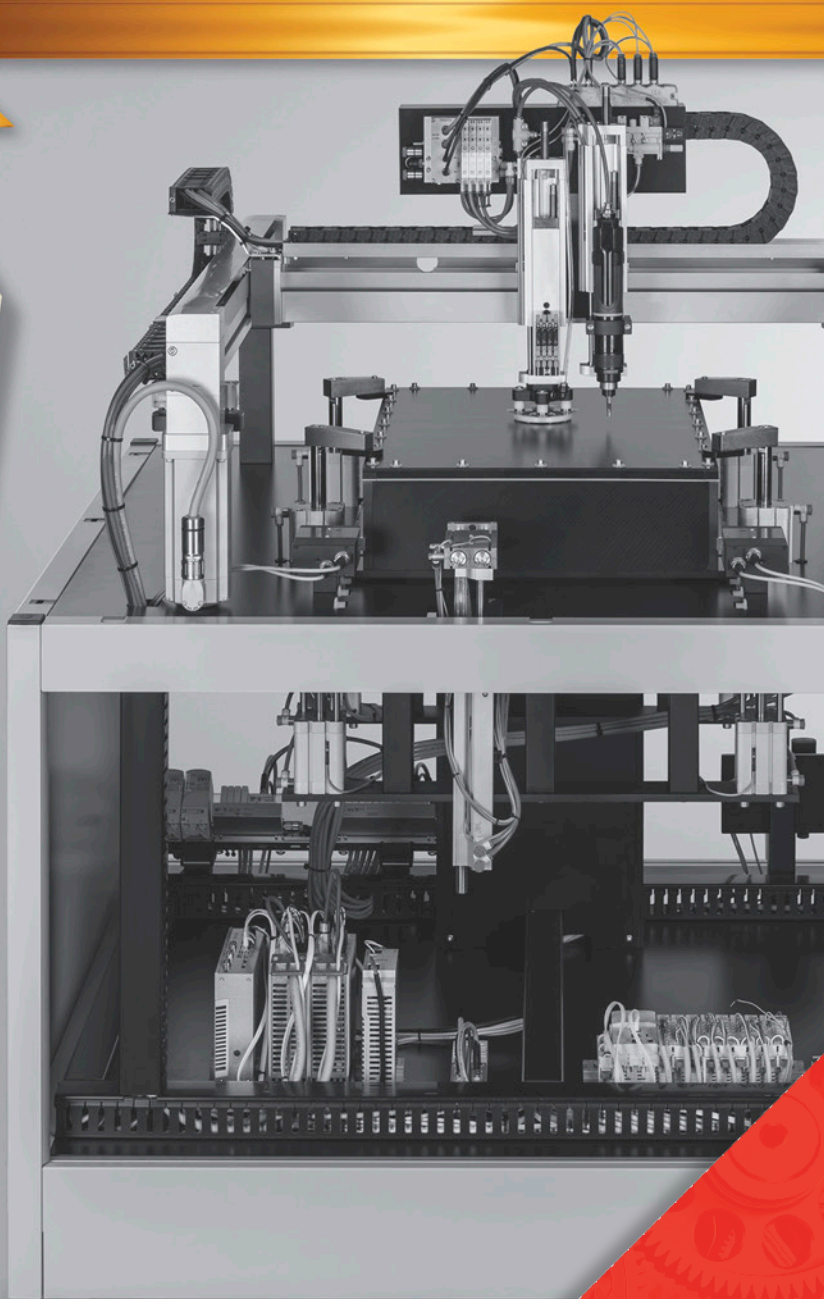
DECEMBER 2023

Linear Motion Systems in Washdown Applications

Bearing Considerations for Pumps and Compressors

Gearbox Development in Marine Transmissions



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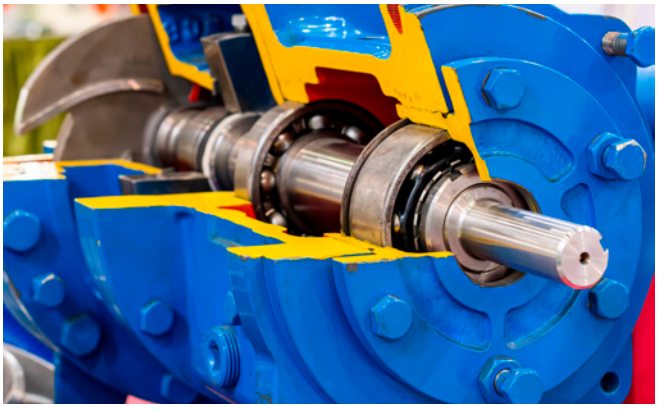

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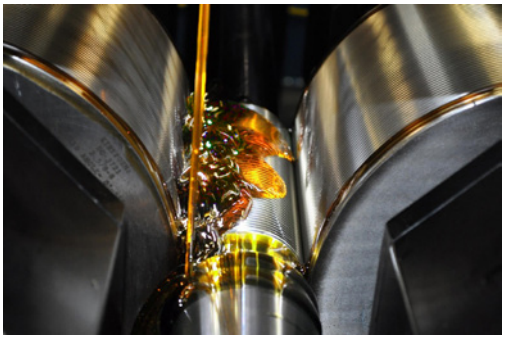

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TECHNICAL ARTICLES

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PTE Extras

Solid Edge 2024 Focuses on Performance and User Experience

Solid Edge is a portfolio of affordable, easy-to-use software tools that address all aspects of the product development process. Solid Edge combines the speed and simplicity of direct modeling with the flexibility and control of parametric design—made possible with synchronous technology. The following Q&A discusses Solid Edge 2024 with Dan Staples, vice president, mainstream engineering, Siemens Digital Industries Software.

powertransmission.com/blogs/1-revolutions/post/9525-solid-edge-2024-focuses-on-performance-and-user-experience

Omron i-Belt Solves Food & Beverages Challenges

Cleca, the San Martino-based company known for its sweets mix and savory dishes, chose Omron and its new IoT data analysis service to optimize the efficiency of its ready-made broth line, which was considered insufficient to meet current demand. The upgrade, performed without installing new machinery, has enabled the Mantuan brand to produce over 800,000 cartons from the line per month.

powertransmission.com/media/videos/play/250

Interact Analysis Revises Manufacturing Outlook Forecast

Global market intelligence firm Interact Analysis recently made some revisions to its global manufacturing outlook forecast. According to the company's latest research, the outlook for global manufacturing is bleak, and this looks set to continue throughout 2024 into early 2025.

powertransmission.com/blogs/1-revolutions/post/9511-interact-analysis-revises-manufacturing-outlook-forecast

EDITORIAL
Publisher & Editor-in-Chief
Randy Stott
stott@agma.org

Senior Editor
Matthew Jaster
jaster@agma.org

Senior Editor
Aaron Fagan
fagan@agma.org

GRAPHIC DESIGN
Graphic Designer
Jess Oglesby
oglesby@agma.org

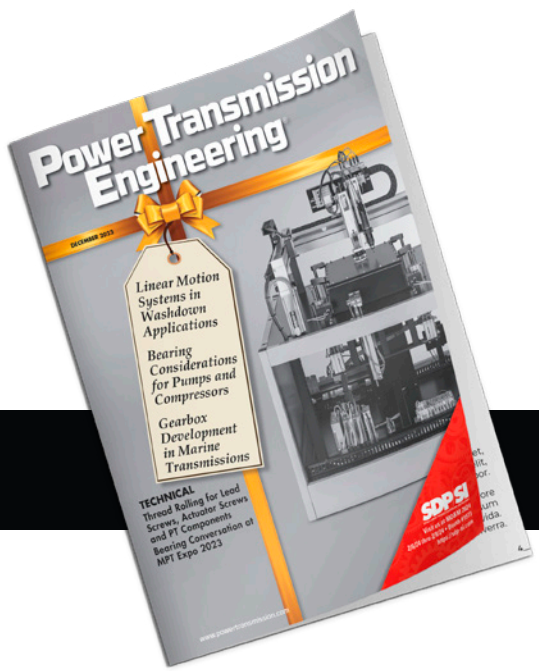
ADVERTISING
Advertising Sales Manager & Associate Publisher
Dave Friedman
friedman@agma.org

Materials Coordinator
Dorothy Fiandaca
fiandaca@agma.org

CIRCULATION
Circulation Manager
Carol Tratar
tratar@agma.org

MANAGEMENT
President
Matthew Croson
croson@agma.org

FOUNDER
Michael Goldstein founded *Gear Technology* in 1984 and *Power Transmission Engineering* in 2007, and he served as Publisher and Editor-in-Chief from 1984 through 2019. Michael continues working with both magazines in a consulting role and can be reached via e-mail at *michael@geartechnology.com*.



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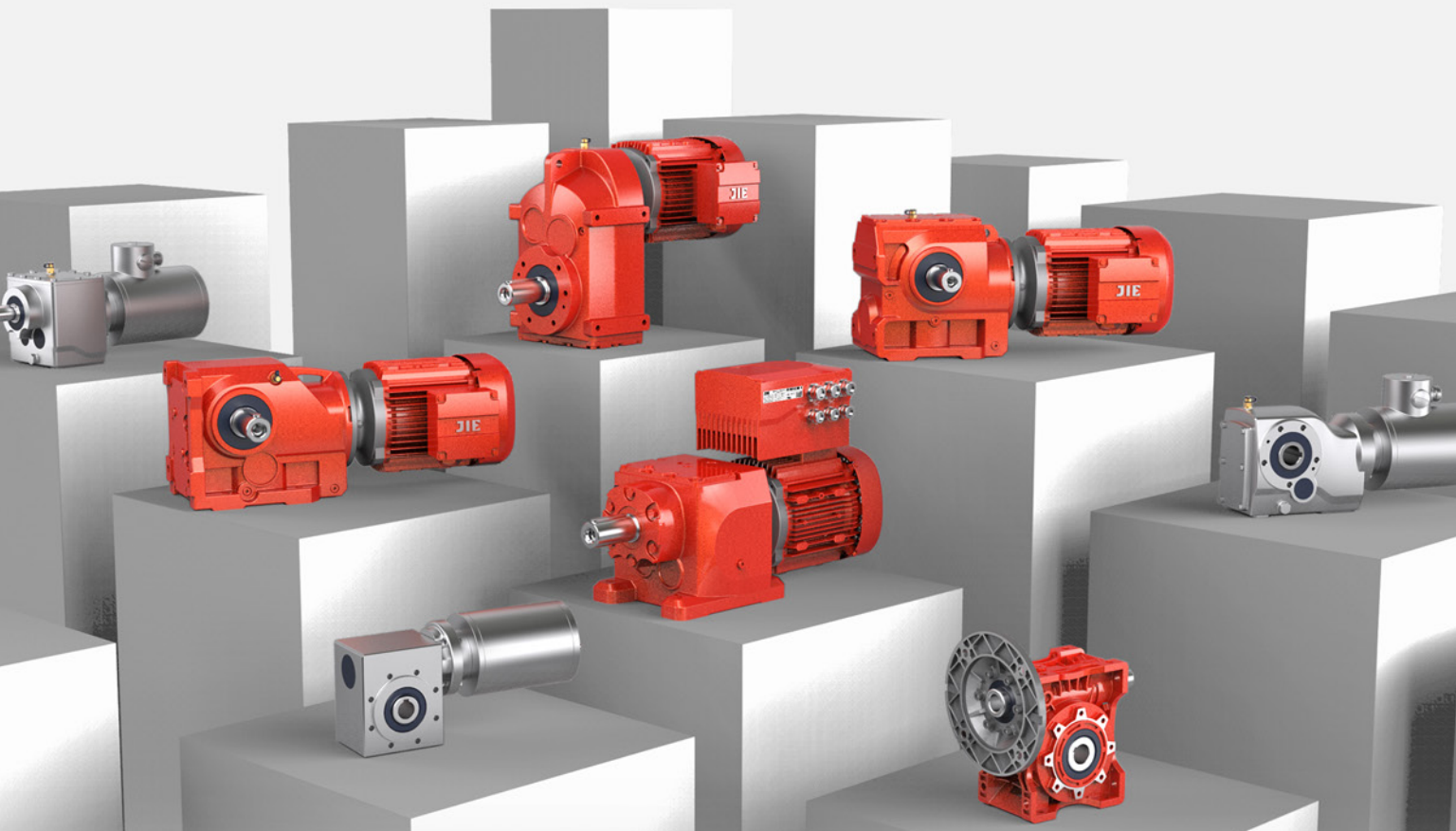

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Randy Stott
Publisher & Editor-in-Chief

Time Flies. Are We Having Fun Yet?

Wait, what? It's the end of the year already? How did that happen?

December is the sneakiest of months. I know it's out there, lurking behind the other months. But no matter how old I get, it always manages to creep up on me. I swear I only looked away for a day or two, but alas, December got me again. You'd think by now that I'd be ready, that I'd have more of a clue about how time works. But no, apparently not. Here I am again, surprised that the year is almost over.

I suspect I'm not alone in this.

I guess that's just how it goes when you're busy. When I look back at 2023 and really think about everything I've experienced and accomplished, I recognize that I've had a whirlwind year. For my wife, Wendy, and I, that's included our son's wedding (Congratulations, Matt!), our daughter's college graduation (Congratulations, Diana!), a couple of funerals, a family vacation that included our other two daughters (Becca and Renee), a road trip and much, much more.

And that's just the personal side. Here at AGMA Media, we've been extremely busy, too. We've managed to send our team to multiple industry events, including some far away, like Hannover Messe and the VDI International Conference on Gears, some closer to home, like MPT Expo, the Turbomachinery and Pump Symposia, Automate and many more.

We've also been extremely busy finding new ways to bring you content. We launched the flipbook version of our magazine in addition to the HTML and PDF versions of each article. We've also significantly ramped up our social media presence. Hopefully you've noticed our increased activity on LinkedIn, Facebook and Twitter. We're also launching Power Transmission Engineering TV on YouTube (with fresh new video content prepared by our editorial team). Stay tuned as we continue to add content there throughout the year.

In addition, we've spent a lot of time preparing for next year. Our 2024 media kit is online at *powertransmission.com/adinfo*. This includes our schedule of topics we're planning to cover each issue and in our e-mail newsletter. It includes updated editorial guidelines for those of you who might be interested in submitting or contributing to articles. And, of course, there's also information about how to advertise—in print, online or via e-mail.

But most of all, what we've been up to in 2023 is producing a lot of really great content focused on mechanical power transmission and motion control. If you've missed any of it, you can just hop on over to *powertransmission.com/issues* to scroll through it all and get caught up.

So, yeah. Time flies. But when you look back and realize how much you've accomplished in a year, it's easy to see that it was time well spent.

P.S. On behalf of the entire AGMA team, I'd like to wish all of you a safe, happy and healthy holiday season! See you in 2024!

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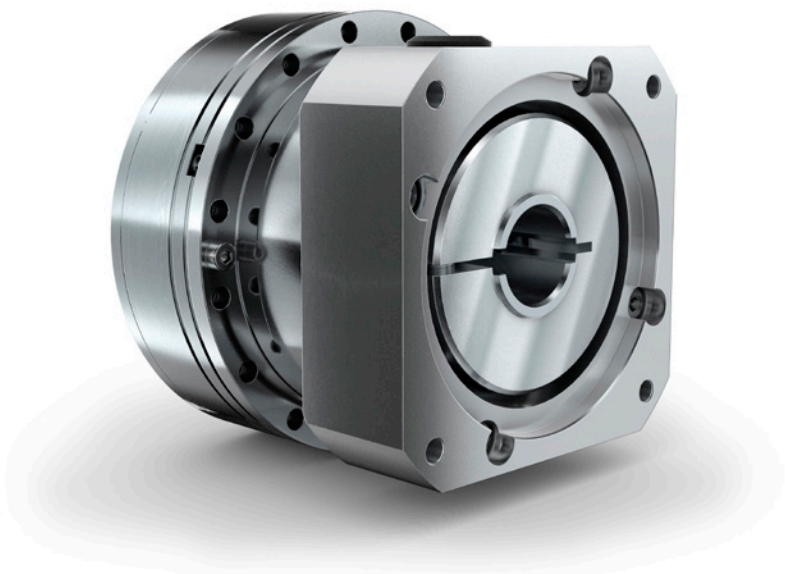
Sumitomo Drive Technologies

PRESENTS NEW GENERATION OF ITS ECY SHAFT GEAR SERIES



Sumitomo Drive Technologies is expanding its range of precision gear products and upgrading its ECY series with higher torque and a plug & play drive for motor connection. The ECY series comprises high-precision shaft gears, used for example for surface machining in dental technology or in collaborative robots (cobots). Thanks to their internal cylindrical roller bearings, the gear units provide both high rigidity and higher performance in a smaller design envelope.

With this new generation, Sumitomo Drive Technologies has once again significantly increased the torque density of the gears, enhancing the internal structure while maintaining the same gear principle and external dimensions. The new ECY 203 and ECY 205 units deliver a more than 30 percent improvement in performance levels, in terms of nominal (rated) torque, acceleration torque, and emergency stop torque, compared with previous models. The maximum drive speed is up to 8,500 revolutions per minute, depending on the size.

Plug & Play Attachment to Any Motor

The ECY gears have also been upgraded in terms of flexibility. Thanks to a modular connection system, they can now be fitted to any motor directly at the factory. The modular gear input system enables short delivery times. The main body of the unit comes ex stock, with the flange assembly being based on the customer's requested input. Overall, the units' modularity helps boost the efficiency, flexibility, and cost-effectiveness of machinery and equipment.

"Our performance-enhanced generation of precision gears is based on a plug & play approach. The user benefits from a highly compact performance package that is ready for use. ECY shaft gears can be used in a wide range of demanding applications where exact positioning and high torsional stiffness are required. One standout feature is their ability to prevent ratcheting effects (i.e., unwanted teeth slippage). This is achieved by a significantly higher tooth contact area than cup-type gears," says Michael Berger, product manager motion control drives at Sumitomo Drive Technologies.

Bearings Ensure High Performance

The torsional stiffness of ECY gear units is around double that of an ordinary shaft gear of the same size. The drive shaft transmits the elliptical shape to two cylindrical roller bearings. Cylindrical roller bearings can transmit the radial force better than the ball bearings that are normally used. A cycloid spline is deformed by the bearing movement and transmits the torques at two symmetrically opposed tooth engagement areas through two further gears with internal toothing.

This means that around 30 percent of all teeth are permanently engaged. The difference of two teeth in these gears produces the transmission and a relative motion. The main bearing consists of a cross roller bearing capable of absorbing the highest radial and axial loads.

Precision and Versatility in High-Performance Applications

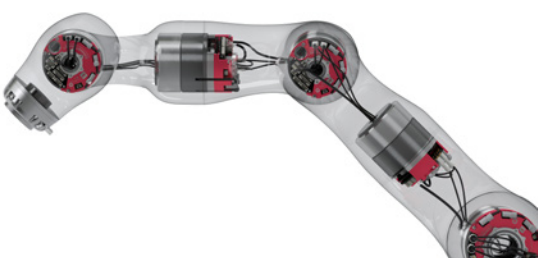
The ECY gear unit is ideal for high-precision applications and movements with maximum repeat accuracy. It offers further advantages for applications with a very small installation space as well as weight requirements or the need for a hollow shaft.

Its high rigidity ensures clean surfaces when drilling and milling, for example in medical technology. Other areas of application include semiconductor manufacturing, to enable precise movement and positioning of wafers and other components. In measuring technology, the units ensure precise alignment of optical components and high image quality. They also deliver optimal results when used in diamond grinders.

In addition, ECY precision gears demonstrate their full potential in cobot applications such as Sumitomo Drive Technologies' Tuaka precision hollow-shaft actuator (gear, motor, encoder, and safety driver), a completely integrated drive that won the prestigious Hermes Award last year.

ECY units are fully sealed and have a hollow shaft with an inside diameter of up to 25.5 mm for passing cables or media. The new generation of gears is available in two versions with acceleration torques of up to 107 Nm with compact outer diameters of 84 mm.

emeia.sumitomodrive.com/en-gb



Bodine Electric Company

INTRODUCES NEW STAINLESS-STEEL HOLLOW SHAFT GEARMOTORS

Bodine Electric Company introduces six new type 56R1-50JW/H stainless-steel hollow shaft gearmotors. These new geared motors combine a stainless-steel AC inverter-duty, 230/460 VAC motor with a stainless-steel hollow shaft gearhead. When used with an AC inverter (VFD) control, these gearmotors deliver variable speed and maintenance free operation over a wide speed range. Ideal for equipment that is subject to intensive cleaning, these new gearmotors also meet EU hygienic standards for food machinery. They are suitable for use in the food and beverage industry, pharmaceutical industry, and in permanently wet environments.

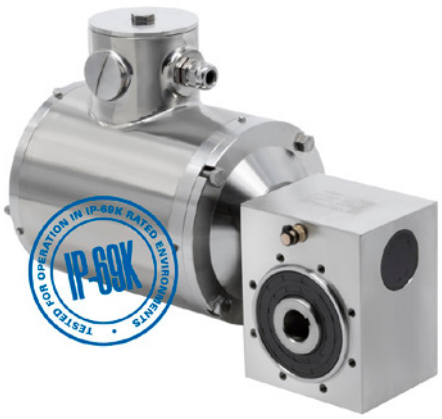
Designed to withstand constant exposure to high-pressure water washdowns, Bodine's new 56R1-50JW/H gearmotors feature high-grade, corrosion resistant stainless-steel housings and are fully watertight. The gearmotor's smooth surface allows thorough and efficient cleaning, reducing the possibility of bacteria growth. The totally enclosed, nonventilated (TENV) motor prevents airborne re-contamination caused by air movement from a cooling fan. The large, water-tight junction box is in the 12 o'clock position for easy access. The gearmotors meet IP-69K standards.

Driven by a maintenance-free 1/2 hp AC inverter-duty 3 phase motor (230/460VAC), the gearmotors achieve up to 638 lb-in. (72 Nm) torque and speeds from 29 to 176 rpm. The sealed gearmotor is available with gear ratios from 10:1 to 60:1, and it utilizes food-grade lubricant.

The new type 50JW/H hollow shaft gearmotors optimize mounting space, simplify installation, and reduce the number of required parts. They can be connected directly to the driven load eliminating expensive shaft couplings and mounting hardware that can be unsafe, bulky, and present alignment issues. These hollow shaft gearmotors offer left- or right-hand face mounts for maximum application flexibility.

Bodine offers various accessories including a stainless-steel torque arm kit, a stainless-steel mounting flange kit, and single-extension and double-extension, 1-in. diameter stainless-steel shaft kits. Bodine also offers a stainless-steel shaft cover kit for the non-extension shaft side of the gearhead.

Bodine's new type 56R1-50JW/H gearmotors and accessories are



available through Bodine's extensive distributor network or from the Bodine website. Custom options are available to qualified OEMs. Typical OEM modifications include factory-installed mounting hardware, or the motor junction box rotated to the 3, 6, or 9 o'clock position.

bodine-electric.com

NKE Austria GmbH

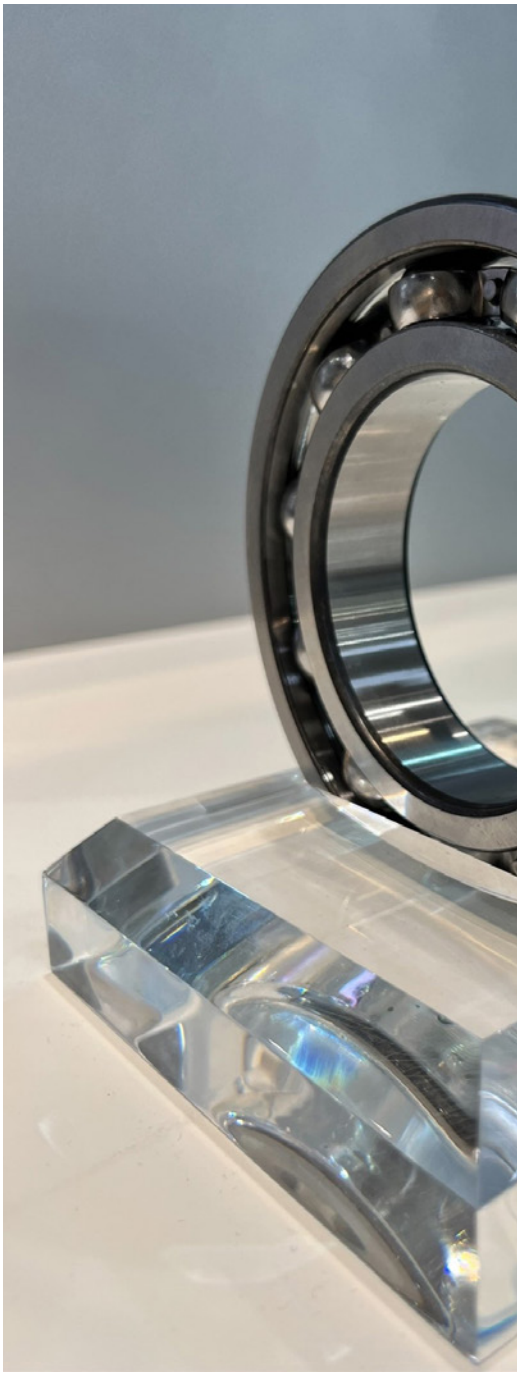
PRESENTS BEARINGS FOR RAILWAY APPLICATIONS

NKE Austria GmbH bearings are used in traction motors and locomotive gearboxes as well as in railcars, trams and underground trains.

When designing a rail vehicle, it is essential to consider factors such as loads, speeds, torques and installation space. These factors must be considered also when selecting the power transmission components. Bearings for gearboxes operate at high speeds and under high loads. They must be able to withstand shocks, vibration, and extreme temperatures. Bearings for traction motors are required to have long service life. The most used bearing types in rail vehicle gearboxes are cylindrical roller bearings, tapered roller bearings, angular contact ball bearings, four-point contact ball bearings and deep groove ball bearings. In traction motors, the most typical are cylindrical roller bearings and deep groove ball bearings. Often these bearing types are electrically insulated, with a corresponding coating on the outer or inner ring. For particularly demanding applications, hybrid variants are available. The rolling elements of hybrid bearings are made from heavy duty silicon nitride (Si3N4), an extremely hard-wearing ceramic. Bearings for gearboxes and traction motors can also be customized and produced to special specifications, for example higher thermal resistance or more stringent tolerance ranges.

"Our design of electrically insulated cylindrical roller bearings and deep groove ball bearings includes an oxide ceramic coating," said Klaus Grissenberger, application engineer with NKE in Steyr, Austria. "This offers simple, effective protection against bearing damage from current passing through the bearing."

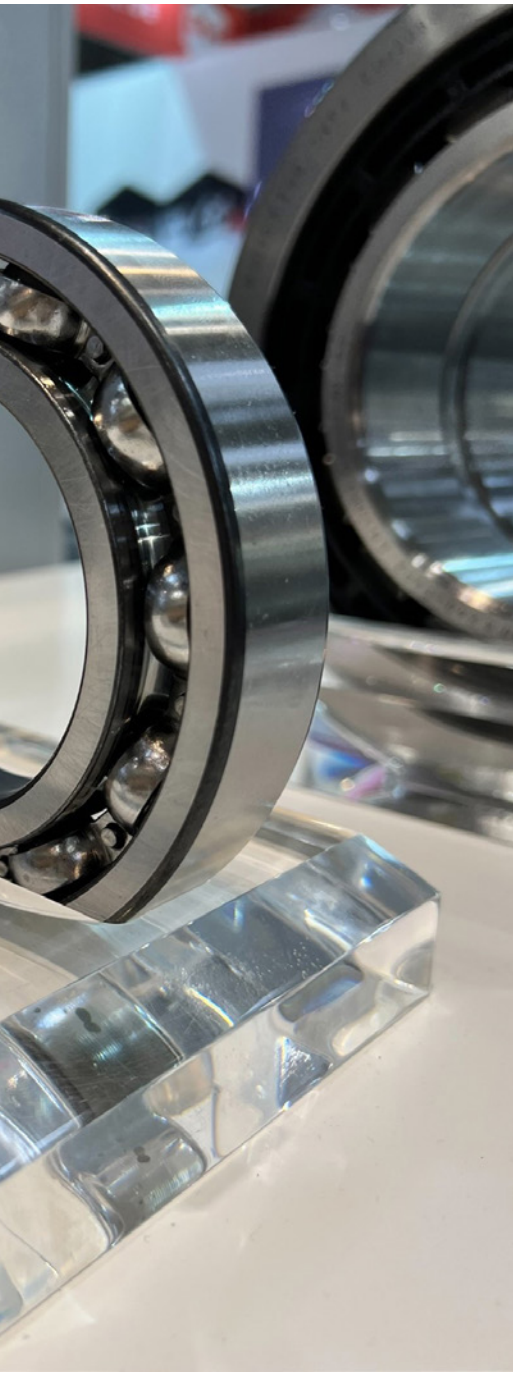
The insulation significantly reduces the risk of damaged raceways and premature ageing of the lubricant and has a dielectric strength of 1,000 V and 3,000 V with DC or AC voltage respectively. Electrically insulated bearings have the same dimensions and



technical properties as conventional bearings, so they are easily replaceable. Versions available are bearings with insulation on the outer ring (SQ77) or on the inner ring (SQ77E).

Hybrid deep groove ball bearings from NKE are noted for the extremely high degree of protection they offer against damaging bearing currents, prolonged service life - also of the lubricant -, exceptionally quiet running, and low friction and associated losses.

"Our hybrid deep groove ball and cylindrical bearings represent the premium solution for the prevention of current-induced bearing damage," said Grissenberger. "This is achieved due to the excellent material properties of the ceramic balls, for example outstanding compressive strength and rigidity, low density, and of course the highest possible electrical resistance."



When developing bearing solutions for railway applications, NKE's Applications Engineering department works closely with customers, which include well-known OEM manufacturers, railway operators and service providers. All bearings undergo rigorous, documented quality control procedures. Apart from product development, NKE also offers technical support in the selection of bearings, dimensioning, and condition assessment, and conducts training courses. Since 2005, the Austrian bearing manufacturer has delivered over 40,000 bearings for rail vehicles.

nke.at

Miki Pulley

EXPANDS RANGE OF BXR-LE BRAKES

Efficient power-saving braking for mobile robots is critical to minimize battery charging downtime. The new larger size Miki Pulley BXR-LE brakes are ideal for factories and similar applications using mobile robots.

These new BXR-LE brakes provide exact sequential motion and timed positioning. They apply holding torque after the motor joint stops and provide dynamic braking in the event of an emergency, such as a power interruption.

The Miki Pulley brake opens and allows for free rotation during robot movements and snaps closed when power is disengaged, thus halting position of the robot. When the robot is in position for long periods of time, the brake consumes no voltage. The brake's internal compression springs mechanically hold the armature plate against the rotor disc, ensuring no movement. When voltage is reapplied, the brake opens and allows for free movement.

The new power control module on these new brake sizes continuously steps voltage down from 24 V to 12 V to mitigate power usage and heat buildup.

These Miki Pulley brakes are a cost-effective safety device for all types of mobile robots including cobot systems. They are a positive "halt and hold" device to mitigate potential mechanical damage to an automated system.

An important operating feature: when compared to most other electric brakes, the unique Miki Pulley brake design is one-half the overall size thickness.

Specifications include three new sizes (06, 08,), maximum rpm of 5,000, static friction torque range of 0.044 ft.lb. to 2.36 ft.lb. (0.06 Nm to 3.20 Nm and an ambient operating temperature of 14°F–104°F (-10°C–40°C).

mikipulley.com

Renewable Lubricants

OFFERS BIO-BASED HYDRAULIC FLUIDS

Equipment fires can happen in any industry. Hot running equipment, and a leaking hydraulic seal or blown hose can be a disastrous combination because traditional hydraulic fluid has a flash point around 240°F, so if equipment has a problem due to overheating of the operating temperature of the liquid, traditional hydraulic fluid is already close to its flash point.

Bio-Ultimax 1000, a biosynthetic formula that directly replaces mineral oil based hydraulic fluids, has a flash point of 450°F. This 200-degree cushion can mean the difference between safety and catastrophe when a hydraulic hose breaks and sprays a hot running engine.

Bio-Ultimax 1000 is available in various weights including ISO 32, 46, 68 and 100. In addition to significantly higher flash points across the entire range, these bio-based products are safer for employees to handle. Should a hose break or a seal fail on a jobsite, the cleanup can be a nightmare for equipment with traditional hydraulic fluids. And an expensive one, especially if the problem occurs near a wetland, a watershed, near a storm sewer, or other sensitive areas. EPA mandated cleanup costs are pricey, with plenty of paperwork involved. Using bio-based, environmentally friendly

hydraulic fluids can eliminate the fines and speed the cleanup.

With oxidation performance comparable to full synthetics, this is one of the safest hydraulic fluids for the environment. These advances in safety are accompanied by performance that meets or exceeds that of traditional hydraulic fluids.

Ideal for stationary or mobile environments these super high Viscosity Index (VI) fluids are proven in systems up to 10,000 psi and in systems with ultra-fine filtration. To ensure performance and long life, Renewable Lubricants developed the stringent IsoGreen filtration standard which meets or exceeds the Rexroth pump guidelines for hydraulic fluids. Nontoxic, zinc-free formulations contain no heavy metals. In addition to enhancing performance, Renewable Lubricants (RL) helps companies achieve their sustainability goals. They are ideal for use in all types of hydraulic systems where low toxicity, biodegradability, and non-bioaccumulation properties are required.

These patented biobased hydraulic fluids are formulated to perform in high- and low-pressure hydraulic systems that require Anti-Wear (AW), anti-rust, antioxidation, antifoam, and demulisibility properties. With patented antioxidants (Stabilized), these biosynthetics provide improved performance in oxidation stability over standard plant/vegetable/HETG and unsaturated HEES type fluids. They are highly inhibited against moisture and rusting in both fresh and sea water, and pass A and B sequences of the ASTM D-665 Turbine Oil Rust Test. Formulated to provide a longer seal life with reduced oil leakage, this environmentally friendly, zinc-free product meets or exceeds high-pressure pump requirements.

Very little wear was encountered in field studies and in accelerated pump tests using biobased formulations in Denison T-5D, Vickers 20VQ, 35VQ-25 (M-2950-S), and V-104C (ASTM D-2882), Vickers I-286-S pump stand tests and pressures and temperatures ranging from 2,000 to 3,000 psi and from 150° to 210°F. Anti-wear performance exceeds requirements for US Steel 126, 136, and 127, load stage 10 in the FZG (DIN 51354) and GM (LS-2).

renewablelube.com

Deutronic USA

INTRODUCES HIGH-CAPACITY CHARGING COMPUTERS FOR OEM AND AFTERMARKET NEEDS

Deutronic has developed a new line of charging computers to supply reliable power to the 12V board net for EV or gas-powered vehicles in multiple environments in the North American market.

At 120 amps, the DBL 1903-14 line is the highest capacity power supply available in the market. A single-phase device with touchscreen controls, it is ideal for original equipment production line charging applications, assembly rework areas, and aftermarket dealer service and showroom environments. A unique automatic detection feature for OEM customers determines the connection to both lead-acid and lithium-ion batteries to deliver smart and safe charging to all vehicles. It's a key feature Verma believes will spark conversations with automotive industry executives.

"We have a history of being a good partner with the leading automotive and commercial vehicle OEMs around the world. With onboard power demands increasing and consumers expressing concerns over battery life, we think the timing is right for this high-power charging device," said Verma, Deutronic USA's general manager who is based in Spartanburg, SC.

Verma added that battery performance

is tracked in J.D. Power Initial Quality and Vehicle Dependability studies, a key customer experience measurement automakers closely follow.

"The DBL 1903-14 line represents the new generation of innovative battery chargers for use in manufacturing facilities and dealer service networks," added Wanzke, who leads business development efforts for parent company Deutronic in Germany. "It also offers tremendous added value with smart networking and Industry 4.0 qualifications, helping OEMs improve their speed to market with products."

The versatility of the DBL 1903-14 is an attractive benefit. Other key features include a user-friendly commissioning wizard and choice of 21 languages. Smart and safe charging or supplying output up to 120A is achieved through an automatic selection process between charging and FSV.

Suitable for lead-acid, gel, AGM, fleece and lithium-ion batteries, a clear selection menu is available for various charging programs: Pb, Li, FSV mode, and a PowerUp function with long-term charging for Pb/Li. Precise load detection guarantees the charger is switched on even at the lowest loads, and input ranges from 100-240VAC, with a permanent output current of 120A at 1,900 W.

deutronic.us

Burckhardt Compression

REVIVES STEEL MILL'S COMPRESSORS TO ENHANCE SUSTAINABILITY

Burckhardt Compression recently partnered with one of Europe's leading steelmaking mills undergoing a significant transformation. The mill aimed to convert one of its plants into a sustainable facility in compliance with stringent environmental guidelines. The project's critical aspect involved reviving four non-Burckhardt compressors that had been inactive for a decade. Acknowledging the crucial role of these compressors in steel production, the mill sought the expertise of Burckhardt Compression.

Addressing the challenges posed by the steel mill's transformation, Burckhardt Compression offered a comprehensive range of services, from major inspection and revamping to supplying necessary spare parts. Its efforts didn't stop at the compressors. The expert team from Burckhardt Compression also revamped auxiliary equipment such as motors and coolers. Its commitment to delivering a turnkey solution within a tight schedule and budget demonstrates its leadership in the realm of compressor technology.

The task at hand required expert knowledge and precise execution within a tight schedule and budget. Alongside the overhaul of the compressors, auxiliary equipment such as motors and coolers also needed an upgrade. A full-service solution was required, and Burckhardt Compression was well-positioned to deliver.

The company's expert team dived into the project, conducting a major inspection, revamp, and upgrade of all four compressors. It inspected the electrical motors and refurbished the lube oil coolers. The team also updated the instrumentation, performed calculations for increasing discharge pressure, and supplied necessary spare parts. The project's success was due to the broad expertise of Burckhardt Compression's team and the company's ability to provide comprehensive, customized solutions.

Despite the challenging nature of the project, Burckhardt Compression maintained its commitment to quality and safety. The result was a set of revitalized compressors optimized for improved performance, ensuring their reliable operation.

The client acknowledged Burckhardt Compression's technical acumen, quick response to challenges, and commitment to safety. A spokesperson for the steel manufacturing facility stated, "Burckhardt Compression has been a crucial partner in our journey towards sustainable steelmaking. Its dedication and skill ensured our compressors were not only revived but also optimized for enhanced performance."

burckhardtcompression.com

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FEATURE

FVA-Workbench Drives Progress in Marine Transmissions at Reintjes

A calculation platform suitable for all areas of gearbox development

FVA GmbH

Reintjes is an internationally recognized marine powertrain specialist. Reintjes focuses on customer-oriented requests and special requirements in the development of their drive solutions. To provide this level of specialized services to customers, management places great importance on the flexibility of Reintjes catalogs. This continually poses new challenges for the drive specialists at Reintjes, such as adapting auxiliary systems for existing drives, developing retrofitting solutions, and offering flexibly configurable drives. This ensures that Reintjes is already able to offer hybrid drives as standard solutions. Klaus Deleroi, managing director at Reintjes, confirms: "As a globally operating mid-sized company, it is not always easy to react flexibly to the market. However, with the tools that the *FVA-Workbench* provides us, we are well equipped!"

Automation Simplifies Processes and Saves Time at Reintjes

Developing a new gearbox series is costly and time-consuming. This is especially true in marine propulsion, as classification society certifications must be achieved in addition to the required verifications. For this reason, Reintjes offers the same drives for various types of ships. In gearbox development, this means that each application requires different loads and usage profiles, with different service lives and maintenance intervals. Thus, each drive must be designed and calculated with advance consideration of every possible profile.

These calculations can be completely automated with the *FVA-Workbench*. Easy-to-use scripting functions can be implemented and combined for fast automation of processes without previous experience. First, the usage profiles are loaded from the database. Scripts then apply loads to the gearbox and perform automated calculations. Finally, the results are compiled and output.

Reintjes uses the FVA-Workbench for design as well as technical calculations which allows them to capitalize on synergies in the development process.

New power density requirements, power take-off/take-in options (PTO/PTI), and special customer requests make it necessary to update the Reintjes catalogs in ever-faster cycles. The *FVA-Workbench* is perfect for this task. Gear data is read from a database and the gearbox models are automatically adapted in an automated calculation process. The loads are then applied, and the calculation is started. As a result, the catalog data can be exported. This makes updating the catalogs fast and easy.

Before the *FVA-Workbench* was implemented, updating the catalogs was a manual process in which models were adapted by hand and the results were copied into a table. Updating the entire catalog kept several people occupied for an entire week. Thanks to the available scripts in the *FVA-Workbench*, this has been reduced to a few hours. It also ensures that there are no copying errors, a source of error that could never be completely avoided with manual work. Dr. Hagen Birkholz, head of development at Reintjes, confirms: "The *FVA-Workbench* makes it easy to create automations. The resulting cost and time savings allow our experts to focus on other things, which in turn benefits our customers."

Design Department Calculations

To capitalize on synergies in the development process, Reintjes uses the *FVA-Workbench* for design as well as technical calculations. As the external dimensions and bearing arrangements are key to the design process, a switch was added at Reintjes' request to simplify gear calculations. The influence of load distribution on the shaft bending line is typically considered in the *FVA-Workbench*, and the microgeometry design plays a decisive role. The new switch makes it possible to assume constant gear loads during the design process, based on the assumption that a suitable microgeometry design is already available. This allows the design department to calculate the bearing life using the same tool as the technical calculations, which not only guarantees consistent results but also makes continuous and seamless product development processes possible. Furthermore, the same databases and scripts for creating technical calculation models can also be used. This makes it quick and easy to perform design changes, such as adding a new gear ratio to an existing gearbox.

This close contact with customers is important to the *FVA-Workbench* development team. This makes it possible for them to respond quickly and easily to customer requests and help.

Report Templates Streamline Classification Society Certifications

To be insured, all critical marine technology products must be certified by a classification society. This includes the gearbox, propulsion device, and more. The classification society rules specify calculation approaches and minimum safety levels for gearboxes. For example, the port entry of a yacht and a working vessel clearly have different gearbox requirements. Of course, these calculation approaches are also integrated into the *FVA-Workbench*. This greatly simplifies the design of marine transmissions.

The customizable reporting system in the *FVA-Workbench* supports companies like Reintjes in the certification of their products. This integrated feature makes it easy to create report templates that include all required information for certifications. Instead of sorting through cumbersome PDF output files, the visualization of outputs in the *FVA-Workbench* provides a clear and simple overview.

Conclusion

The automation options in the *FVA-Workbench* make it easy to perform recurring processes. Models can automatically be built, mass calculations can be configured, and results can be exported. Simple workflows as well as complex processes can be automated with well-documented and easy-to-use scripting commands. This creates additional time for innovation.

The *FVA-Workbench* calculation platform is suitable for all areas of gearbox development. With simple standardized component calculations and detailed simulations, the *FVA-Workbench* can already be used during the design phase. This saves time, allowing errors to be detected and corrected earlier in the process, and eliminates interface problems.

Furthermore, the large number of calculation approaches in the *FVA-Workbench* makes it possible to quickly design drive systems per requirements. This is of particular interest to the shipbuilding industry, as it makes it easy to apply the extensive classification society rules.

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Bearing Design Considerations for Pumps and Compressors

Loads, life, fits, material, and lubrication must all be evaluated to ensure optimal performance of turbomachinery.

Mark Manegold, Technical Marketing Manager, AST Bearings

Pumps and compressors are ubiquitous in industrial settings. These machines can be found anywhere there is a need to transport liquids or circulate or compress gasses. Manufacturing, chemical processing, food and beverage, construction, mining, oil and gas, agriculture, and power generation industries all employ the use of turbomachinery. Reliability and minimizing downtime are critical in these applications. Rolling bearings are integral to the operation of pumps and compressors and must be able to withstand moderate to heavy loading and harsh operating environments. A wide variety of ball, roller, and needle bearings can be found in these machines; however, this article will focus on the most common type of bearing used, the deep groove ball bearing.

Benefits of using deep groove ball bearings include the ability to handle high speeds and carry loads in the radial—and to a lesser extent—axial, directions. To ensure reliable and efficient operation, correct bearing selection is an essential step in the design process of pumps and compressors. It is important to perform an analysis of the components and operating conditions from both a static and dynamic perspective to gain a complete understanding of the loads (both magnitude and direction) the bearings will encounter in the application. Deep groove ball bearings are designed to primarily carry radial loads , but they can also support moderate axial loads as well. In most turbomachinery applications, bearings are subjected to both radial and axial, or combined, loading. Once the loading is understood, the basic bearing life is calculated and then adjusted if necessary. This adjusted life is then compared to the desired design life to determine if the bearing is suitable for the application. Lastly, specifications including shaft and housing fits, bearing material, and lubrication need to be determined.

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Bearing Load Ratings

Manufacturers of ball bearings typically publish load ratings—both static (C_{or}) and dynamic (C_r)—for each bearing part number they produce. The static load rating, or static capacity, is the amount of load a non-rotating bearing can support without causing permanent deformation to its rings and/or balls. Industry standards specify that a total deformation of 0.0001 of the rolling element diameter (at the center of the most heavily loaded element) is acceptable for most bearing applications. The dynamic load rating, or dynamic capacity, is the amount of constant radial load a rotating bearing can withstand for one million revolutions. While the methods used to calculate load ratings vary from one manufacturer to the next, both the American Bearing Manufacturers Association (ABMA) and the International Organization for Standardization (ISO) have published equivalent standards related to load ratings and bearing life:

- ABMA Standard 9—Load Ratings and Fatigue Life for Ball Bearings
- ISO 76—Rolling Bearings—Static Load Ratings
- ISO 281—Rolling Bearings—Dynamic Load Ratings and Rating Life

Industrial compressor refrigeration station in a manufacturing facility.

An important point to remember about load ratings: the static and dynamic load ratings are derived differently and have no direct relationship. While both load ratings depend on bearing component geometry, the static load rating also depends on the applicable contact stress level, whereas the dynamic capacity depends on the accuracy to which the components are manufactured and the quality of the material used.

Bearing Life

The inner and outer rings of a radial ball bearing are constantly loaded during rotation. This produces material fatigue which eventually leads to bearing failure. The bearing life of individual bearings can vary considerably, even if they are of the same size, same material, and subject to the same operating conditions. For a statistically large group of identical bearings operating under the same conditions, basic rating life is the number of revolutions reached by 90 percent of the group of bearings prior to the first evidence of material fatigue. The basic rating life can also be expressed in hours. Examples of typical design life requirements for common operating conditions are shown in Table 1.

Both the ABMA and ISO standards use the same method to determine the basic rating life of a bearing. When the bearing experiences combined loading (both radial and axial loads) the standards provide a method to determine the equivalent radial load (P_r).The equation for the basic rating life of a dynamically loaded ball bearing is as follows:

$$L_{10} = \left(\frac{C_r}{P_r}\right)^3 \times 10^6$$

and

$$L_{10,h} = \frac{16667}{n} \times L_{10}$$

Where:
L_{10} = Basic Rating Life [revolutions]
C_r = Basic Dynamic Load Rating [N]
P_r = Equivalent Radial Load [N]
$L_{10,h}$ = Basic Rating Life [hours]
n = Operating Speed [rpm]

The basic rating life formula is acceptable for general use and correlates with 90 percent reliability, common material and manufacturing quality, and conventional operating conditions. However, for many applications where a reliability greater than 90 percent is required, and/or where there are special bearing properties or a deviation from conventional operating conditions, an adjusted rating life formula is used:

$$L_{na} = a_1 \times a_2 \times a_3 \times L_{10}$$

and

$$L_{na,h} = \frac{16667}{n} \times L_{na}$$

Where:
L_{na} = Adjusted Rating Life; Reliability of (100-n) % [revolutions]
a_1 = Life Adjustment Factor for Reliability
a_2 = Life Adjustment Factor for Special Bearing Properties (Material Type and Quality)
a_3 = Life Adjustment Factor for Operating Conditions
$L_{na,h}$ = Adjusted Rating Life; Reliability of (100-n) % [hours]
n = Operating Speed [rpm]

Life Adjustment Factor for Reliability, a_1

Bearing reliability is expressed as the percentage of a group of identical bearings operating under the same conditions that will attain or exceed a specified life. For the basic rating life, L_{10}, the bearing reliability is 90 percent and $a_1 = 1$. When a reliability greater than 90 percent is required, the corresponding life adjustment factor should be selected from Table 2.

Life Adjustment Factor for Special Bearing Properties, a_2

Special bearing properties can be accounted for by using the life adjustment factor a_2. Improvement in manufacturing techniques and heat treatment of bearing components have led to an extended fatigue life for bearings. Most bearing manufacturers commonly use a value of $a_2 = 1$, representing the use of high quality, vacuum degassed steel. However, a value of $a_2 > 1$ may be used if the bearing steel has an extremely low level of impurities. Conversely, if a hardness reduction is caused by a special heat treatment process, a value of $a_2 < 1$ should be applied. It is important to note it is not possible to define relationships between special bearing properties and the values of a_2. These values are determined through empirical means and can vary widely between suppliers. Always consult the bearing manufacturer before considering using an a_2 factor other than 1.

Life Adjustment Factor for Operating Conditions, a_3

Non-conventional operating conditions related to lubrication, speed, and mounting are considered with the life adjustment factor a_3. Under good lubrication conditions, i.e., a permanent oil film exists between the rolling elements and the rings, then $a_3 = 1$. In situations where the lubricant film thickness is less than the composite roughness of the two surfaces, $a_3 < 1$. If the rotational speed of the bearing is very low (mean bearing diameter times operating speed is ≤ 10,000) then a value $a_3 < 1$ is required. For designs in which a bearing is mounted to a shaft with a loose fit, a value of $a_3 < 1$ should be used.

Table 1 - Typical Design Life Requirements (hours)

Operating Condition	Basic Rating Life $L_{10,h}$
Infrequent operation	500
Short or intermittent operation; failure has little effect on function	4,000 - 8,000
Intermittent operation; failure has significant effect on function	8,000 - 12,000
8 hours of non-continuous operation	12,000 - 20,000
8 hours of continuous operation	20,000 - 30,000
24 hours of continuous operation	40,000 - 60,000
24 hours of guaranteed trouble-free operation	100,000 - 200,000

Table 2 - Life Adjustment Factor for Reliability, a_1

Reliability, %	90	91	92	93	94	95	96	97	98	99	99.6	99.9
a_1	1	0.92	0.84	0.77	0.64	0.62	0.53	0.44	0.33	0.21	0.1	0.037

Life Adjustment Factors—Additional Considerations

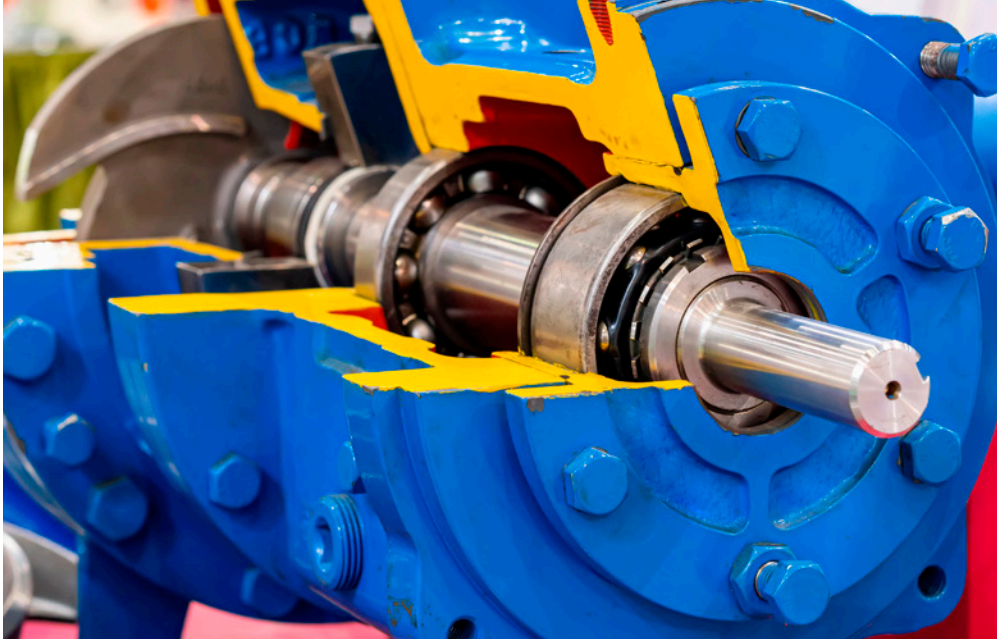
Pumps and compressors are often subjected to non-standard loading and operating conditions that may require further consideration beyond the life adjustment factors previously described. Additional life adjustment factors are typically provided by bearing manufacturers, based on empirical data. These include adjustments for:

- Sinusoidal loading (encountered in rotating and reciprocating machinery)
- Step loading (due to operating modes and/or external forces)
- Reversing loads
- Vibration
- Oscillation
- High speeds
- Inner ring versus outer ring rotation
- Temperature and environmental effects

Life adjustment factors allow engineers to develop a more accurate approximation for bearing life, specific to the application and/or operating conditions. Bearing manufacturers often use additional, proprietary factors in determining both load ratings and life calculations for their customers. Accordingly, it is important to consult with bearing manufacturers in conjunction with the previously referenced industry standards during the bearing selection process.

Bearing Fits

Selecting the proper shaft and housing fits is critical in optimizing a radial ball bearing's performance and life. Improper bearing fits—too loose or too tight—can cause undesirable operating conditions and premature failure. Fits that are too loose lead to damage of the housing bearing seat, reduced rotational accuracy, and excessive wear, noise, and vibration. Conversely, fits that are too tight will give rise to a reduction in radial play, overheating, or unintended preloading. Overly tight fits also require very large forces to mount a bearing on a shaft (or remove it). The internal design of a pump or compressor should allow for the support of the bearing rings across their entire width and circumference. In doing so, the entire load carrying capacity of the bearing will be utilized. The housing and shaft fits must be selected so that there is no creep, or slippage, between the components. These fits are determined by the tolerances specified in the ISO-286 standard, along with the specified bore and outer diameter tolerances of the bearing.



Cutaway view of an industrial centrifugal pump. Ball bearings can be seen in several locations on the shaft.

Bearing Material

It is generally assumed the load ratings published by bearing manufacturers are based on the use of high-quality, heat-treated steel. This is the basis for using a life adjustment factor $a_2 = 1$ discussed previously. The most common material used to produce load carrying bearing components (balls and rings) is AISI 52100 chrome steel. The chemical composition of this steel features a high carbon content and the inclusion of chromium. Using controlled processing and heat-treating methods, the finished bearing components possess high strength able to resist cracking and a hard surface to resist wear and subsurface rolling contact fatigue. Accordingly, 52100 steel exhibits good fatigue life in rolling element bearings. A disadvantage of using 52100 steel for bearing applications is its poor corrosion resistance. Consequently, bearing surfaces must always be protected with a coating of rust inhibitor oil to prevent oxidation. Bearings manufactured from 52100 chrome steel have a maximum operating temperature of 120°C (248°F). In applications requiring resistance to higher temperatures, it is possible to increase the maximum operating temperature of the bearing through heat stabilization of the components. This process involves a tempering treatment at a temperature corresponding to the desired operating temperature. This elevated tempering treatment does have a detrimental effect on the hardness of the steel, and as a result the load carrying capacity of the bearing is reduced. Table 3 lists common designations for specifying the heat stabilization treatment and the corresponding temperature ranges. These designations can vary from one bearing manufacturer to the next, so the supplier should always be consulted prior to selection. While bearings made from heat stabilized steel are an expensive solution, they offer enhanced resistance to high temperatures, reduced risk of failure, and extended operating life. Applications such as ovens, furnaces, kilns, blowers, and exhaust systems can benefit from using heat stabilized bearings.

Table 3 - Bearing Steel Heat Stabilization Levels

Designation	Heat Stabilization for Operating Temperature
S0	≤ 150 °C (302 °F)
S1	≤ 200 °C (392 °F)
S2	≤ 250 °C (482 °F)
S3	≤ 300 °C (572 °F)

Stainless steel is a common alternative for making bearing components, as it is more resistant to surface corrosion (due to a higher content of chromium). The chromium in the steel reacts with oxygen to form a thin, passive layer of chromium oxide on the material surface, rendering it resistant to corrosion. AISI 440C stainless steel has a high enough carbon content that it can be hardened using standard heat-treating methods. However, due to differences in the chemical composition between 440C and 52100 steels, 440C steel cannot achieve the same level of hardness as 52100 steel. As a result, the load carrying capacity of a stainless-steel bearing is 20 percent lower than that of a chrome steel bearing of the same dimensions.

Lubrication

Appropriate bearing lubrication is one of the most critical factors in ensuring bearings achieve their required design life. Designers of pumps and compressors must consider the most suitable lubricant for the operating environment, as well as the method of lubrication, when specifying a bearing. The life adjustment factor $a_3 = 1$ assumes that the loads, speed of rotation, and lubricant characteristics all contribute to maintaining a constant thin fluid film between the balls and raceways.

Grease lubrication is commonly used for ball bearings. Bearings are often lubricated "for life" by the manufacturer due to the design configuration and/or constraints. Some designs may include grease fittings, which allow for bearing lubrication at regular maintenance intervals. Temperature range, load, and speed are the primary considerations when selecting a lubricant. Bearing manufacturers typically lubricate ball bearings with a standard all-purpose grease that is suitable for most applications. However, it is a best practice to always consult with an engineer to either ensure the standard lubricant is appropriate or to select an alternate lubricant for optimal life and performance. Grease lubricants consist of a base oil and thickener, and often contain additives. Many different types of base oils, thickeners, and additive packages are commercially available to address a variety of operating conditions including:

- High and low temperatures
- High speeds
- High loads
- Moisture and humidity
- Vacuum

Designers should select sealed or shielded bearings whenever possible. These enclosures prevent contaminants from entering the bearing and assist with grease retention. Single lip seals are most common, but double and triple lip seals are very effective at preventing moisture and liquids from entering a bearing. There is a trade-off, however: using these multiple lip seals lead to an increase in torque, friction, and heat generation during bearing rotation.

Oil lubrication is effective in high speed and high temperature applications, providing excellent cooling properties. Unlike grease, oil should never be considered a lubricant "for life" option for bearings. Oil lubrication requires a continuous flow of oil supplied to the bearing. The oil bath lubrication method is commonly used in larger, slow speed compressors and pumps. By design, the bearings are either partially or completely submerged in an oil bath. Oil mist lubrication, used in high-speed applications, involves injecting a fine mist of oil into the bearing. Oil mist lubrication offers better heat dissipation than an oil bath. As with grease lubricants, selecting the proper oil is crucial to optimal bearing performance. Oil lubrication systems should include filtering and continuous monitoring of both the quality and amount of oil.

Summary

Proper bearing selection is one of the main factors in achieving reliability and longevity from turbomachinery. Application loads, bearing load ratings, and the selection of proper bearing fits, material, and lubrication all must be evaluated to achieve the required life of the equipment. Periodic maintenance and re-lubrication is also important for trouble-free operation. Pump and compressor failures are costly and difficult to repair. A thorough analysis of the application will provide guidance on both proper bearing selection and preventative maintenance, leading to the optimal performance of the machinery.

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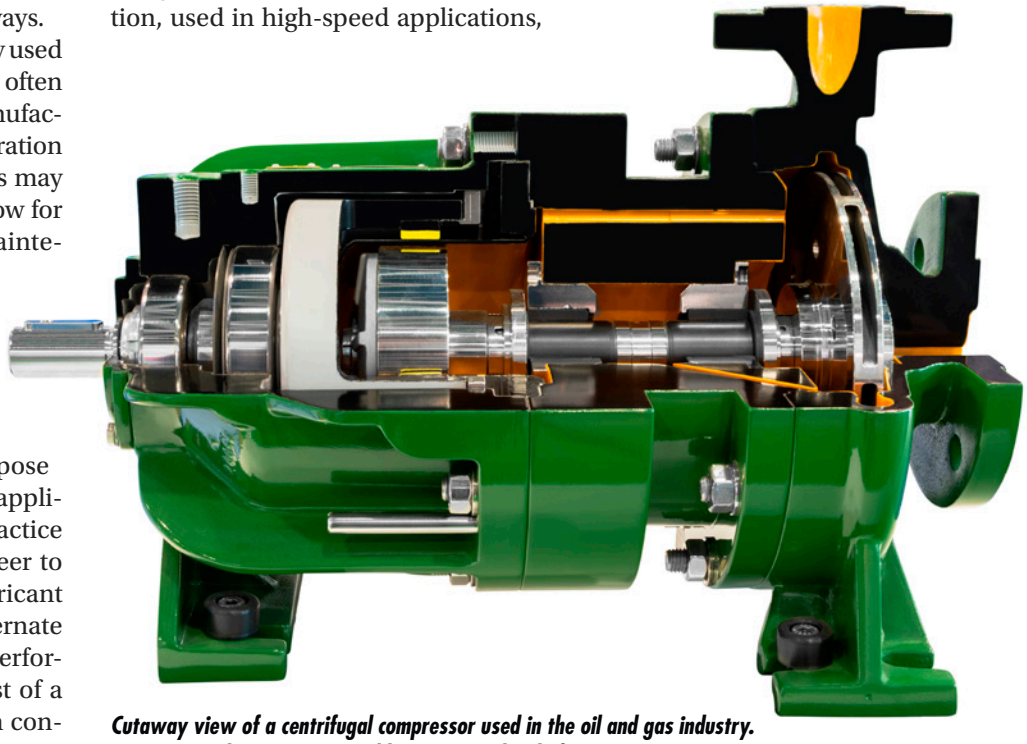

Cutaway view of a centrifugal compressor used in the oil and gas industry. Bearings can be seen in several locations on the shaft.

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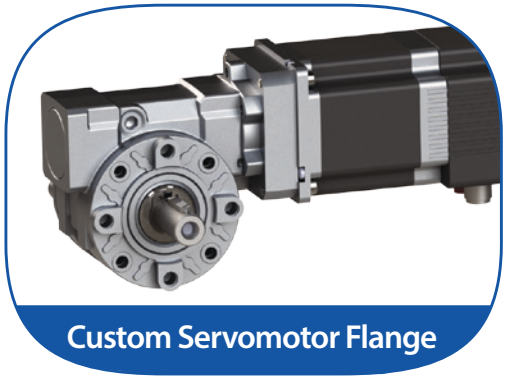

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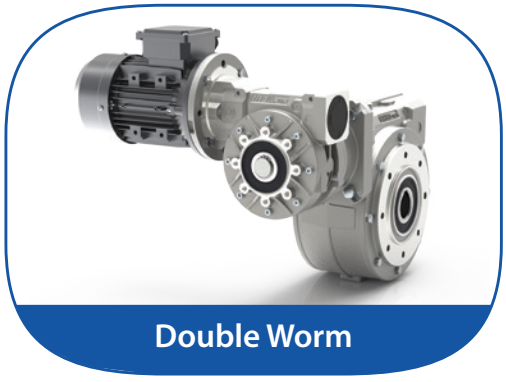

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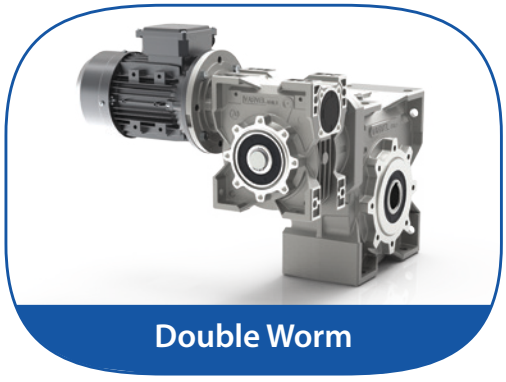

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Design Tips for Linear Motion Systems in Washdown Applications

Designing linear motion systems for washdown applications requires careful component selection to solve problems associated with contamination as well as liquid and chemical interactions.

Tim LeCrone, Director of Manufacturing Engineering at PBC Linear

When food and pharmaceutical contact is a factor, it's often necessary to wash or sterilize processing, packaging, handling, and automation equipment. When specifying components for such environments, design engineers must not only select components capable of withstanding high-pressure and high-temperature sprays with caustic materials. They must also consider regulations, standards, and inspections required for maintaining and operating equipment in highly regulated food, beverage, and pharmaceutical applications.

This article examines the sound engineering practices and design principles needed to ensure the performance of mechanical linear motion components in sanitary washdowns or chemically cleaned environments. Relevant regulations and agencies, washdown-compatible materials, and best mounting practices and motion components for washdown applications are also discussed.

Washdown environments require cleaning with water, chemicals, or a mixture of these either by hand or by automatic means. The washdown equipment may range from a simple cloth and bucket or hose to sophisticated high-pressure and controlled systems. Automatic cleaning of industrial equipment can involve CIP (clean in place) or SIP (steam in place). The goal? Killing and eliminating bacteria and other microorganisms that can cause and spread disease. In recent years, E. coli and mad cow disease outbreaks have rightfully led to greater scrutiny of processing equipment where unwanted bacteria might develop.

Standards and Regulatory Agencies for Washdown Design

No specific agency or standard approves or prohibits the use of a linear motion system. But multiple groups at the local, state, and federal levels inspect installed and in-use equipment. These organizations typically publish standards and guidelines for the acceptable performance and cleanliness of finished equipment. The equipment design engineer and the material or product manufacturer must ensure compliance or compatibility of materials selected for use in a machine.

Standards Organizations and Regulatory Agencies

Food and Drug Administration (FDA)

The FDA is the regulatory division within the Health and Human Services Department of the United States government. It determines standards for material that comes in contact with food and food products. It publishes the Code of Federal Regulations (CFR), which are general rules covering a broad range of areas. Within that code, *Title 21 — Food and Drugs* contains nine volumes, covering such topics as production aids, sanitizers, and indirect additives from contact with components made of polymers.

The FDA does not inspect or oversee the material a company produces. However, the agency provides specifications for the makeup and properties of materials used in processing equipment. A material that meets the standards set forth can be considered FDA-compliant. It is the responsibility of the material producer and machine builder to ensure that materials used are compliant with FDA guidelines.

United States Department of Agriculture (USDA)

The USDA is responsible for regulations and enforcement within food agriculture, meat processing, and poultry processing, including the manufacturing, handling, and packaging of food items. USDA requirements for materials are satisfied if those materials are FDA-compliant, but the agency may require a letter guaranteeing that products are being manufactured in accordance with regulations if they are used in direct food contact.

3-A Sanitary Standard Inc. (3-A SSI)

Comprising many representatives from government agencies, manufacturers, and processors, 3-A SSI is an independent, not-for-profit organization created to set standards and best practices for dairy equipment and processes. Many states require that dairy equipment meet 3-A standards and that the 3-A symbol be prominently displayed. For a material or piece of equipment to display the symbol, it must use 3-A-approved materials. The organization annually publishes a list of approved materials by product, grade, form, and supplier, and materials may not be replaced by generic alternatives.

NSF International (formerly the National Sanitation Foundation)

An independent organization, NSF sets the standards regarding all direct and indirect drinking water additives. To display the NSF symbol, a manufacturer needs to apply for approval. Such approval is for a finished product or device, not for specific materials or components. However, all components within the device must comply with the standards.

American Society for Testing and Materials (ASTM)

ASTM is an independent, not-for-profit organization created to establish standards for a range of products, systems, and materials. Compliance with the guidelines is strictly voluntary, and guidelines are not binding in a legal sense unless they are referenced by a governmental body in a regulation or are referenced in a specific contract.

Food Safety Management and Regulatory Compliance

Hazard Analysis and Critical Control Points (HACCP)

HACCP is a management system dealing with the analysis and control of hazards in raw food processing, handling, manufacturing, and distribution. Certified HACCP auditors inspect processing plants and equipment and grade them on performance.

Generally Recognized as Safe (GRAS)

GRAS is a voluntary disclosure of ingredients in substances intentionally used as food additives. The term is sometimes used to describe historically and scientifically acceptable materials and practices.

European Organizations

The European Hygienic Engineering and Design Group (EHEDG) does not issue standards. However, it publishes guidelines for the cleaning and manufacturing of food processing equipment. Some European countries require that equipment be tested and approved by the EHEDG. The International Dairy Federation (IDF) and the International Standards Organization (ISO) also set cleanliness standards in Europe.

Best Washdown Design Materials

Materials selection is critical for the bearing, shaft or rail, and seal components in linear motion design for washdown environments because it is key for meeting corrosion-resistance and machine performance requirements, standards, and regulations.

Stainless steel is typically the preferred material for general use in direct food contact areas because of its corrosion resistance and durability. Variations in stainless steel grades typically involve different levels of chromium and nickel.

300 Series Stainless Steel

In general, 300 series stainless steel is the most widely accepted material for food and medical applications. It is relatively soft, cannot be hardened, and is also nonmagnetic. Each grade discussed below might have different types with slightly different formulations and varying strengths and weakness based on additions to the mixtures.

303—Called A1 under ISO standards, 303 is a free machining version of 304 due to added sulfur and phosphorus.

304—Called A2 under ISO standards or 18/8 due to the 18% chromium and 8% nickel in its makeup, 304 is the most common grade of stainless steel.

316—Called A4 under ISO standards or 18/10, 316 is the most commonly used alloy for food- and pharmaceutical-grade applications. The addition of up to 3% molybdenum aids in prevention of corrosion from industrial chemicals and solvents, particularly pitting that can be caused by chlorides.

400 Series Stainless Steel

There are several types of 400 series materials. The most widely available and most used in industry is 440. It can be heat-treated and heat-hardened. It is often used for cutlery, linear shafting, and applications requiring good wear resistance. It can be hardened up to approximately RC58. However, due to added carbon in its makeup, 440 will oxidize under washdown conditions.

Stainless steels do not rust in the normal sense. If particles of red oxide appear on a stainless surface, it is most likely due to iron particulate coming from fillers within the bearing. To cleanse the surface, a solution of 10% nitric acid and 2% hydrofluoric acid at room temperature can be effective.

Aluminum and Coatings

Aluminum can be used in areas of a washdown environment where weight is a concern. However, be aware that bare aluminum has poor corrosion resistance and is susceptible to pitting and cracking. In washdown conditions, aluminum must be coated for protection. Anodizing ceramic coatings and other coatings with polytetrafluoroethylene (PTFE) or other fillers are often used, but they may not provide the resistance or life that stainless steel offers. In more caustic chemical washdown environments, stainless steel is the preferred material.

Electroless Nickel Coatings

These coatings have become increasingly popular because of their corrosion- and wear-resistance combined with a smooth, polished appearance. Some forms include a PTFE infusion to aid in non-sticking properties. Most forms of this coating are FDA-compliant as well.

Plastics, Polymers, and Fillers

These nonmetal materials tend not to have the corrosion-resistance and durability of metal surfaces such as stainless steel over time and are thus not used as often as major components in food and pharmaceutical equipment. However, due to cost, weight, manufacturability, and so on, they are increasingly being used "under the hood"— in mechanical drive components, guides, bearings, fasteners, and more. Many solid plastics, such as injection-molded bearing inserts, present drawbacks in washdown applications in that most absorb liquid, causing components to swell and increasing the potential for binding and failure.

Also be aware that each of the standards organizations covered earlier has extensive information on a wide variety of acceptable plastic materials. However, along with the base plastic, each polymeric material usually has fillers blended in by the manufacturer. These fillers are added to enhance performance, such as increased load capacity and lower coefficient of friction. Be sure that these fillers also are in compliance with standards.

Best Washdown Design Practices for Linear Motion Systems

Linear motion components offer their unique challenges in washdown applications. Rotating components need to be mounted and sealed within a limited area, but because the moving component of a bearing, slide, or actuator system travels in a linear fashion, the space needing to be sealed or cleaned will be far larger — often up to several feet larger. Below are some tips on how to minimize areas of potential bacteria buildup and maximize cleanability.

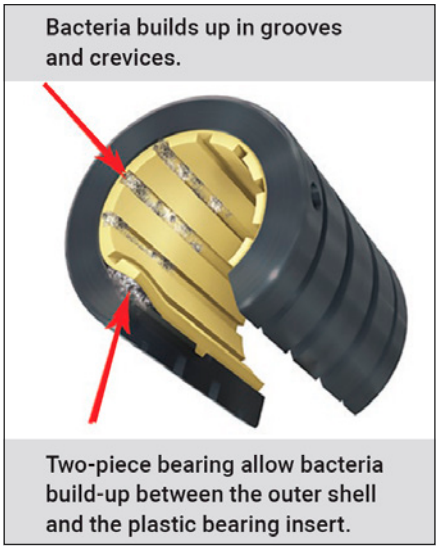

Figure 1 — Bacteria tends to build up in areas that are difficult to clean, such as grooves, crevices, and between the outer shell and plastic insert of two-piece bearings.

Linear Guide and Bearing Design

For linear recirculating ball bearings, use only stainless steel–sealed bearings with compliant seal materials and approved lubrication. There are two basic types of plain bearings. When using plastic inserts, be aware of moisture absorption that will lead to the bearing material swelling. This can result in binding issues. If the inside diameter is increased to deal with swelling, this often causes loose tolerances and inaccuracies in the system.

It is best to avoid open-ended bearings with grooves or inserts in areas that may be susceptible to bacteria buildup. These two-piece bearings will allow microscopic bacteria to seat in crevices, grooves, and between the outer shell of the bearing and the plastic bearing insert. One-piece bonded bearings eliminate this potential for bacteria collection.

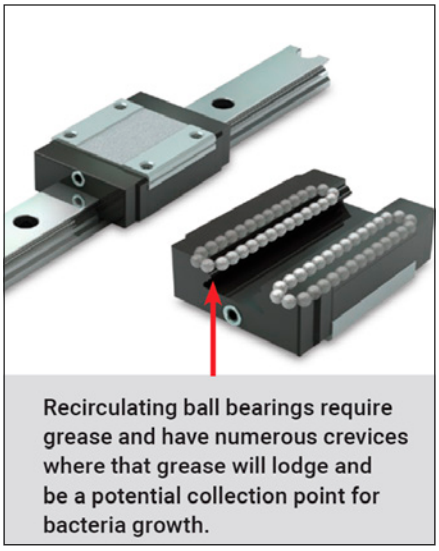

Figure 2—Recirculating ball bearings require grease and have numerous crevices where that grease will lodge and be a potential collection point for bacterial growth.

If they are to be used in a food-grade environment, ensure that materials and fillers are compliant with applicable standards.

The same design principles apply to recirculating ball bearing products, such as roundway linear ball bearings and profile rails. They provide advantages such as low friction and tight tolerances and are often available in stainless steel materials with FDA-compliant lubrication. However, they can present disadvantages in that they require grease lubrication to be used due to metal-to-metal contact. This lubrication picks up material from food items being processed, which can become trapped inside the multiple crevices and cavities around the balls and in the raceways of the bearing. This can potentially be a breeding ground for unwanted bacteria.

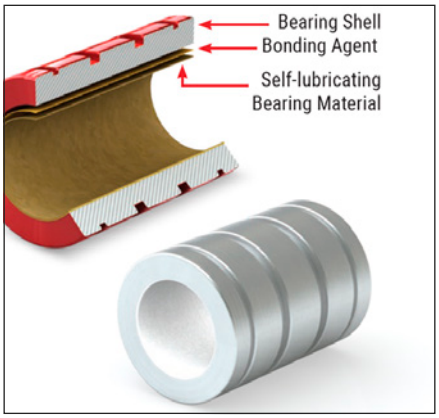

Figure 3—One-piece bonded bearings are the best solution for most washdown applications.

The best solution for most applications is a one-piece bonded bearing that uses PTFE-based, self-lubricating bearing materials that require no external lubrication. In addition, there are no grooves, crevices, or spaces between the liner and bearing shell where residue can become lodged, allowing bacteria to grow. The bearing material and outer shell are bonded together, creating a true one-piece bearing.

In vertical applications such as those found on in-line and carousel bottle-filling machines, it is advisable to utilize a bearing that is sealed at the top end. This eliminates contamination and prevents most of the fluid in the filling and washdown process from penetrating the bearing inside diameter. Yet it allows liquids that do get into the bearing system to easily flow through and exit at the bottom of the assembly.

Another area of concern in this type of configuration is that multiple-component subassemblies utilizing a parallel shaft design can experience bearing binding problems due to misalignment. In addition, these multiple components are also susceptible to bacteria buildup around the connectors and joints. Newer technology that incorporates dual rail load capacities and functionality into a single rail design can eliminate potential areas of contamination.

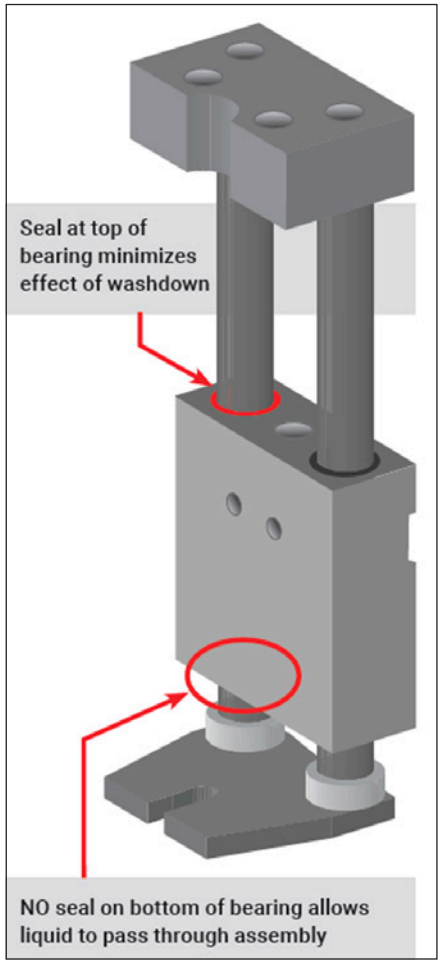

Figure 4—Bearing assemblies used in washdown environments benefit from sealing the top of a bearing to minimize the effect of washdown. Having no seal on the bottom of the bearing allows liquid to pass through the assembly.

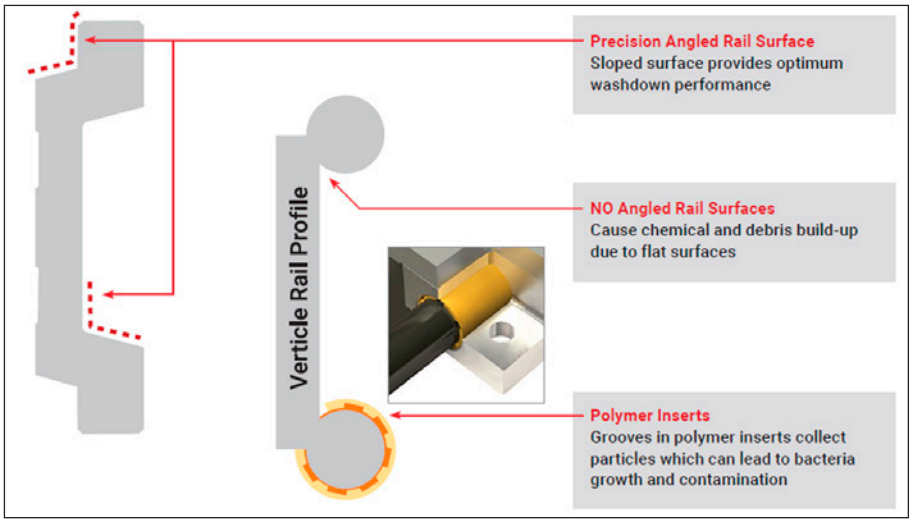

Figure 5—The sloped surfaces of precision-angled rails offer improved washdown performance by eliminating areas where particles can collect, leading to bacteria growth and contamination.

Rail Design and Selection

It is best to avoid as much component assembly as possible in a washdown environment. Traditional linear assemblies utilize a shaft and support rail bolted together, which are then bolted to a mounting plate or carriage. Each of these connection points creates a joint, crack, or crevice and a potential location where liquids can penetrate or where bacteria can begin to cling and build up over time.

New technology in linear motion has created slide assemblies that eliminate the need for multiple components and connectors. Unique two-piece slide systems are an ideal solution for washdown environments. In addition, these components have smoothly curved edges, without recesses where buildup can occur.

Linear Roller Bearings (cam follower style)—Typically used with a V-guide rail or as a cam follower, these bearings have internal bearing raceways that are lubricated for life and are permanently sealed with either a rubber seal or a stainless steel shield. If they are to be used in a food-grade environment, be sure the seal and lubricant are compliant with the applicable standards.

Shafting and Rails—Many different materials are available: 303, 304, 316, 440, coated aluminum, and more. Be sure that the grade selected is compatible with washdown conditions and regulations in the particular environment.

Linear Slides—These are typically twin-rail systems built up on a mounting plate. They utilize round rails or profile rails with recirculating ball bearings and have a top plate. These slides can be built with a variety of washdown-compatible materials. For food-grade applications, they can also be built up with compliant materials.

Linear Actuators—Typically, the outer housing for a belt-driven linear actuator is anodized aluminum. As discussed earlier, aluminum can be susceptible to pitting and corrosion, so these types of linear motion components are not ideally suited for washdown applications.

Standoffs

When mounting linear rails in washdown applications, especially where contamination and bacteria buildup are a concern, it is good practice to use standoffs to maximize cleanability around the linear motion system. Below is an exaggerated example of good practice when mounting with standoffs. (Be sure to calculate shaft or rail deflection when using standoffs to ensure proper operation.)

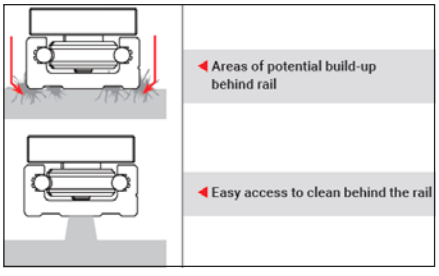

Figure 6—Using standoffs to mount linear rails in washdown applications helps reduce areas of potential particle buildup by providing easy access for cleaning behind the rail.

Fastener Location

When possible, avoid mounting connectors from the washdown side. They protrude and create another area where contamination can collect. It is best to bring the connector up through the bottom of the rail to be mounted. If necessary and if connectors enter the washdown area, use a domed nut for easier cleaning.

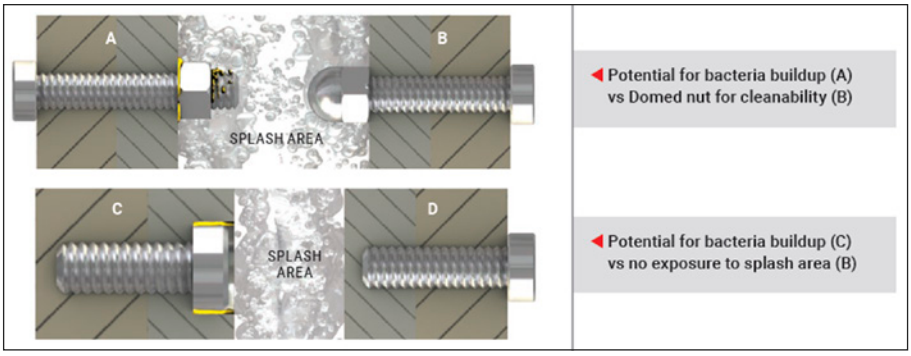

Figure 7—It's best to avoid mounting connectors from the washdown side. Instead, bring the connector up through the bottom if possible.

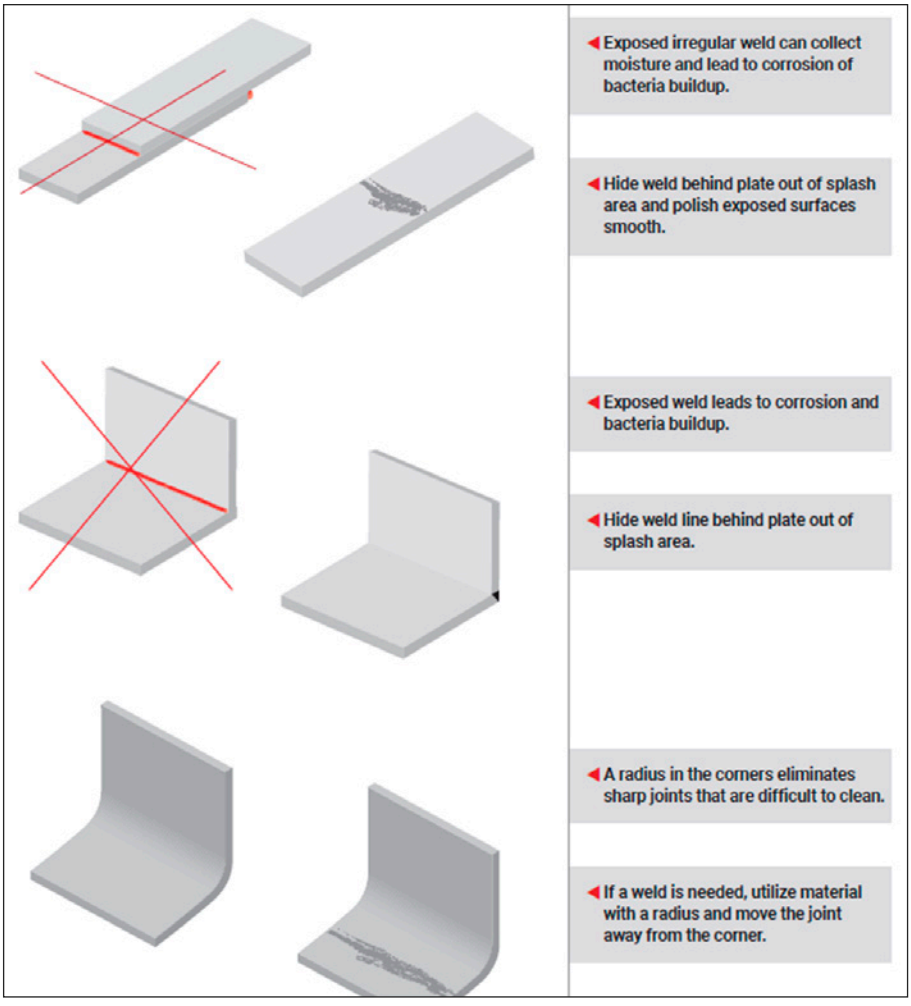

Figure 8—It's best to avoid small collection points for moisture and the potential for corrosion and bacteria buildup, such as welds exposed to the splash area. Whenever possible, radius all corners.

Location of Linear Components

Particularly in food-grade applications, it is important to consider where the linear motion device is to be mounted in relation to the food being processed. When components that are not FDA-compliant or do not meet other regulations for food contact are used over the open food path or where they can potentially come into contact with the food items being processed, risk can be eliminated by installing a stainless steel shield or cover over the components.

When constructing shields and other covers, it is important to give consideration to how the panels and plates are to be connected or welded together. Small collection points for moisture and the potential for corrosion and bacteria buildup can result from leaving the irregular surface of a weld exposed to the splash area. Whenever possible, the best case scenario is to radius all corners.

Another tactic used to manage moisture and fluids around linear motion components is to add weep holes, drainage

Figure 9—The addition of periodic weep holes can aid in draining liquids away from a linear rail.

channels, slots, or other porting features designed to channel moisture away from potential pooling areas.

The example below shows a long rail that often is mounted flat in a washdown environment. Liquids can naturally collect and pool along the length of the rail. By adding slots at strategic points along the rail, these collection areas can be easily eliminated. When combined with standoffs, this type of rail feature creates a linear guide system that is fully exposed and can be sanitized completely.

PBC Linear Products for Washdown Design

PBC Linear offers a wide range of linear motion solutions for washdown and food processing applications. The key is to know your application and to match up the correct components based on the industry standards and chemical makeup of the washdown environment at hand.

RST (Round Shaft Technology) Simplicity Self-Lubricating Bearings, FL (inch)/FM (metric)—The outer shell of the standard bearing is anodized aluminum. For washdown and food-grade bearings, it is best to use the optional 316 stainless steel bearing shell. The part number is noted with an "S" (example: FLS16). Along with not absorbing water or swelling, the bearing liner materials are self-lubricating and eliminate the need for external lubrication. Not requiring lubricants, even food-grade grease and oil, decreases the amount of material deposits on the shaft surface — and the potential for bacteria buildup.

FrelonGOLD—This bearing liner has good chemical resistance but is not FDA-compliant for direct food contact (Bearings lined with FrelonGOLD and Frelon J can be used in food processing applications when they are to the side of or below the food and will not come into contact with it. If FrelonGOLD or Frelon J bearings are above food items that have not been packaged, a shield is required). It can be used in wet environments, but due to the composition of the fillers, over a period of time, surface oxidation may appear. Do not use it with deionized water. FrelonGOLD is compatible with RC60 steel, ceramic-coated aluminum, and 440 stainless steel shafting.

Frelon J (optional liner material)—This polymeric-based material is not FDA-compliant but performs extremely well in washdown and caustic applications. It is compatible with 300 series stainless steel and clear anodized shafting.

Frelon W (optional special-order liner material)—This is an FDA-compliant material that is suited for direct food contact and is available as a special-order item from PBC Linear. It is compatible with 300 series stainless shafting.

Redi-Rail Cam Roller Technology (CRT) Linear Guide—Highly resistant to corrosion in washdown applications, this rail is composed of an aluminum base with an antimicrobial powder coating. In addition, 440 stainless steel shafts are embedded in the aluminum and provide a hard raceway. The three-, four-, and five-wheel slider has 440 stainless bearings and stainless hardware for the preload adjustment feature. The seal of the stainless end caps is NSF-registered for H1 (where there may be incidental contact with food) and H2 (no direct contact with food) applications.

Commercial Rail Linear Guides—These are nonprecision, cost-effective linear guides for washdown applications. Roll-formed 304 stainless steel rails guide a three-wheel slider composed of 440 stainless steel bearings.

V-Guide System, Cam Roller Technology (CRT) V Wheel Bearings and Linear Guide Rails

For washdown applications, the V-Guide System offers 400 series stainless steel rails. The V wheel bearings are constructed of 420 stainless steel raceways and 304 stainless steel shields or nitrile rubber seals. The concentric and eccentric wheel or mounting bushings are composed of 303 stainless steel. These components can be utilized to build up a variety of linear motion configurations.

Conclusion

Whether in an outdoor environment, a simple water washdown, or a location working to eliminate bacteria and other contaminants using chemical solvent mixtures or caustics, design engineers and maintenance teams are increasingly being asked to meet difficult challenges. Selecting the right components for the conditions requires a good understanding of the environment, component life expectancy, standards, and other parameters, along with a knowledge of materials that meet these challenges and comply with regulations.

PBC Linear has experience in a variety of outdoor, washdown, and food processing applications. In addition, it offers a broad range of products that give engineers and maintenance technicians multiple options to solve problems associated with liquid and chemical interactions. By utilizing these products, application experience, and best practices for working in washdowns, predictable life for the linear motion components and assemblies can be increased.

pbclinear.com

PTE

Tim LeCrone is a seasoned mechanical expert with over 37 years of experience in the industry. He has spent seven years in aerospace machining and has honed his skills in geometric dimensioning and tolerancing. With PBC Linear for 30 years, he has been a valuable advisor to the company, providing expertise on various linear motion solutions.

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A Shift in Bearing Architecture

A Conversation on Changing Technology at MPT Expo 2023

Randy Stott, Publisher

Randy Stott, publisher of *Power Transmission Engineering* and *Gear Technology* magazines, recently sat down with Norm Parker, technical fellow and technical manager for Torque Transfer Systems at Stellantis, to discuss bearing technology during the Motion + Power Technology Expo in Detroit.

How is the development of EV transmissions affecting the design and specification of bearings?

For automotive, we have a coaxial version which you might think of as a lucid design and then an offset version, which will be more like your Tesla design or the parallel axis version. What we might call Tesla is pretty much like a transfer case, a gear driven transfer case, if you will.

The lucid version is just a compact planetary. Nothing new there. What does make these different is we're putting a ton of speed and power into these boxes like we haven't before, and we're seeing a big uptick from bearing manufacturers in premium features. For the load carrying side, we're looking at a lot of nitriding,, a lot of carbon-nitriding, retained austenite control, custom quenching features, grain refinement, premium steels, etc.

On the speed handling side, we're seeing your typical drivers for speed control. We're seeing reduced tolerances. We're seeing surface finish controls, custom cages, reduce run out control, that sort of thing.

What are the biggest challenges for bearings in the EV environment?

Every bearing in the EV drivetrain has its own unique challenges, and I'll try to break these up into the unique challenges that they provide.

Parallel access design, for instance. I have motor bearings and input gear bearings. Sometimes these are along the same shaft, sometimes they are not. Sometimes, they share bearings and then we go to the intermediate shaft, which has its own unique challenges in every gearbox. And then the differential. And I kind of think of these like little neighborhoods that each have their own unique problems that I mustdeal with.

On the motor side, I must worry about electrical current damage. We have an insulating-isolation system. Then we move into the input gear system. We're coming in at motor speeds, but now we have huge loads to contend with coming off the first gear mesh. The intermediate shaft, like any gearbox, is always challenging because you're typically space limited on the intermediate shaft, and you have huge loads coming in.

You have a reaction coming off the input and the differential both going in the same direction, very challenging loads. And then the differential, which is classically known as the noise maker. Right. So, every one of these has very unique challenges.

Is there a shift towards or away from certain types of bearings?

Architecture is a conversation I have probably every day. If you look at the Tesla box, for instance, it's all ball bearings and it's hard to argue with the success that Tesla has had. So, it's easy to look at this and say, that's my answer. But for new people coming into the market, people want to find an edge over Tesla.

How can I keep up with Tesla? And it's very tempting to look at the ball bearings on the differential and say, I can make the gearbox quieter. You will see people coming in and putting tapers on the differential and sometimes even the intermediate shaft with the angle that they're going to make a quieter gearbox.

We're seeing all different kinds of mixes of architecture along the main shaft or the motor shaft. And we're seeing classic arrangements we haven't seen in automotive in a long time, ball bearings and cylindrical combinations, right? This is a classic machine design that's coming back into automotive and it's really a tradeoff. There's no right answer.

In fact, you might have several answers for every one of your applications. This one, I might want a quieter gearbox, you know, for maybe a luxury feature. Maybe this one I want a little better efficiency. Or maybe I have a sports car or a lightweight, fuel-efficient car. That's it.

How much do bearings contribute to a transmission's NVH performance?

This is a great question, and it has a little bit of a history.So the bearings themselves don't make a ton of noise.

But how they control the gears is really where the meat and potatoes are. And I was a little spoiled coming up. I was trained by probably one of the best hypoid gear designers alive. And he taught me that gears make different noises in every plane X, Y, and Z, and they tilt in every plane X, Y, and Z.

And every one of these noise characteristics are different. And how we control these noise characteristics is at the bearings right? So, the LV NVHcreated by the bearings is relatively small. How much noise we prevent or create due to gear misalignment is really where the story unfolds. Okay, so that's noise. What about efficiency?

There's a lot of anxiety among buyers of EVs about the range of these vehicles. How much do you have to worry about energy loss and the efficiency of bearings?

This is another interesting question, like the noise question. How much do they contribute to noise? It's how they contribute to efficiency. Bearings themselves don't just have one efficiency. You don't just take a taper and say it has this efficiency or in a ball bearing say this inefficiency.

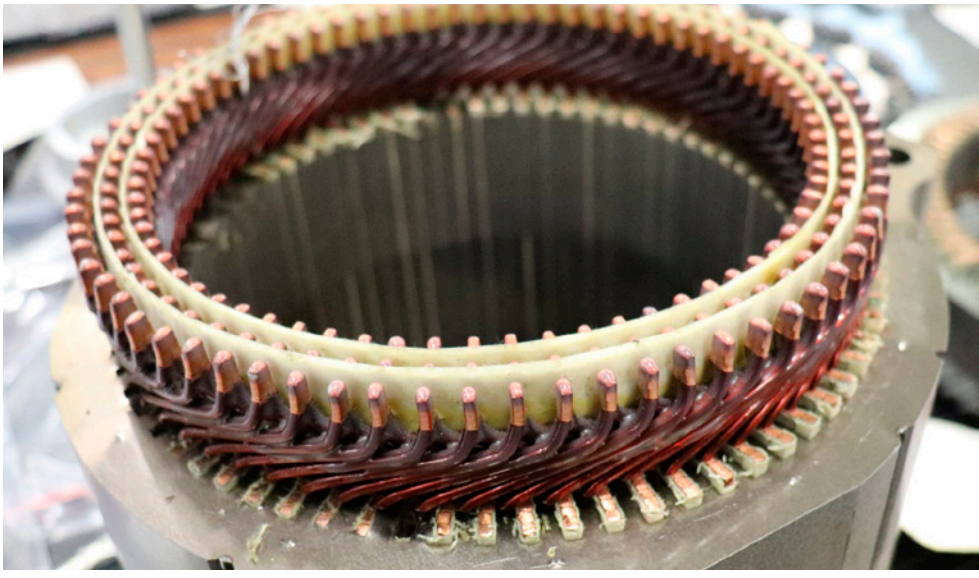
It's a dynamic problem. It depends on how hot we're running, how much oil we have on the bearings and how heavy we load the bearings. Traditionally, I think everybody wants to say ball bearings are always more efficient than tapers, but that's not the full story. If you take a ball bearing and load it with oil, have it sitting in oil, it'll become much less efficient than a taper that has the proper oil now going to it.

This efficiency is very sensitive and dynamic. And when we look at the entire gearbox, we must take that into consideration. It's not just the bearings, but how much inefficiency due to, the atmosphere that the bearings are running in.

How do you think the bearing requirements are going to continue to change as customer requirements change regarding performance, price, NVH, and other factors?

Are they going to start to associate a little bit of gear noise with better efficiency? I don't know, but that's an interesting question. Is it like a muscle car engine? I hear this kind of noise. I know it's good. Or are they going to become less tolerant of gear noise?

I'm tired of this noisy gearbox. And I think we're all going to grow together in this journey we're on. I think we're going to become better gearbox designers. I think we're going to start making more efficient and quieter gearboxes and customers tolerance is going to go down as well for tolerating noise and inefficiency and things like that. I think we all have to get better and learn more about this animal as we move along.



Additional Resources:

powertransmission.com/blogs/5-bearings-with-norm/post/8763-ball-bearing-limiting-speeds

powertransmission.com/blogs/5-bearings-with-norm/post/9150-ball-bearing-inner-ring-fits-and-creep

powertransmission.com/blogs/5-bearings-with-norm/post/9311-bearing-mounting-arrangements

PTE

Precision Thread Rolling Process for High-Accuracy Lead Screws, Actuator Screws, and Power Transmission Components

The cylindrical die rolling process can produce helical, axial, and annular forms on shaft-like parts at high rates of speed with precision tolerances.

David C. Willens, Director, Research & Development, Kinefac Corporation

Figure 1—Precision rolled lead screw, actuator screw and power transmission components.

Why use the rolling process to produce high accuracy lead screws, actuator screws, and other power transmission components rather than traditional cutting processes such as turning, grinding, milling, whirling, or hobbing? Rolling processes and cutting processes both produce a precise form on the workpiece. But if the form geometry, tolerances, and material selection allow, rolling is the process to beat. Speed, surface finish, fatigue strength, precision, dimensional stability, and material savings are some of the primary advantages realized when the rolling process is applied.

Precision CNC cylindrical die thread rolling equipment and dies make it possible to produce high accuracy standard and custom thread forms, ACME and trapezoidal lead and actuator screws, gothic radius ball screws, involute worms, splines, and serrations on shaft-like components. The rolling process has been applied to parts below .25 mm (.010-in.) in diameter up to over 150 mm (6-in.) in diameter.

Process Defined

Cylindrical die thread and form rolling is a metal forming process whereby helical, axial, and annular profiles such as threads, worms, splines, and grooves are formed in the surface of a cylindrical blank by the phased interaction of two or three round dies. The dies are forced into the periphery of the blank while rotating it at nearly the same surface velocity to displace the blank material radially into the form of the die until the final geometry is achieved. Dwell is used to round-up and calibrate the final form before disengaging the dies. It is a constant volume process whereby material is neither added nor removed.

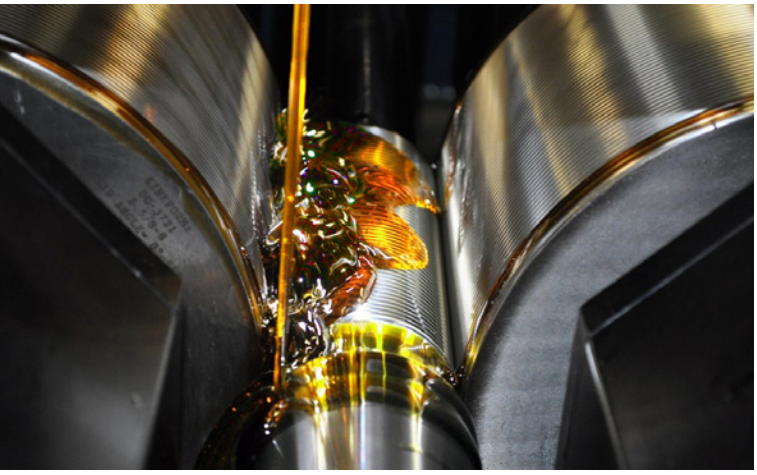


Figure 2—Infeed thread rolling process.

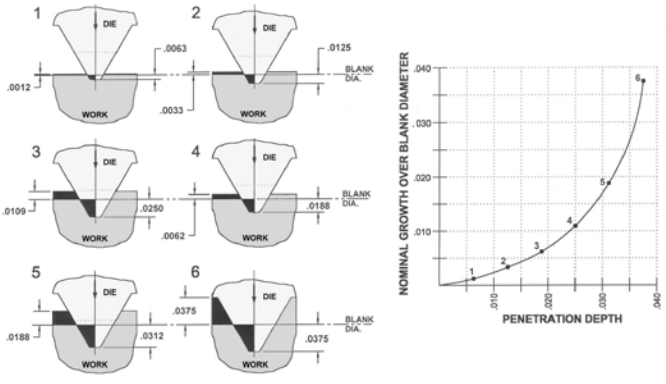


Figure 3—Volumetric material displacement during die penetration.

Process Origins

Screw thread rolling itself is not new. The process originated from the fundamentals of the techniques used to roll metals into flat sheets, plates, and bars. The earliest known patent for screw thread rolling or screw thread swaging, as it was initially referred to, was in 1831 by Hazard Knowles of Colchester, CT. The patent was for an improved method of manufacturing wood screws using flat dies. The dies replicated a mirror image of their form into the periphery of a cylindrical screw blank by a parallel reciprocating motion. The patent also covered the use of one round die with an external segment die, now referred to as planetary rolling. Cylindrical die rolling using two or more round dies followed in 1855 with a patent by Martin Griswold of Watertown, CT, for profiling continuous lengths of metal tubes. Cylindrical die rolling was developed in various forms over the next several decades primarily in the northeast United States, England and Germany.

Thread rolling in its infancy was considered a crude low-precision process that was limited to wood screws, carriage bolts, stove bolts, and other low-precision fasteners. This was mainly due to limitations of die manufacturing accuracy and the availability of die steels and good forming steels for screw blanks. The process saw increased industrial use throughout the late 1800's into the early 1900's, but it wasn't until the wartime demands of the aviation industry in WWI and WWII, along with advances in cylindrical die rolling machinery and dies, that thread rolling became the preferred method of producing high-precision forms on critical fasteners and components. Since then, the technology has been extended to many different applications requiring high accuracy and strength. The application of the cylindrical die rolling process to the manufacture of precision lead screws and actuator screws for transport and positioning was a natural evolution.

High Speed

Rolling is generally several times faster than any cutting operation. It is not uncommon to see a 5x to 10x order of magnitude difference. A single point cutting tool usually requires multiple passes to achieve full depth of form, and depending on the length of form, it can take in the order of minutes to complete the cycle. Rolling processes generally take on the order of seconds.

The primary cylindrical die rolling modes used for producing precision lead screws and actuator screws are infeed and throughfeed cylindrical die rolling.

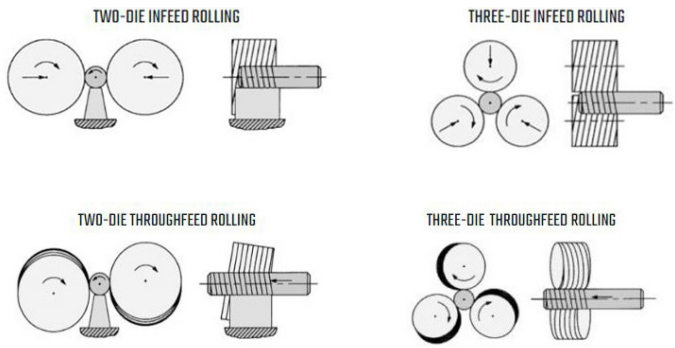


Figure 4—Cylindrical die infeed and throughfeed rolling.

Infeed is used to roll discrete lengths of thread within the width of the die face using a single plunge and retract operation. Two or three dies are positioned on parallel axes with the blank, and there is little to no axial feed of the part during the forming operation. Infeed rolling can produce complete forms in two to three seconds or less. The forming operation itself is generally much faster than the time it takes to transfer the part in and out of the dies. Automated infeed thread rolling systems with mechanized feeders can achieve production rates of 15 to 60 parts per minute depending on the part configuration and forming cycle.

Throughfeed is used to roll continuous lengths of thread using relatively narrow dies tilted on opposite skewed axes. The blank rotates and feeds through two or three dies at fixed

center distance while the form is progressively generated as it travels through the dies. Throughfeed rolling of long forms having lengths of four meters (12 feet) or more can produce rolled product at rates of 30 to 60 inches per minute or more depending on the capability of the thread rolling machine and design of the dies. Forms that are rolled in long lengths can be colletted in a screw machine and cut into shorter pieces for subsequent machining or finishing operations.

Figure 5—Throughfeed lead screw rolling.

In a cutting operation you're limited by the power of the machine tool, the length-to-diameter ratio of the part with respect to form depth, and the ability to remove heat at the cutting insert. In a cold rolling operation, you're limited by the power of the rolling machine and the ability to transfer the electro-mechanical energy into forming the threads without slipping or stalling the blank. The unbalanced cutting forces of a single-point cutting operation can severely limit the length of form to be cut based on the length-to-diameter ratio and form depth. Rolling has balanced forces around the part which essentially allows you to produce unlimited lengths if the parts can be sufficiently supported.

Excellent Surface Finish

The conjugate interaction of the dies and the part during a rolling operation is like a transmission gear mesh. The outside diameter of the die continuously forms the root diameter of the part which forces material to flow along the die flanks into the die root diameter. The die root diameter forms the major diameter of the part. This meshing relationship forces the velocity ratio of the dies and part to achieve equilibrium. However, since there is continuous uninterrupted contact between the die and part transitioning from part root to crest, this means there is only one theoretical diameter of matched angular velocity. Above and below this zero-slip diameter, which usually occurs around the pitch line, there is a differential of angular velocity. The differential results in a sliding and burnishing action on the surface of the rolled part. This means excellent surface finish is achieved directly from the forming operation without the chatter marks of a cutting tool.

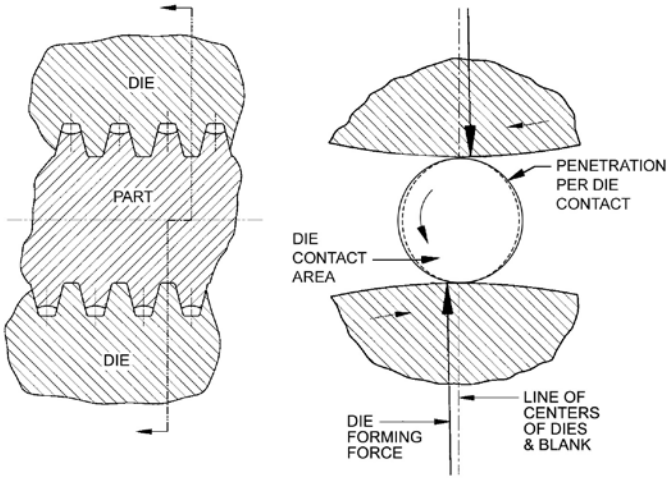


Figure 6—Die and part conjugate relationship.

Finishes superior to that of grinding in the range of .020 µm to .100 µm (2 µin to 4 µin) Ra can be achieved by rolling operations. Smooth finish also means improved wear resistance and high efficiency in rolling and sliding contact, especially in the direction of the helix. These characteristics are very important for the performance of lead screws, ball screws, and other similar actuator screws which must interact with a mating bearing component.

Figure 7—Surface finish achieved by rolling operation.

Improved Fatigue Strength

Rolling can be considered a continuous but intermittent rotary forging process. A single point on the blank contacts each die once per revolution of the blank following an epicycloidal path. The radial velocity of the point goes to zero at the point of contact with the die like the converging behavior of a hammer forge. The result is a forged part structure with uninterrupted grain flow lines that follow the geometry of the rolled form. Compressive residual stresses in the root area of the thread combined with the uninterrupted grain flow and smooth surface finish help retard crack initiation and propagation under cyclic loading conditions.

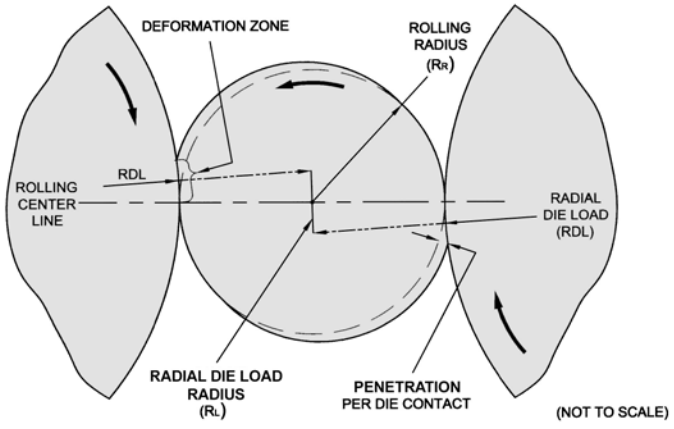


Figure 8—Two-die rolling system diagram.

Strain hardening that occurs due to cold working of the material is another mechanism to be considered with respect to overall strength. Alloy steels and stainless steels which work-harden when cold worked, can strain-harden as much as 5 to 8 HRC points or more during the rolling operation. It is not uncommon for a rolled thread to be in the vicinity of 10 to 20 percent stronger than a cut thread of the same size in a given material. A cutting process removes portions of the existing material structure and does not yield beneficial residual stresses in the form. It can also leave sharp transitions whereas rolling leaves radius transitions which minimize stress risers.

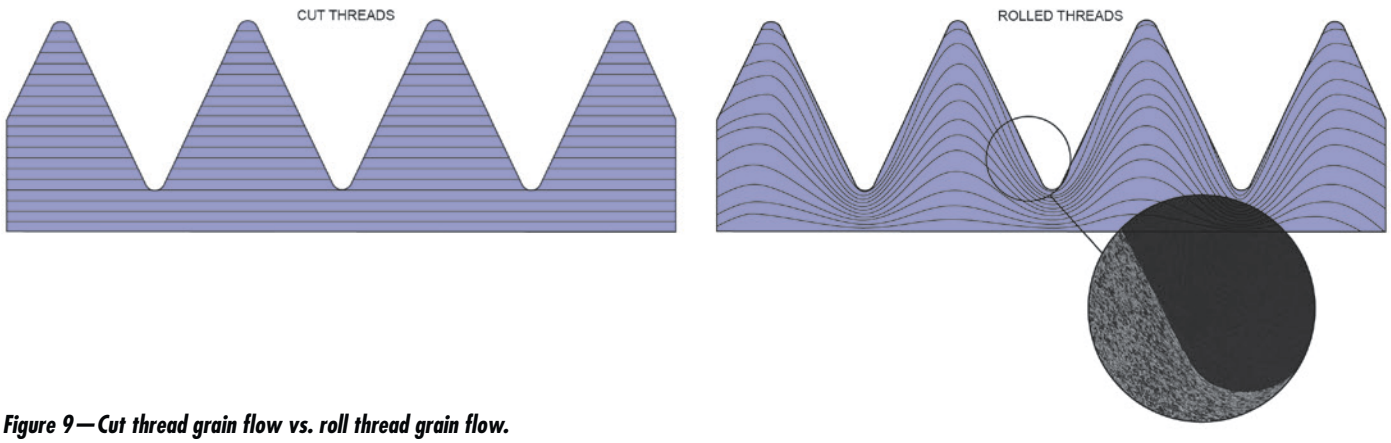


Figure 9—Cut thread grain flow vs. roll thread grain flow.

Rolling can also be carried out in heat-treated materials which can result in additional fatigue resistance. This can be a showstopper for cutting processes where machine stiffness and cutting edges don't hold up. However, high hardness blanks significantly reduce the tool life of a thread rolling die and significantly increase forming loads. Rolling is regularly carried out on pre-roll blanks with hardness of up to 36 HRC, and higher. Above this level of hardness, the tool life is significantly reduced. Some high-strength threaded studs, bolts, and actuator screws require rolling to be performed on blanks up to and exceeding 46 HRC.

Precision Tolerances & Dimensional Repeatability

Achievable tolerances and dimensional repeatability are governed by the accuracy of the die form, type of rolling process used, accuracy and stiffness of the rolling machine, and quality of the pre-roll blanks.

The final form geometry of a rolling die is precision ground, typically after the die steel has been heat treated. This minimizes the risk of distortions that could occur in the die threads during the hardening process. The high accuracy ground form geometry is then replicated in the blank during the rolling process.

A thread rolling die does not typically wear like a standard form-cutting tool and thus does not require continuous compensation over its life. Rolling dies tend to last a long time with very little wear before they begin to fail. This means a single rolling machine size setting is often required to produce precise and repeatable rolled forms until complete die failure occurs. Localized die wear is not usually the cause for changing the dies because remaining good sections of the die will calibrate the final rolled form until the entire die surface has failed.

The rolling machine directlycontrols the workpiece pitch and root diameters by precisely positioning the dies at the appropriate center distance. The diameter of the pre-roll blank controls the level of fullness of the final major diameter and whether there is a closed or open seam at the thread crest. However, once the dies are filled completely, the major diameter is directly controlled by the dies, and the elastic stiffness of the rolling machine will inhibit the dies from penetrating any further. Precision CNC thread rolling machinery can hold part to part diameter variation of .005 to .008 mm (.0002 to .0003 in.) with tightly controlled blanks.

With infeed rolling of shorter length parts, all the form characteristics including the lead accuracy follow the geometry of the die. Most materials that are good for rolling have negligible elastic spring-back after infeed rolling and thus don't require any special compensations of the die form or die lead. Precision CNC thread rolling machinery and infeed dies can hold part to part lead variation within .002 mm per 25 mm (.00008 in. per inch) rolled length with tightly controlled blanks.

Throughfeed rolling, which is primarily used for producing long lead screw and actuator screws of four meters (12 ft.) and longer involves more variables when it comes to characteristics such as lead tolerances. The rolled form length is considerably longer than the working face of the die and lead error becomes cumulative. There tends to be some axial flow of material during throughfeed rolling as the penetrating ribs of the die simultaneously feed the part. Resulting internal residual stresses cause axial spring-back of the part which results in a lead which is shorter than the lead of the die. This condition is more pronounced when the form depth is 15 to 25 percent or more of the part diameter and when the root profile of the part has a relatively wide flat.

Figure 10—Kinefac MC-15 CNC KineRoller with bar feed unit.

Thermal characteristics of the throughfeed process also contribute to the amount of die lead compensation. The energy required to roll is transferred into the part and comes out as heat. Part shrinkage due to cooling to room temperature can also result in a lead which is shorter than the dies.

Spring-back compensation for lead accuracy is generally determined by testing due to the multitude of variables involved. Once determined, it will remain constant and repeatable assuming good consistency of the blanks. Precision CNC rolling equipment and throughfeed dies with good blanks and thermal stabilization of the rolling lubrication and dies can produce ball screw, trapezoidal screw, and ACME screw lead accuracy of .025 to .050 mm per 300 mm (.001 in. to .002 in. per ft.) rolled length. Meeting a tolerance of .100 mm to .150 mm per 300 mm (.004 in. to .006 in. per ft.) is standard. A good thread cutting or grinding machine with an accurate lead screw and high stiffness slides can also achieve precision lead tolerances.

Material Savings & Reduced Waste

Thread and form rolling is a constant volume process, meaning material is neither added nor removed. Therefore, the volume of the pre-roll blank is the same volume as the final rolled part. The pre-roll blank diameter is smaller than the major diameter of the rolled form and is usually close to the pitch diameter. This is because material is displaced radially from the blank into the die form during penetration. The angled flanks of the die thread form provide a wedge-action to raise the material above the blank surface as the dies are penetrating. A cut thread must start out with a blank which is at least at the major diameter because material is removed to leave the desired form. A calculation by volume can demonstrate a potential material savings of close to 20% or more when using the rolling process.

Example: Throughfeed Rolling 1-1/4"-5 TPI ACME Lead Screw

Pre-Cutting Blank Diameter	~1.250-in. (31.75 mm)
Pre-Roll Blank Diameter	~1.132-in. (28.75 mm)

$$\%Savings = \frac{\pi r_{Pre-Cut}{}^2 h - \pi r_{Pre-Roll}{}^2 h}{\pi r_{Pre-Cut}{}^2 h} = 18\%$$

Another key benefit of rolling is the elimination of waste. Rolling could be considered a green manufacturing process since it is displacing material from one location to another on the same blank without creating waste. This is unlike a cutting or grinding process which generates chips or swarf that must be disposed of.

Material & Form Geometry Considerations

Most low-carbon steels such as 1018 and 1020, medium-carbon steels such as 1045 and 1050, alloy steels such as 4140 and 4340, and stainless steels such as 303 and 304 are good for rolling. Non-ferrous materials such as copper and aluminum can also be rolled. Alloying with elements such as nickel or chromium can increase the effects of work-hardening during cold work and should be considered for tool life.

Softer materials have more of a tendency to form a seam at the crest of the rolled part than harder materials. The seam is a mechanical closure of material due to metal flow behavior along the die flanks in the rolling process. Seams are generally very shallow and have no effect on the strength or performance of the rolled form. The seam can be closed completely for visual purposes, but it does mean the rolling dies are filled completely and can result in reduced tool life.

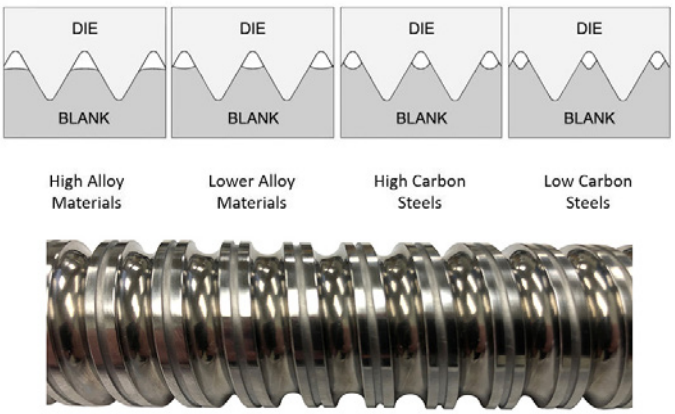


Figure 11—Material seaming behavior with rolling ball screw example.

Thread form geometry also influences the performance of the rolling process and tool life. Rolled forms are ideally designed with sufficient corner radii to help promote material flow and reduce stress risers. Flank angles and pressure angles are ideally kept above a low of 10° to 12° and lead angles are ideally kept under 30°. Form depths should be kept under 25% of the part major diameter, and tooth thickness versus tooth space should be as balanced as possible.

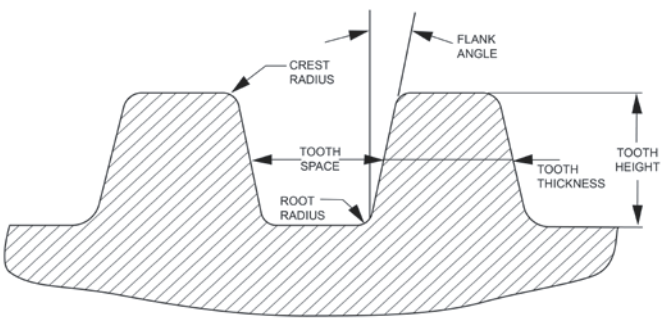


Figure 12—Form profile geometry.

The rolling process has been applied to parts as small as .25 mm (.010-in.) in diameter to over 150 mm (6 in.) in diameter. Size and length are limited by rolling machine tonnage, power, and die size capacities. Forming loads of over 330-tons are possible on large CNC thread rolling equipment.

Summary

Cylindrical die thread and form rolling is an ideal process for producing high accuracy lead screw and actuator screw components with many benefits. To learn more about what can be rolled and how to apply the rolling process to your precision lead screw and power transmission products - including splines, knurls, and serrations, visit *kinefac.com* or email *sales@kinefac.com*.

PTE

David C. Willens is the Director of Research and Development at Kinefac Corporation, Worcester, Mass. He has a Ph.D. in mechanical engineering from Worcester Polytechnic Institute and is co-author of the chapter on the Rolling Process in the 2015 McGraw Hill Manufacturing Engineering Handbook. He has been involved in the design of thread and form rolling machinery, dies, and processes for over 18 years.

GKN Powder Metallurgy and Schaeffler

JOIN FORCES TO DRIVE PERMANENT MAGNET INDUSTRY

Schaeffler AG and GKN Powder Metallurgy, recently announced their joint commitment to advance the development of the permanent magnet industry in Europe and North America through a memorandum of understanding. GKN Powder Metallurgy will supply Schaeffler locally with permanent magnets with the aim to ensure a stable, local supply whilst improving sustainability and transparency in the supply chain.

Diego Laurent, CEO of GKN Powder Metallurgy, said: "We are delighted to partner with Schaeffler to jointly provide solutions to the challenges of supplying permanent magnets to the automotive and other industries. This is a perfect match of two companies with a long-standing relationship and a strong commitment to sustainability and innovation. The development of permanent magnets for EVs is a logical step for GKN Powder Metallurgy, as we continue to expand our capabilities to support the needs for electrification in the industry whilst pursuing ambitious sustainability targets."

Matthias Zink, CEO Automotive Technologies at Schaeffler, comments: "Schaeffler has key strengths in passenger car electrification, particularly in electric motors, which are integral components of all electric axles and hybrid modules. To ensure our successful growth in this segment especially in Europe and North America we aim to establish resilient, local, and sustainable supply chains for the relevant components like permanent magnets. This cooperation with GKN Powder Metallurgy is an important step towards this goal."

gknpm.com/en/solutions/permanent-magnets
schaeffler.com

WEG

ACQUIRES REGAL REXNORD'S INDUSTRIAL ELECTRIC MOTORS BUSINESS

WEG recently announced, through its indirect subsidiaries abroad, the acquisition of the industrial electric motors and generators business of Regal Rexnord Corporation. The acquisition value is $400.0 million, subject to common price adjustments for this type of transaction.

This transaction focuses on the industrial electric motors and generators businesses of the Marathon, Cemp, and Rotor brands within the Industrial Systems operational segment of Regal Rexnord. WEG will also integrate a team of approximately 2,800 employees operating in 10 factories located in seven countries (United States, Mexico, China, India, Italy, the Netherlands, and Canada), as well as commercial subsidiaries in 11 countries.

According to WEG's President, Harry Schmelzer Jr., this acquisition aligns with the strategy of continuous and sustainable growth, international expansion, and diversification of the industrial operations of the WEG Group.

"The geographical distribution of these operations complements WEG's current presence and will help achieve greater scale and cost efficiency as we integrate the new operations with the existing ones. With a long history in the market and a global presence, this acquisition will support the ongoing growth of the WEG Group in the industrial electric motors and generators markets, through the incorporation of recognized brands and a product line that complements the Group's current portfolio.

weg.net

AGMA

PROMOTES BLACKFORD TO CHIEF OPERATING OFFICER

The American Gear Manufacturers Association (AGMA) recently announced the promotion of Jenny Blackford to the organization's chief operating officer (COO). In her new role, Blackford will oversee the association's systems and processes, enterprise wide. In addition, she will have expanded roles relative to human and technology resources and investments.

"Jenny Blackford is a recognized leader within the association space, and her value to AGMA is tremendous," said Matthew Croson, president, AGMA. "This promotion provides her space and responsibility to continue to grow AGMA's resources to best support our members and the organization as a whole."

Most recently, Blackford oversaw AGMA's Business Division, which touches all of the organization's face-to-face events, tradeshow and training, as well as outward facing communications. She joined AGMA in 2000 as the communications manager, and has added increased responsibilities over the years, including guiding AGMA's trade show for 15 years, and being named President of the American Bearing Manufacturers Association in 2019.

"Jenny is a pragmatic, thoughtful leader who has demonstrated the ability to move strategy to execution," added Croson. "As COO, she will bring synergy across AGMA, and align both systems and human resources to ensure member value is leveraged to its fullest."

"I'm honored to have learned from and assisted AGMA's members over the past two decades and am looking forward to the new challenges in this new role as COO," said Jenny Blackford, chief operating officer of AGMA. "Over the past few years, it has been exciting to see AGMA's programs and membership grow, and I welcome the opportunity to guide AGMA's staff to continue building on these successes in the future."

agma.org

January 17–18—AGMA Involute Spline Design and Rating–Winter

This live online course will address both geometry and rating of involute splines of various types. The types of spline joints and their applications will be discussed. Spline configuration variations, including half depth, full depth, and special function designs, will be addressed. Both fixed and flexible spline configurations will be examined in terms of usage and design. Lubrication methods, including grease, oil bath, and flowing oil, as well as coatings appropriate for various spline applications, are examined. Shear and compressive stress rating methods are discussed with analyses methodology presented in both equation and graphical methodology via various rating charts.

powertransmission.com/events/968-agma-involute-spline-design-and-rating-winter

February 6–8—WestPack 2024

WestPack, Anaheim, CA, pairs design and packaging challenges with smart solutions in a setting that fosters interaction and inspiration. Pushing the boundaries of sustainability, environmental protection, and product vitality, WestPack brings together the leading packaging manufacturers from multiple industries, including food & beverage, medical device, pharmaceuticals, cosmetic and personal care, and electronics. Theater stages will cover topics such as sustainable packaging, medical device packaging, thermal shipping systems, sustainable cannabis packaging, food and beverage packaging and more. The event is co-located with MD&M, ATX West, D&M West, and Plastec West.

powertransmission.com/events/967-westpack-2024

February 13–15—Motor, Drive Systems & Magnetics 2024

MDSM (Orlando, FL) features the latest technical advancements in motor, drive systems, motion control, magnetic applications, technology, and rare earth materials. This is an opportunity for professionals to hear content in design, efficiency, and application advancements in automation, robotics, manufacturing, utilities, automotive, medical, consumer, aerospace & defense industries. Motor & Drive Systems is focused on the latest technical advancements impacting the design, integration, and efficiency of motor, drive systems, and motion control.

powertransmission.com/events/966-mdsm-2024

February 22–24—IPTEX 2024

IPTEX 2024 (Pune, India) is an important event for all relevant stakeholders in automobile, aerospace, or energy as well as manufacturers, buyers, partners, and consultants. Focus industries include mechanical power transmission, electrical power transmission, linear motion drives, fluid power and IoT/smart technology. IPTEX will provide a consistent channel of communication to the members of this industry to come together under one roof and participate in technical seminars, share knowledge and expertise with industry leaders and to be a part of discussion on policy codes, standards and challenges faced by the industry.

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February 27–29—Gearbox CSI

This AGMA live online course examines individual failure modes and the failure scenarios that lead to actual system failure, an essential skill to designing gear/bearing systems that will operate properly for their full design life. In this course, AGMA will define and explain the nature of many gear and bearing failures and discuss and describe various actual failure scenarios. In addition, a detailed primer on bearing technology prefaces the failure scenario discussions. Attendees will gain a better understanding of various types of gears and bearings. Learn about the limitation and capabilities of rolling element bearings and the gears that they support. Grasp an understanding of how to properly apply the best gear-bearing combination to any gearbox from simple to complex.

powertransmission.com/events/969-agma-gearbox-csi

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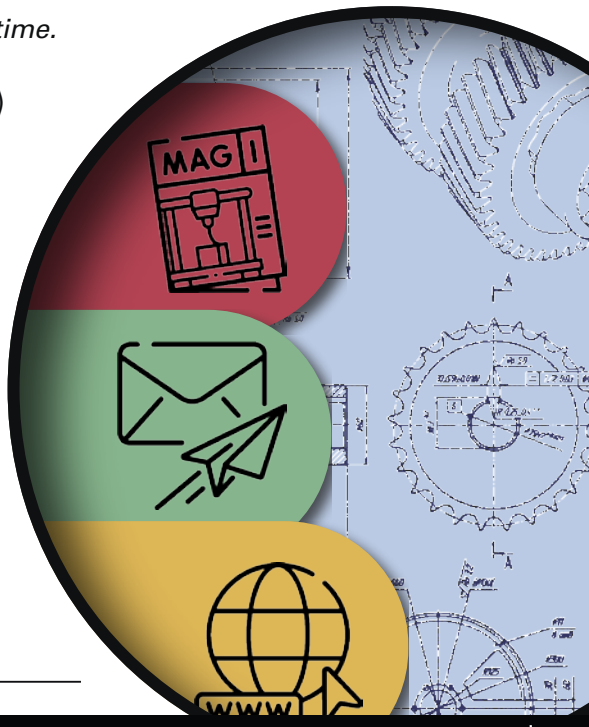

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The Art of Folding

Origami-Inspired Sensors Offer Precision and Repeatability in Soft Robotics and Medical Applications

Matthew Jaster, Senior Editor

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How does one accurately examine the components in a robotic arm or prosthetic leg? There's not exactly time (nor space) to set up multiple cameras to track deformation or changes in shape of soft components.

According to the USC Viterbi School of Engineering, cameras can gather data that enables researchers to measure stretchability and recovery, crucial information for predicting and therefore controlling the motion of the robot. This process, however, rarely works outside the lab. If a robot is navigating the ocean, operating up in space, or enclosed within the human body, a set-up of multiple cameras isn't practical.

Hangbo Zhao, an assistant professor in the Department of Aerospace and Mechanical Engineering and the Alfred E. Mann Department of Biomedical Engineering, recently developed a new sensor design using 3D electrodes inspired by the folding patterns used in origami that can measure a strain range of up to three times higher than a typical sensor.

Zhao said these sensors can be attached to soft bodies in motion—anything from the mechanical tendons of prosthetic legs to the pulsating matter of human internal organs—for the purpose of tracking shape-change and proper functioning, with no cameras required.

"To develop the new sensor, we leveraged our previous work in the design and manufacture of small-scale 3D structures that apply principles of origami," Zhao said in a news article by Matilda Bathurst for USC. "This allows the sensors to be used repeatedly, and to give precise readings even when measuring large and dynamic deformations of soft bodies."

Existing stretchable strain sensors typically use soft materials like rubber—but this type of material can undergo irreversible changes in the material properties through repeated use, producing unreliable metrics when it comes to deformation detection.

But what if the material of the sensor wasn't inherently soft or stretchy? Instead, the 3D structure of the electrodes would convert stretch and release to a process of unfolding and folding.

As the electrodes unfold, the strength of the electrical field is captured. A model developed by the team then converts this reading into a measurement of the deformation. This approach is ideal for responding to large deformations that existing sensors can't identify accurately, through the art of folding.

While the design of the new sensor was originally intended for controlling soft robotics—from delicate robotic grippers to snake-like surveillance devices—they are also ideally suited for innovation in biomedicine.

"We can apply these sensors as wearable or implantable biomedical devices for healthcare monitoring," Zhao explained. "For example, tracking the movement and flexibility of our skin or our joints. There's also high demand for developing implantable sensors that can continuously monitor the functional status of internal organs that undergo cyclic expansion and contraction."

This research resulted in a paper, "High-Stretchability and Low-Hysteresis Strain Sensors Using Origami-Inspired 3D Mesostructures," which was recently published in the journal Science Advances.

The combination of large stretchability, small hysteresis, fast response speed, directional strain response, and small sensor footprint is critical for accurately measuring local strain of large, complex, and multimodal deformations, as found in animals (e.g., octopus arms and elephant trunks), humans (e.g., lungs), and soft robots.

The scalable fabrication process and predictable sensor performance further expand opportunities for practical implementation. Future work may involve 3D electrode designs for increased strain range and gauge factor, as well as enhanced resistance to normal pressure and electromagnetic interference.

These findings suggest potential applications for accurately measuring large and complex deformations of soft bodies in wearable and implantable devices, soft robot proprioception, and human-machine interfaces.

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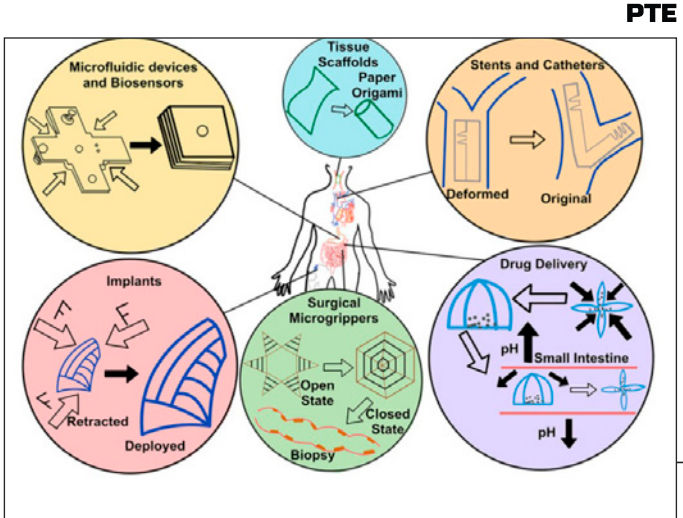

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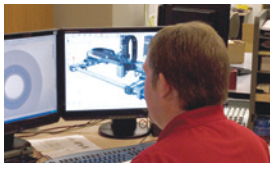

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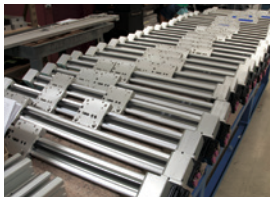

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