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Power Transmission Engineering®

MARCH 2015

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Engineering Showcase

A celebration of some of the leading products and companies in mechanical power transmission.

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Power Transmission Engineering

VOL. 9, NO. 2

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3-D Printing.

SERVO GEAR REDUCER

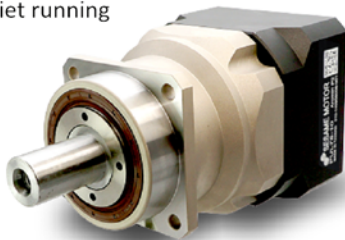
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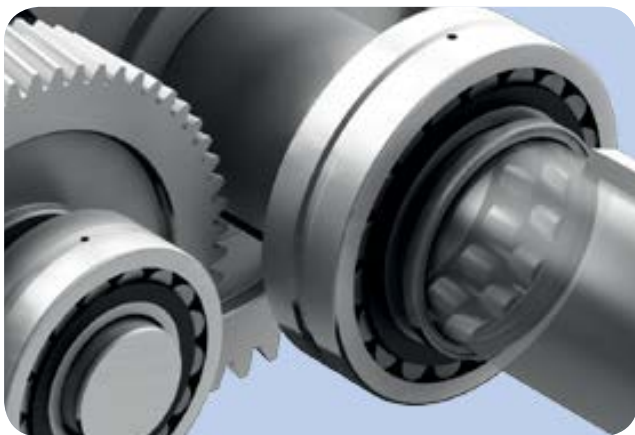
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Dealing with Aluminum Housings

Blogger Norm Parker tackles the challenges of aluminum housings in his latest posts, including entries on bearing cup fits, bearing cup distortion after assembly, and preload change. This expert technical advice is only available online on Norm's blog: www.powertransmission.com/blog



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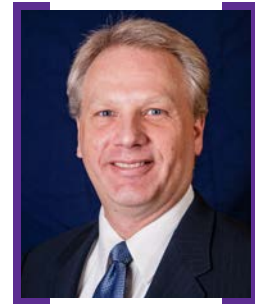
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Engineering Extravaganza



This issue we present our Hannover Fair pre-view. As most of you know, Hannover is one of the biggest trade shows on Earth, and by far the largest that includes a significant focus on mechanical power transmission components.

I mean, there are complete halls of exhibitors waiting to demonstrate their mechanical components technology. The official Hannover Fair website lists more than 400 exhibitors of bearings, 350 exhibitors of gears and gear drives, 900 exhibitors of motors – you get the idea. Hannover isn't just a big show. It's *the* big show. Every other year, Hannover includes a strong focus on power transmission components, with its Motion, Drive and Automation sub-show. Because this is an MDA year, Hannover is especially relevant to us in 2015.

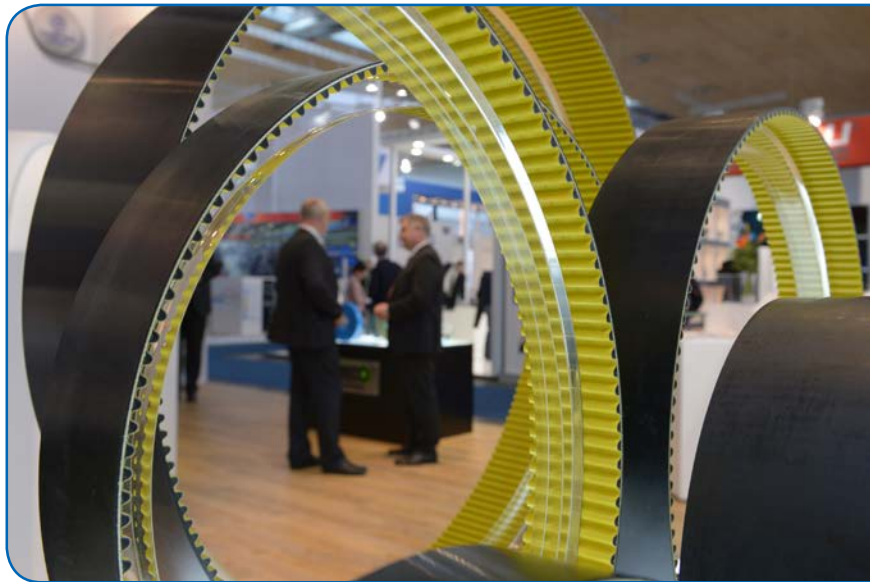
What's more, Hannover Fair isn't a trade show like we're used to here in the United States. Over there, the exhibitors bring the goods. Visitors will see displays of enormous gearboxes, giant slewing rings, bearings taller than you are, and so forth. It's not at all like a typical American trade shows where the local sales rep sets up a table-top display. Large global companies like SKF, Siemens and SEW-Eurodrive will erect exhibits that resemble small cities more than trade show booths.

If you've never had the opportunity to visit Hannover Fair, I encourage you to go. The show takes place April 13-17. In addition to the exhibition, there is a comprehensive lineup of conferences and technical programs. This year's focus is on Industry 4.0 and the digital factory. If you can make it to Hannover, I'm confident you'll walk away with a much better appreciation for the depth and breadth of the global power transmission industry. And you'll also get the chance to meet with numerous potential suppliers who might have the solutions you're looking for.

We'll be represented at the show by my colleague, Associate Publisher Dave Friedman. Dave will do his best to make the rounds and learn as much about as many of these suppliers as possible, and he'll bring that information back here so we can share it with you.

In the meantime, please have a look at our show preview article beginning on page 26. We've spoken to the show organizers and some of the exhibitors to present you with some ideas about what you might find at this year's show. Although we can't possibly do justice in a few short pages to a show as large and as comprehensive as Hannover, we hope you'll get a feel for the level of engineering technology that's out there.

Speaking of engineering technology, we've put together a display of our own this issue, in the form of our second annual Engineering Showcase. It doesn't compare with Hannover, of course, but we're proud of it just the same. Check out pages 30-39 to see what some of the leading suppliers have to offer this year.



Finally, if you're interested in looking for new potential suppliers, don't forget to stop by *powertransmission.com*. We're constantly adding new suppliers to the Buyers Guide, including, over the last couple of months: ATA Gears, Continental Conti-Tech, Framo-Morat, KTR Couplings, Nachi America, PSL of America, Rave Gears and Machining, Yieh Chen (Six Star Machinery) and more. These and hundreds of other premium suppliers of mechanical power transmission components are waiting to help you solve your engineering challenges. Why not visit them today?



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Stieber Clutch

AIDS ATTEMPT AT WORLD RECORD IN HIGH-SPEED BIKE COMPETITION

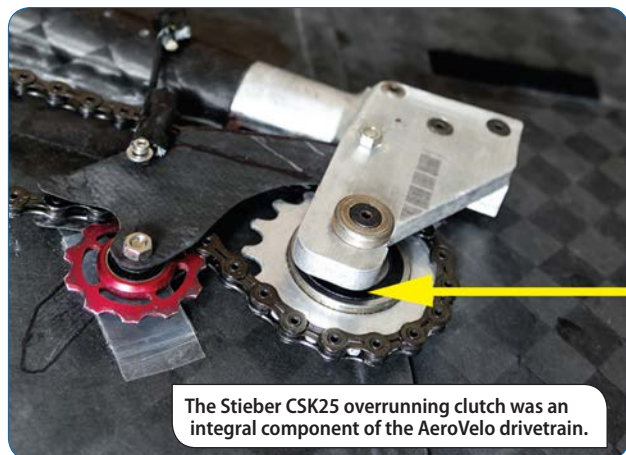
Humans have an innate thirst for adventure and an instinctive desire to expand their knowledge through first-hand experience. By testing the limits of personal strength and endurance, humans can obtain a better understanding of themselves. One aspect of adventure is the art of competition.

Team AeroVelo, comprised of professionals and engineering students from the University of Toronto, recently pursued this quest for adventure by joining others in an attempt to set the world human-powered speed record.

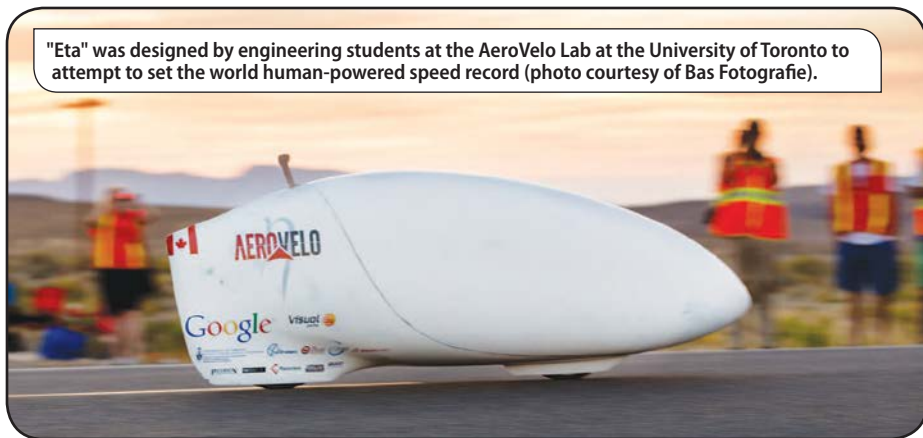
Every year, teams gather from around the world to compete at the World Human-Powered Speed Challenge (WHPSA) in Battle Mountain, NV. Team AeroVelo brought their newly designed "Eta" speed bike to the 2014 competition. AeroVelo, a design and innovation lab, pursues engineering projects that foster a sense of adventure and passion in scientific development.

"We're very small and right now our main activities are the student summer projects, public speaking and outreach and limited consulting on wild engineering projects," stated Cameron Robertson, co-founder of AeroVelo, Inc. "AeroVelo partners with the University of Toronto's Human-Powered Vehicle Design Team (HPVDT) and shares the team workspace full-time during the summer."

HPVDT, comprised of U of T undergraduate students in aerospace, materials and mechanical engineering, focuses on the design and construction



The Stieber CSK25 overrunning clutch was an integral component of the AeroVelo drivetrain.



"Eta" was designed by engineering students at the AeroVelo Lab at the University of Toronto to attempt to set the world human-powered speed record (photo courtesy of Bas Fotografie).

of innovative, high-performance human-powered vehicles. The goal of the AeroVelo/U of T partnership is to provide students with hands-on, practical engineering design experience that promotes efficiency and sustainability while encouraging the reduction of society's impact on the environment. Each year the student team has four months to engineer and build a human-powered vehicle.

"The students' time at AeroVelo counts toward a 600-hour engineering experience required of all graduates," Robertson said. "For students, it's similar to a research internship in a lab, but the design freedom, creative opportunities and time spent in hands-on fabrication are above and beyond what is available elsewhere. This summer, all of the students have been extremely motivated and have very quickly picked up on many of the design concerns and tradeoffs in developing this year's high-powered speed bike. Students with no specialization in bicycles or aerospace have quickly become familiar with both."

"Eta," the name of AeroVelo's 2014 speed bike, is the Greek letter used in engineering as the symbol for efficiency, and represents the team's goal of building the world's fastest human-powered vehicle, capable of breaking the current ground level speed record of 133.8 km/h (83.1 mph).

The speed bike's internal components are as equally fundamen-


tal to the successful performance of the bike as the aerodynamic design. A portion of Eta's transmission is designed to use a more efficient chain than what is typically used in bicycles.

"Most bicycles have a free-wheel which allows the wheel to rotate even when the pedals and chain are stationary," said Alex Selwa, a member of the U of T student engineering team. "In our front-wheel drive design we are not using a standard bike chain and cannot use an off-the-shelf bicycle free-wheel."

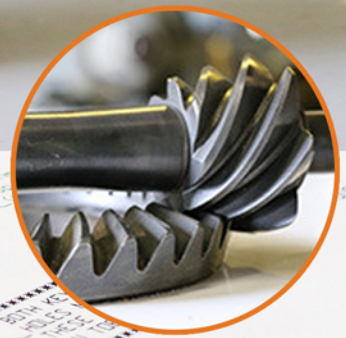
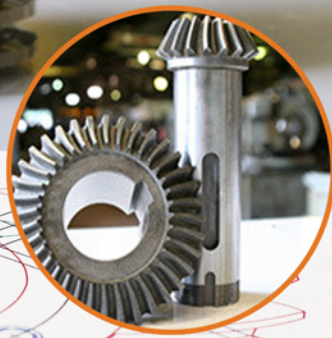
The team contacted Formsprag Clutch in Warren, MI to request an overrunning clutch solution. Formsprag, an Altra Industrial Motion company, donated a Stieber CSK25 PP overrunning clutch to the AeroVelo team as part of Formsprag's Student Support Program. The CSK clutch was chosen in order to accommodate the size and load requirements of the unique hub.

"The front hub design involved fitting many different components into a small and efficient package," said Selwa. "The clutch needed to be as small as possible in order to fit inside the sprocket and stay within the width requirements of the hub. The clutch is press-fit onto the hub body and then pressed inside of the sprocket. It is responsible for driving the wheels at speeds up to 145 km/h or 90 mph."

Stieber's model CSK25 PP is a bearing-supported sprag-type clutch, delivered grease-lubricated and protected against dust particles as small as 0.3 mm. It provides instant locking/engagement when the clutch shifts from overrunning to engagement, with a maximum overrunning speed



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of 5,000 rpm and a 77.5 lb. ft (105 Nm) torque capacity. The sprag-type backstop keeps the shaft from turning backwards with keyways on both the inner and outer races that prevent the bearing from rotating on the shaft. All CSK clutches feature Formchrome sprags with chromium-infused steel that produces an ultra-hard surface to maximize wear resistance.

With the help of Stieber Clutch, Team AeroVelo's Eta speed bike reached a top speed of 126 Km/h (78 mph) at the 2014 World Human-Powered Speed Challenge.

"Our goal with Eta is not simply to break a speed record," stated Todd Reichert, co-founder of AeroVelo, Inc. "Our goal is to reach such unbelievable speeds that it gets people to think twice about preconceived limits of what is possible."

For more information:

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Marsh Bellofram

LAUNCHES TYPE 5000 PRESSURE TRANSMITTER

The Precision Controls Division of Marsh Bellofram Corporation, (Bellofram PCD) a member of the Bellofram Group of companies and an ISO9001:2008 certified designer and manufacturer of industrial air pressure regulation instrumentation, recently announced the launch of the Type 5000, a two-wire I/P pressure transmitter for industrial field service requirements.

The Type 5000 pressure transmitter converts a signal pressure input into a 4-20 mA or 10-50 mA output with 0.1% typical accuracy. Its design incorporates a temperature compensated piezoresistive transducer for the accurate gauge pressure measurements of both non-corrosive gases and liquids. The transducer is insensitive to mounting orientation and most industrial vibration inputs.

The lightweight housing of the Type 5000 includes a ¼ inch NPT pressure port and ½ inch NPT conduit port for field wiring. The arrangement of mounting holes on the transmitter housing also permits direct pipe mounting for minimum installed cost. Connections are accessible via the unit's top cover removal.

Type 5000 pressure transmitters are available with a variety of industry certifications, including NEMA 4X housing approval for explosion-proof service; FM Class I, Divisions 1 and 2, Groups B, C & D approvals for explosion-proof service; FM Class II, Divisions 1 and 2, Groups E, F & G approvals for dust ignition-proof service; and FM Class III Divisions 1 and 2 approvals. Other industry specific approvals and certifications may be available upon request.

All Marsh Bellofram products are 100% designed and manufactured in the USA at the company's manufacturing facility in Newell, WV. Standard models are typically available for shipment within just ten business days, with expedited delivery upon request.

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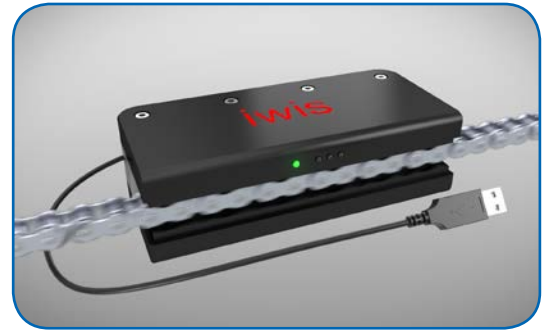


Chain manufacturer Iwis Drive Systems recently developed a new monitoring system for measuring chain elongation. The new, patented CCM (Chain Condition Monitoring) system measures the wear elongation of chains in use and warns the maintenance personnel in advance if the chain needs to be replaced.

The CCM system can be integrated in numerous chain applications and retrofitted in existing plants and machines without the need for special add-on components for the chain. The device determines the wear in a chain drive and notifies maintenance personnel where and when preventive maintenance is required. Operating state and wear status are indicated by LEDs and readings can be transmitted to a computer through USB and viewed with a special interface. Because measurement is contactless, the chain drive is not affected in any way. No additional deflection pulleys or supports are needed.

“The main benefit of the new CCM system for our customers is that maintenance personnel can react on time,” said Florian Madlener, design and development engineer at Iwis’ headquarters in Munich, Germany. “No long downtimes of plants and machinery, no risk of missing delivery deadlines, no interruption of the logistics chain. All of these contribute to avoiding financial loss through production outages. The system can also continually monitor high-precision chain applications.”

The CCM system can be used independently of chain speed. Depending on the chain size, possible chain speeds range from 0.02 m/s to over 15 m/s. The device has protection class IP67 and can be used under normal environmental conditions and at temperatures from 0 to 60°C. Calibration of the CCM system to the respective chain sizes is performed by Iwis before delivery.



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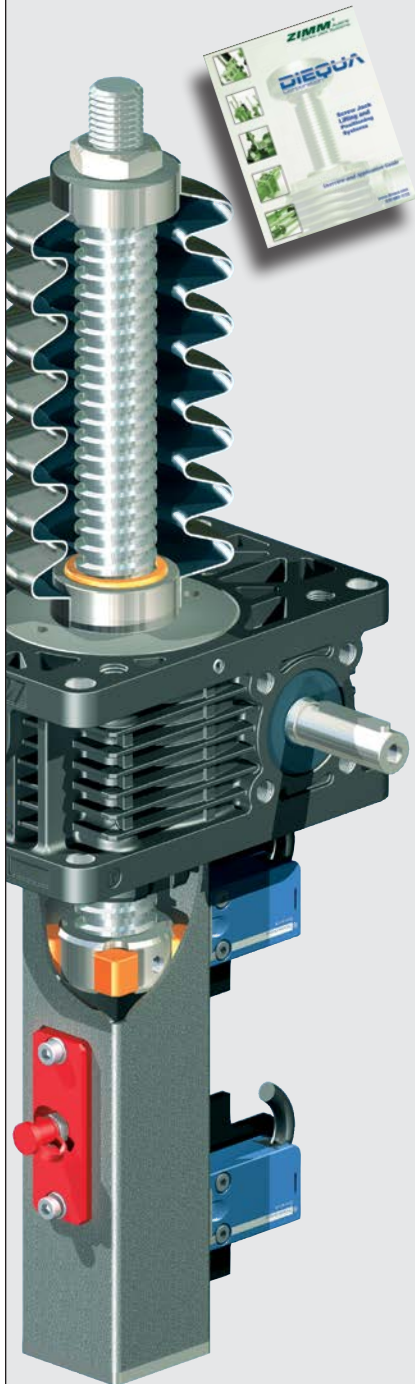


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SKF spherical roller bearings feature two rows of patented self-guiding rollers with a common sphered raceway in the outer ring and an optimized internal design. These features serve to reduce friction, minimize heat generation, accommodate shaft misalignments and heavy loads, and contribute to longer bearing life.

SKF CARB toroidal types are self-aligning radial bearings merging the benefits of standard “locating/non-locating” bearing systems typically found in continuous caster applications. They are designed to accommodate misalignment (similar to spherical roller bearings) and normally supplied as full complement bearings to take advantage of their increased load rating.

All SKF caster bearings are available in a wide range of sizes and can be specified with specialized seals and otherwise customized to meet demanding application requirements.

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RSF

ELEKTRONIK RELEASES NEW MODULAR ENCODER

RSF Elektronik recently unveiled the MSR 40 modular rotary position feedback system to machine designers who want a way to measure angle on larger rotary axes. Common applications for the MSR 40 include medical technology, general automation, textiles, and auxiliary axes in machine tool and metrology.

The MSR 40 optical kit style encoder provides a 200 micron grating pitch on a steel tape that has three ways of being applied to the axis of motion. The MSR 40 is suited for machines which require motion feedback for a full 360 degrees or a segment thereof.

The MSR 40 is available with a minimum diameter of 150 mm to a maximum of 1,150 mm; however, larger diameter versions are available upon request. The same reader head can be used for all the various diameters offered, and is available with analog 1 Volt peak to peak interface as well as digital TTL interface with up to one

hundred times interpolation.

All measuring tape versions of this encoder have a ± 30 micron per meter accuracy associated with the circumference of tape. The MOR version tape requires a small pocket to be milled from the axis in order to accommodate a clamping mechanism which ensures accuracy over the joint of the measuring tape ends. The MER version has small plastic tubes on the back of the measuring tape as a supporting structure and the measuring tape can be screwed together to complete a full 360 measurement. This version mounted to the axis has a benefit because of the tube backed measuring tape. This version is rated for a lower dynamic performance and rigidity as a consequence of simple mounting.



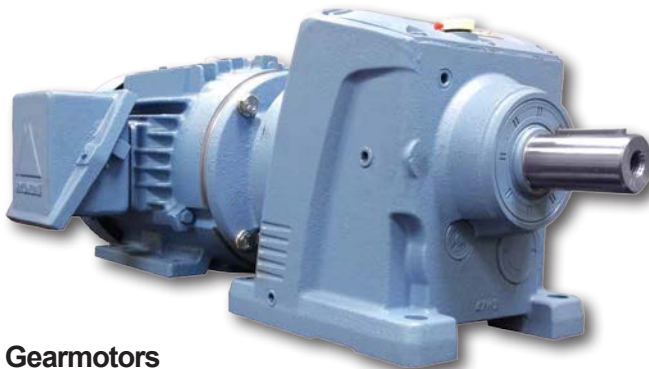
RSF Elektronik encoders are available in North America through parent company Heidanhein Corporation, and found in the metrology, machine tool, and semiconductor industries.

For more information:

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Parker

RELEASES ETH125 ELECTRIC CYLINDER

Parker's Electromechanical Automation Division, a supplier of motion control technology, recently announced the release of the ETH125 electric cylinder.

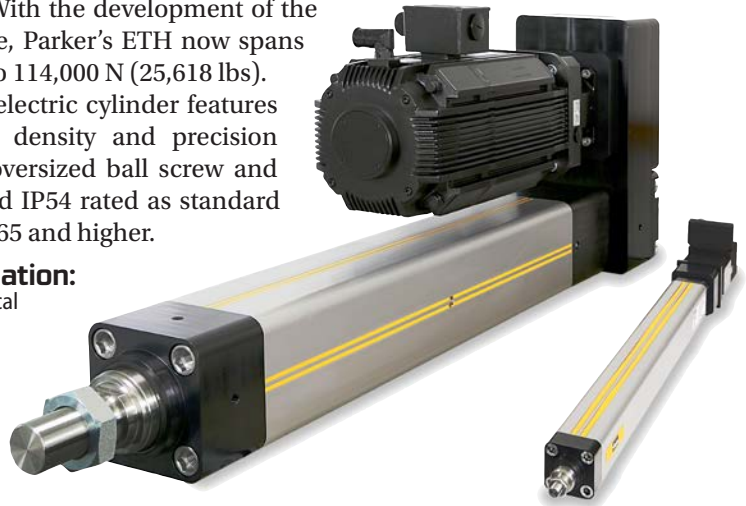
The ETH125 is the fifth and largest frame size in the series and expands this line of industrial cylinder product to serve a broader range of application requirements.

The ETH is the next generation of electric thrust cylinder product and utilizes a new integrated drive train and guidance design that has enabled Parker to maximize the overall thrust capacity within a smaller overall footprint. With the development of the 125 mm frame size, Parker's ETH now spans a thrust range up to 114,000 N (25,618 lbs).

ETH high force electric cylinder features maximized thrust density and precision position control, oversized ball screw and thrust bearings and IP54 rated as standard with options for IP65 and higher.

For more information:

Parker Electromechanical
Automation
Phone: (707) 584-7558
www.parkermotion.com



Bosch Rexroth

DEVELOPS CONTROL SOLUTIONS FOR CRANE DRIVES

Rexroth recently developed a new control solution that is suitable for both simple and complex winch and crane drives

The control system from Rexroth can be connected to the customer's system using predefined interfaces. Numerous hardware variants in the form of an extensive modular system allow the designer maximum flexibility and reduce costs and errors during commissioning by means of a simple "plug-and-play" interface.

In the software, for example, the designer can access standardized modules for control functions. Integrated security features ensure compliance with the required safety level. The modular structure of the software makes using the control system very flexible, in both simple and complex applications. The designer

can choose the degree of networking, also in terms of security features, according to the specific application requirements.

For example, for applications with a hydraulic power unit and a single winch drive Bosch Rexroth offers with this solution a cost-effective and extremely compact integrated control system, based on its BODAS RC28-14/30 controller.

Originally developed for mobile applications, the controller is designed



Metcar

ANNOUNCES AVAILABILITY OF CUSTOM VANES, ROTORS AND END PLATES

Metallized Carbon Corporation, a manufacturer of oil-free, self-lubricating, carbon-graphite materials for severe service lubrication applications, recently announced the availability of custom vanes, rotors, and end plates for use in rotary vane pumps.

The carbon-graphite components provide lubrication in most environments, and are designed for pumping liquids with poor lubricating qualities, strong chemicals that attack metals, and to pump air, vacuum, combustion products and gasoline vapors.

Metallized Carbon's carbon-graphite vanes, rotors, and end plates are used in such dry running applications as automotive anti-smog pumps and gasoline vapor pick up pumps, breathable air pumps and vacuum pumps. In-liquid applications include vending machine beverage pumps, fuel and liquid chemical pumps, and medical liquid pumps.

Metallized Carbon supplies the carbon-graphite vanes, rotor, and end



for use in harsh environments, as it can withstand temperature changes as well as vibrations and shocks. The control solution is also compact and can be installed saving space on deck for workboats or platforms.

Modifications, enhancements, and the interface to the customer's system can be tested and adjusted by the designer directly on a test stand provided by Rexroth. This saves an expensive commissioning and testing of the solution on board the ship.

Based on proven technology, field-tested components and validated software, Rexroth's control solution enables engineers to develop crane and winch systems with optional active heave compensation capabilities faster and cheaper.

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plates to rotary pump and compressor manufacture and rebuilders. The materials are chemically resistant and are compatible with FDA food and beverage regulations. They have a low wear rate running in both gas atmospheres and low viscosity liquids.

Carbon graphite vanes can withstand the rubbing of the vane tip against the housing bore and the rubbing of the side of the vane against the slots in the rotor. Lightweight carbon graphite rotors save energy and withstand the rubbing against the vane and

the end plates. Carbon graphite end plates are pressure tight and dimensionally stable so that they can make a close clearance seal with the rotor and vanes. They also withstand the rubbing of both the vanes and rotor.

These materials work best in severe service applications.

“With dimensionally stability and high strength to weight ratio, the components are available in several grades of Metcar’s proprietary carbon/graphite material,” said Matthew Brennan, chief operating officer of Metallized

Carbon. “Our engineers assist in selecting the optimum grade based on application, environment, housing materials, rpm and other parameters.”

For more information:

Metallized Carbon Corporation
Phone: (914) 941-3738
www.metcar.com

NSK

LOW TORQUE BEARINGS IMPROVE ENERGY EFFICIENCY IN MRO SECTOR

Within the global automotive sector, NSK has worked with the industry to produce low torque bearings which help to reduce power consumption and emissions. Now these advances in engineering design are being applied to general purpose, deep groove ball bearings, which are used in a wide range of industrial applications.

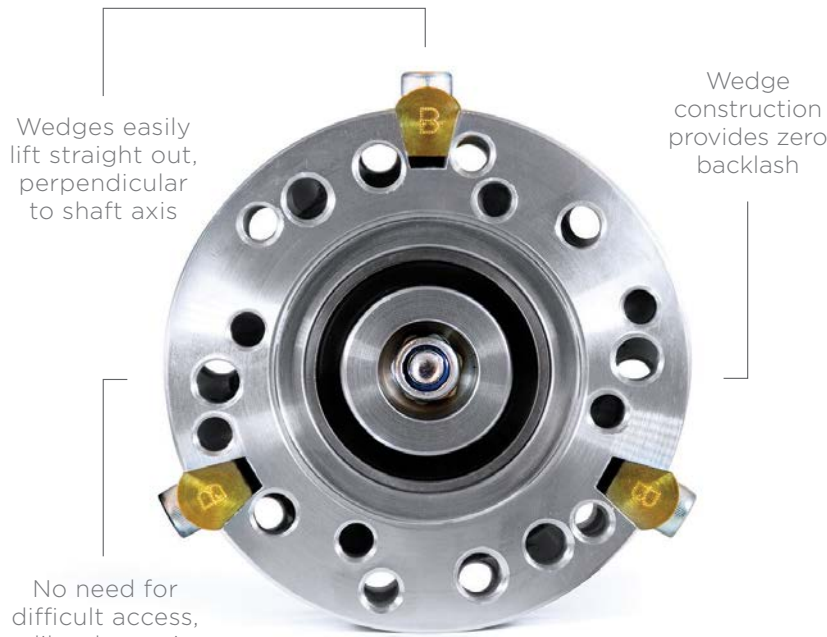


There is a worldwide focus on energy efficiency and, increasingly, production engineers are looking beyond initial procurement prices when assessing capital investment in new equipment. Instead, attention is drawn to the total cost of ownership (TCO) as well as CO2 emissions for the expected life of the machine. Most notably, this has led to changes in electric motor design and the regulations which govern it.

NSK recently developed a series of improvements for bearing design and manufacture. These have resulted in standard deep groove ball bearings demonstrating up to a 47 percent torque saving for high speed domestic appliances compared to conventional bearings of the same size.

NSK has made several developments in tribology and material technol-

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ogy as well as advancements in steel cleanliness to produce an improved steel fatigue life. In addition, further advancements have been made in the heat treatment process which increase hardness and wear resistance characteristics.

In terms of actual bearing manufacture, NSK has modified the ball bearing raceway surface finish and geometry. This reduces internal friction which

in turn reduces power consumption, operating noise levels, heat generation and wear. This is complemented by further improvements to the lubrication and sealing properties of the NSK bearings.

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R+W

INTRODUCES NEW MINIATURE VIBRATION DAMPING DRIVE SHAFT

R+W America recently expanded upon its design of vibration damping drive shafts, series EZ2, with a new miniature design, size 5. The new size 5 shafts feature customer specified lengths and bore diameters, along with fully split clamping hubs for easy drop-in mounting. Speeds in excess of 5,000 rpm can be achieved without any intermediate support bearings required.

Improvements include clamping hub bore diameters from 5 mm to 1/2", with or without keyways, peak torques up to 24 Nm with an outside diameter of just 25 mm, customer specified lengths of up to 6 meters and custom application engineering datasheet with each quotation request.

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In addition to this new smaller size there are also new larger sizes, expanding the R+W range of vibration damping drive shafts to include torque capacities up to 25,000Nm and bore diameters up to 140 mm.

For more information:

R+W America
Phone: (630) 521-9911
www.rw-america.com



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Please send press releases, along with high-resolution photos, to Erik Schmidt, Assistant Editor, via e-mail at erik@powertransmission.com.



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Diagnosing the Health of Medical Motors

Brushless motors proving to be the cure for the common medical device

Erik Schmidt, Assistant Editor

John Morehead, national sales manager of Crouzet Motors (Vista, CA), was bunkered down in his office in Palatine, IL surrounded at all points by ankle-deep snow from an unfortunately terrible Chicago's winter night. After a polite pardon, he removed himself briefly from conversation for a quick refreshment to clear his throat.

Once a safe distance from the receiver, Morehead coughed heartily for the umpteenth time, sending a muffled squawk through the mouthpiece, and then revealed information that any solid sleuth would have found quite elementary.

"I'm coming down with a bad head cold," he said.

The topic of discussion that icy afternoon: motors being used in medical devices.

How very fitting.

Motoring Forward

True, there is no application for a motor to cure the common cold. So, despite Morehead's deep knowledge on the subject, he was simply going to have to overcome his ailment the old fashioned way—with a bag of Halls and ceaseless patience.

While Morehead himself was stuck in phlegmatic purgatory, countless hospital patients across the world were being aided by machines powered by Crouzet motors.

Unpoetic justice, perhaps. But you won't see Morehead complaining about the positive development.

"We're seeing more and more applications in the hospital for motorizing tasks that were before done with human power," Morehead says. "I think part of that—I saw a study on this—is that the average age of a nurse in the workforce today is something like 52 years old. There's just so much more for them to do."

And that's where motors come in.

More and more, the world is becoming motorized and automated—and hospitals are no exception. Brushed direct drive motors and brushless direct drive motors have been used for years to power diagnostic equipment, blood and DNA analysis machines, and peristaltic pumps. In recent years the demand for motorized medical equipment has only grown.

"How many electric motors do you think you have in your home?" asks Dan Jones, president of Incremation Associates, Inc. "How about 60 on average. How many motors are on an automobile? There's about an average of 30 to 40. If you didn't have them your windshield wipers wouldn't work, your windows wouldn't go down, and your seat wouldn't adjust.

"Motors are so ubiquitous that nobody thinks about them until they have a problem."

That "problem" in regards to the medical profession was posed by Morehead as such: "How do we take



The Crouzet Motors' line of DCmind Brush motors are designed specifically for medical applications.

away the workload of nurses and allow them to be more productive?"

The most prominent way that motors help in this process is their utilization in various medicine-administering pumps, such as a peristaltic pump — a type of positive displacement pump used to pump sterile or aggressive fluids because cross contamination with exposed pump components cannot occur.

"They're used in dialysis machines and a lot of other areas," Morehead says. "For example, when someone is going into a dialysis center they may be injected with what's called Venofer iron. That's put into the bloodstream before the kidney dialysis, and a vial of the Venofer takes about five minutes to inject by the nurse.

"One of the customers that [Crouzet] works with has a product that is an addition for the dialysis machine, so it's able to administer the Venofer iron with just the nurse doing the initial injection. This frees up the nurse for the five minutes she might be standing

there otherwise manually doing the entire process."

According to Morehead, other innovations in recent years include making motors more discreet, mobile and efficient.

"It boils down to a few key words: quieter, conserving, controllable and connected," Morehead says about the current state of medical motors. "Basically, we're seeing more and more interest in quieter motors in the medical market, and the interest is heightened even further in the operating room where there is an especially strong incentive to reduce high-frequency noises.

"On the conserving side, it's in reference to energy efficiency and battery-powered equipment. When you're looking at devices that are portable, energy efficiency becomes very important so that you can get the greatest running time between charges for the equipment.

"Controllable is the fact that people are wanting to operate equipment at

varying speeds and at the speeds that are required by the task at hand.

"I think that plays into what we're seeing with the brushless motors a lot."

Brush it Off

Since the dawn of Homo erectus, the brushed DC motor has been aiding two-legged primates tackle the enormity of the planet earth.

OK, so maybe not.


Brushed motors don't actually date all the way back to the days of cave paintings and Oldowan stone tools, but close—DC distribution systems were used for more than 100 years to operate motors in commercial and industrial buildings.

A brushed DC motor is an internally commutated electric motor designed to be run from a direct current power source. They're economical, but also noisy and often in need of maintenance because the brushes wear down due to friction.


Slowly but surely, the brushless DC motor — also called the direct drive

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motor or the electronically commutated motor—has begun displacing brushed motors in many applications.

And in terms of effective usage in medical devices, brushless DC motors have been a natural fit.

“Brushless motors have been around a long while. It’s just that it takes a long time to percolate to various locations,” Jones says. “The brushless motor is the best motor for torque and the smallest motor for performance power for power, so it has a lot of advantages.

“It’s linear, where induction motors are not, so you have more current and get the torque you want. You have more voltage and you get more speed. It’s better and it’s easier to control—so people are figuring out a way to use it.”

Brushless motors became commercially available in 1962, but were not widely used in medical devices until about 15 to 20 years ago, according to Morehead.

A typical brushless motor has permanent magnets which rotate around a fixed armature, eliminating problems associated with connecting current to the moving armature. An electronic controller, which continually switches the phase to the windings to keep the motor turning, replaces the commutator assembly of the brushed DC motor. The controller performs similar timed power distribution by using a solid-state circuit rather than the commutator system.

“It used to be that you could buy a brushless motor and then if you were to buy a control to operate that motor and vary the speed, the control might cost as much as the motor,” Morehead says. “That control was typically on a separate circuit board on a bracket or in a small enclosure that was separate from the motor.

“I would say that in the late ’90s, early 2000s time frame, the state of electronic development advanced to the point where you were able to reduce the size of the control. The other part of that was in order to get electronics to live, you had to be able to isolate the electronic components from the heat that would be produced by the motor. Some of the early ventures to try to do that were kind of short lived, because



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they would put a control board on a motor generating heat and get premature failure on the component.

“The thing was to figure out how to properly isolate and provide the right thermo-barrier there. I would say in the last five to eight years, there’s been a big growth in brushless motors with integral electronic controls. In some instances, that control can be used to vary the speed of the motor and can use various IO, as well. More recently, that control capability has gone to positioning controls, so basically you can have the equivalent of a servo drive all on the motor.

“That’s really become an important growing area. It’s a much higher value component.”

Brushless motors are used in CT-scanners and equipment related to opening protective barriers in medical environments such as an x-ray room, but it’s their use in various pumps that seem to be having the most influence in the medical field.

“We tend to see, in terms of the types of motors [Crouzet] produces, a lot of interest in changing the type of motor used in various pumping applications,” Morehead says. “Some of the motors we make are used in various surgical procedures where the motor is pumping a saline solution that provides a kind of lubricant while the procedure is being done.

“Of course, in all of this, the big thing is reliability and the lifetime of the product.”

There is no doubt that brushless motors represent the future. For a moment, though, let’s travel back to the dark ages and posit a question:

Do brushed motors hold any sway in today’s world?

The answer according to Morehead: thanks to Crouzet, they certainly do.

“I sound kind of boastful, but there haven’t been any real significant developments in brushed DC motors in probably 25 years,” he says. “[Crouzet’s DCmind Brush] is one where we do feel like it’s pretty significant, because of the noise being reduced from something like 60 decibels to 34 decibels, and the increase of life can be three times longer or more.



Pictured is an arterial plaque removal system that uses motors from Crouzet Motors.

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“The DCmind Brush is probably the most innovative product on the market on the brushed side.”

On the brushless motor side, Portescap recently introduced a new addition to its Ultra EC mini motor platform—the 16 ECH brushless motor. According to a press release, the 16 ECH was designed specifically to provide an economic motor solution for high performance applications. It’s specifically optimized for high continuous torque at low to medium speeds,

maximizing power between 40 K and 55 Krpm, and rated speed at approximately 60 Krpm.

The advantages of the 16ECH make it a great match for low speed, high torque end applications, or applications in the medium speed range (30 K to 55 Krpm). The 16ECH is a good choice for geared applications because of its minimal speed drop and low motor heating under load. Additionally, the 16ECH’s efficiency, power density and long life make it an alternative for

a brush DC motor solution, the press release said.

A Quick Look through the Crystal Ball

Now that we’ve touched on both the past and present of medical motors, you may be asking yourself, “But what of the future?”

Morehead said it’s closer than you may think.

“I think one thing you’ll see more of is the magnetic pump drive for gear pumps,” Morehead says. “There aren’t many companies who are doing that and we’re a player in that. We’re actually making a brushless motor without any [internal] moving parts.

“It’s a brushless motor with variable speed control mounted to it, but there’s nothing rotating within the motor. Rather, instead of the rotor rotating like it would in a regular brushless motor, it’s replaced by a magnetic cylinder that couples to the gear pump. Therefore, the gear pump is able to operate without any seal so there’s no leakage or contamination.

“This makes for a more precise dispensing and calibration than you would have with a typical peristaltic pump.”

Looking through his crystal ball, Morehead saw that these magnetic pump drives would be a prominent fixture of the medical market in the next several years.

And, presumably, he also saw himself healthy as a horse, devoid of any nagging head cold or annoying throat condition.

Either way, it would seem that happy, healthy days are surely ahead. **PTE**

For more information:

Crouzet Motors
Phone: (214) 906-0182
www.crouzet.com

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The Future Rests on the River Leine

The biggest day in industrial manufacturing has even bigger expectations

Erik Schmidt, Assistant Editor

“[Motion, Drive & Automation] at Hannover Messe is the place where the future is determined.”

That lofty line was delivered by Hartmut Rauhen, the deputy CEO of the German Engineering Federation (VDMA) and the VDMA management board member in charge of power transmission and fluid power – and it certainly bears repeating, if only because such weighty expectations simply can’t be carried by one meager sentence.

The place where the future is determined.

Not in some mahogany-soaked boardroom of a Fortune 500, mind you. Not at a grand summit of the world’s powers in New York City. Not at 1600 Pennsylvania Avenue – but, of all places, Hannover, Germany, the smallish capital of Lower Saxony that rests rather unassumingly on the high bank of the River Leine.

And it’s there, at this formerly medieval metropolis of fairs and festivals, where the fate of the world rests, eagerly waiting to be decided. Now, you may be wondering what such a pivotal, momentous event looks like. Imagine, just for a moment, the grandness of 250,000 worldwide visitors descending upon a city of barely over 500,000.

That, in essence, is Hannover Messe: The physical manifestation of humanity’s infinite ambition. So ambitious, in fact, that it attempts– and, somehow, succeeds – in delivering 10 different shows in five days to a number of people nearly half the size of Hannover’s entire population.

The sheer massiveness, both literally and figuratively, of Hannover Messe is undeniable. But will it really be able to determine the future of mankind in just a few days in April? It’s hard to say.

One thing is for sure, though: It’s sure as hell going to try.



What it is

It is fitting that, like all things at Hannover Messe, the show itself began in a factory.

Emerging from the rubble of the humblest of beginnings in an undamaged industrial unit in Laatzen, Germany, Hannover Messe has come a long way since its inception in 1947. Now the world’s largest industrial show – an epic, nearly endless conglomeration of over 4,000 of the planet’s most well-regarded companies, businesses and organizations – Hannover Messe, for lack of a better word, is *it*.

“Hannover Messe itself is generally a manufacturing technology show,” says Aryan Zandieh, director of industrial events, Deutsche Messe Worldwide. “It’s really a horizontal show with a couple of different lineups from various industries.”

With these “various industries” all converging in one location, Hannover Messe proves to be at both times excessively large and uniquely narrow, as spectators are allowed to view the show as a grand, writhing mass of numerous themes and exhibits, as well as hone in on one of the many individual sectors available to them for a more exclusive experience.

The 2015 lineup includes trade fairs for Industrial Automation, Energy, MobilTec, Digital Factory, Motion, Drive & Automation (MDA), Wind, ComVac,



All photos of Hannover Messe 2013 courtesy of Deutsche Messe.

Surface Technology, Industrial Supply and Research & Technology.

“As a single company coming to market with the brands that we have,” said David Brooksbank, director of marketing at Altra Industrial Motion Corp., “the Hannover fair offers us one great opportunity to be able to understand what is going on in the industrial world – because many of the industrial leaders are there – in terms of just production and how our products fit in as we move forward in the next five to 10 years.”

It seems rare – impossible, even – for such a massive enterprise to also come across as intimate, but Hannover manages to deliver a sense of synergy between the copious companies lining the labyrinth-like halls that few other shows can rival, according to R+W America Sales Manager Andy Lechner.

“It’s bigger than any industrial trade show in the Americas, that’s for sure,” he said. “I want to say the number of halls is in the range of 25 to 30. To put it in perspective, I want to say that McCormick Place (Chicago, IL) has like six or seven. It’s very, very diverse and I think pretty well organized.

“If you go to a lot of industry trade shows, even big ones here in the states, you’ll see that except maybe for the major players by the front door the companies are just sort of randomly scattered around and not really well-organized by technology or product. The difference with Hannover is that there will be multiple halls – let’s say two or three – that are dedicated to the areas of manufacturing technology that we’re involved in.

“Motion, Drive & Automation is an important category and that’s where it can be assumed you will find R+W and its competitors.”

Typically, the largest of all the individual trade fairs is MDA, a broad-based event spanning offerings such as antifriction bearings, pumps, motors, gearboxes, drive elements, clutches and brakes. One of the main benefits of the show is that it’s strategically positioned alongside the MobilTec and Wind fairs – whose exhibitors and visitors are among the biggest users of power transmission and control technology – which enables drive technology solutions to flow through into

enhancement areas in keys areas, according to the Hannover Messe official website (www.hannovermesse.de).

“You only have [the MDA fair] in odd years,” said Zandieh. “In even years you don’t have that so the show is generally smaller than in the odd years. We’ve been putting the show on for over 50 years and it’s been consistently growing.”

The numbers for the MDA fair in 2013 were rather robust: 1,200 exhibitors from over 100 different countries, 79,900 visitors and 2,142,000 business contacts made over the five-day period.

Zandieh expects more of the same in 2015.

“We have all the halls sold out,” he said. “It’s hard to predict, but yes, we do expect one of the record shows this year. We’re very, very excited.”

What to expect

Ah, the excitement – can you feel it?

Everyone who talks about Hannover Messe seems to speak with a little more melody in their voices, like it’s Christmas morning and old Saint Nick just dropped a bounty of packaged prizes down the chimney. In fact, that comparison isn’t all that far off – Hannover Messe is basically industrial manufacturing’s biggest holiday.

And, like Christmas itself, you can expect tons of shiny new toys – from

R+W America (Bensenville, IL), Altra (Braintree, MA) and hundreds of other companies.

“Hannover has always been a really important show for R+W internationally,” said Lechner. “It’s obviously key to show some things that are new. Basically the biggest development that we’ve made that we want to showcase there is a high-torque, high-speed safety coupling.

“R+W has made safety couplings since the ’90s, and about six years ago we introduced a heavy-duty line that basically increased our torque capacity from 2,800 Nm up to 160,000 Nm. Since we’re so involved in high-speed machinery, namely in automotive testing machinery, we came up with a system that handles both high-torques and high-speeds that really kind of hits the power requirements for a lot of people doing E-motor testing in the automotive industry.”

According to Lechner, R+W will be debuting its fully integrated torque coupling at Hannover Messe. It’s a high-torque, high-speed safety coupling that can be fitted with a bellows coupling. That particular configuration is well-suited to automotive testing applications, with the ability to disengage at speeds of over 10,000 rpm, with higher running speeds on request. Disengagement torques are available in the range of thousands of Nm. When



configured with a flexible bellows coupling they offer protection from misalignment and torque overload, while maintaining very smooth and high precision rotary motion with zero backlash. They are also available with flexible disc pack couplings and multiple other custom configurations.

“We’re excited to introduce this new product,” Lechner said, “along with providing our customers and international partners with a better look at our full line of heavy-duty industrial drive couplings through an augmented reality system, which R+W will be bringing to the fair.”

Excited – there’s that word again.

It flows through the veins of Hannover, pumping and beating electric lifeblood from the Americas over to Europe, where Brooksbank originally hails from. Now stationed at one of Altra’s U.S. locations in South Beloit, IL, Brooksbank spoke about showcasing Altra’s expansive list of varying brands, including two new ones not seen at the MDA fair during Hannover 2013.

“This will be the third time [we’ve been to Hannover Messe] as Altra,” Brooksbank said. “Every time we’ve been there we’ve represented all our (22) brands on a global basis. Now, two years ago did we have Svendborg Brakes and Guardian Industries? No, but every time we’ve gone we promote every one of our brands because every one of them has a global presence of some range.

“We do, in fact, try to promote the main European brands. Obviously they have a big presence – Stieber being one; Wichita Clutch, Warner Electric, Bauer Gear Motor and Matrix International.

“One of the main things we’re really trying to do this year is promote our Altra couplings brand, which are the Bibby Turboflex, Huco Dynatorck, Ameridrives and TB Wood’s brands, as we try to go to market in Europe as one brand.

“Couplings are very big for us, as well as our heavy-duty group with the acquisition of Svendborg.”

Altra will debut its brand new line of custom designed extra small brakes from Warner Electric, which are designed to be light weight and fit into the smallest areas.

Also being showcased by Altra is Stieber’s new torque limiting/load sharing low-speed backstop RDBRE releasable under load – the highest torque capacity for releasable external backstops available in the market today with a torque capacity of 700,000 Nm.

“In the overrunning clutch we have Stieber, Formsprag and Marland, which are formidable brands,” he said. “We have Warner Electric with electromagnetic clutches and brakes, and Warner Linear with the actuators. And then, of course, there’s Bauer as well.

“It just goes on and on – it can become very boring talking about each brand individually.”

The list, indeed, does seem to go on and on when looking at the complete rundown of Hannover’s exhibitors:

According to a recent press release, Parker Hannifin (Cleveland, OH) will be presenting the latest addition to its range of CMS system solutions. This involves a series of new sensors that can measure a variety of parameters, such as the viscosity, density and dielectric properties of hydraulic media, and which eliminate time-consuming calibration processes. The company will also showcase a new measuring technology that simultaneously counts particles and measures relative humidity. In terms of general industry trends, Parker Hannifin points to a move towards integrated CMS solutions.

“Customers now want total system health management solutions that

capture and rapidly analyze all the relevant data,” Parker Hannifin’s Sales Manager of Hydraulic & Engine Filtration, Stefan Nilgen, said in the press release.

Condition monitoring will also be a key theme at the stand of Festo Corporation (Esslingen am Neckar, Germany), according to a press release. The company will be showcasing its CPX valve terminal – an automation module that connects pneumatic and electrical systems. The terminal has a modular design with integrated condition monitoring functionality, diagnostics and electrical and pneumatic safety functions. The Festo stand will once again feature a new bionics study that provides a fresh perspective on a range of topics, including condition monitoring and diagnostics, the press release said.

Fluid-power specialist Argo-Hytos (Zug, Switzerland) will be using MDA to showcase a range of hardware-based CMS solutions for hydraulic systems, according to a press release. It will also be presenting its “CMS Systems & Services” package – a suite of turnkey measurement solutions that includes installation, calibration and monitoring services.

“The data captured by condition monitoring systems provide the basis for plant integration and optimization in the sense of Industry 4.0,” Christian Kienzle, CEO of the Argo-Hytos Group, said in the press release. “New digital





integration and information processing solutions are opening the way for the optimization of ever more complex processes and systems. To harness the full potential of CM solutions, we are increasingly using intelligent CM components, which we tailor to our customer's individual applications."

Bachmann Monitoring (Bonn, Germany) is going present a CMS solution for end-to-end wind turbine drivetrain monitoring. According to Bachmann, one of the key technology trends in the wind energy sector is the development of integrated solutions that can monitor entire turbines, from rotor blade to tower foundation.

Prüftechnik AG's (Ismaning, Germany) showcase will also center on wind turbine technology, according to a press release. The company will be presenting Vibguard XP, a new version of its Vibguard online condition monitoring system that was specifically developed for the wind energy industry. Vibguard XP captures and analyzes signals on up to 20 channels simultaneously. It can pick up irregular vibrations in the drivetrain and tower and can even detect the formation of ice on the rotor blades, the press release said.

And remember: These are just a few of over 1,000 companies from the world of motion, drives and automation appearing at Hannover.

Are you beginning to get the picture yet? Hint: it's big.

What to learn

By this point you've probably gathered there's plenty to see at Hannover Messe. Even with a set of the world's strongest binoculars and an operational time machine you couldn't possibly see everything in the five-day window.

But more important than seeing what Hannover Messe has to offer is *learning* its secrets.

"The lead topic of this year's show is Integrated Industry," Zandieh said. "So anything that has to deal with Industry 4.0."

This may be news to you, but the world is currently square in the middle of the fourth industrial revolution – which is not an insurgency of metal and fire, but one of hypertext, file sharing and social networking – and Hannover Messe is aiming to educate the masses.

Defined as Industry 4.0, this "massive upheaval of the industrial sector" will be the main topic of discussion during Hannover's forum, according to Zandieh.

"Microsoft is going to be giving a presentation of Industry 4.0," he said. "They have a huge presence at the show this year and will be making some new announcements. Also at the MDA forum we will cover energy ef-

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iciency and sustainability, industrial automation, smart factory and condition monitoring systems."

Heralding itself as the "trailblazer of Industry 4.0," Hannover Messe will feature the reports from three public task forces for the Industry 4.0 platform: "Norms & Standards," "Security" and "Research & Innovation." The report will come during the Industrial IT forum, which is jointly organized by the Industry 4.0 platform and VDMA and the German Electrical and Electronic Manufacturers' Association.

And if the future is in fact going to be determined at Hannover Messe, the forum on Industry 4.0 might just be the catalyst.

"Power transmission and fluid power technology are fast becoming key components of Industry 4.0," said Rauen in a press release. "Intelligent actuator units and actuator CPS modules for instance are currently being used to capture, understand and interpret actuator motion and function data and wear parameters. To that extent, condition monitoring systems are already being put to work to create viable business models."

According to IT reports on Hannover Messe's website, the importance of Industry 4.0 at present time is "moderate," but within five years it will rise to "great" or "very great."

Five years? You don't have to be Doc Brown to know that's most definitely the future.

It begins off the shores of the River Leine on April 13. **PTE**

For more information:

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Power Transmission Engineering

Engineering Showcase 2015

One of our goals at *Power Transmission Engineering* is to help you understand, identify and select the best technology for your mechanical power transmission or motion control applications. With every project, you have to decide which components to use, and which suppliers, based on functionality, quality and price. We aim to help you make those decisions *informed* by providing the latest information on current technology, especially when it comes to mechanical components.

With that in mind, we are pleased to present our second annual Engineering Showcase, a celebration of some of the leading products and companies in mechanical power transmission. In the pages that follow, you'll find examples of engineering excellence and technological know-how in the field of gears, drives, couplings, machine parts and other mechanical components.

This guide is meant as a complement to our annual Buyers Guide and our permanent online directory of suppliers at powertransmission.com. In this special section, we have the opportunity to go into more depth in describing the products and capabilities that make each of these suppliers unique.

So please browse through the section and read about the latest these suppliers have to offer. If you have an upcoming project that matches their manufacturing capabilities, we're confident that giving one of them the opportunity to bid will be well worth your efforts.



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Over the past year R+W has also expanded its design and manufacturing operations in the USA, allowing for ever faster turnaround times for both precision couplings as well as the more recently introduced industrial drive coupling and torque limiter product lines. More catalog items are being added to inventory in Illinois all the time. Also new to the program, R+W now offers custom machined accessories, such as pre-mounted sprockets for torque limiters and custom motor / gearbox mounts for coupling applications. Contact R+W today to see what's new, and get the ultimate connection.

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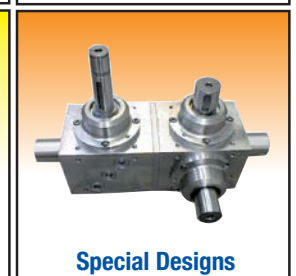
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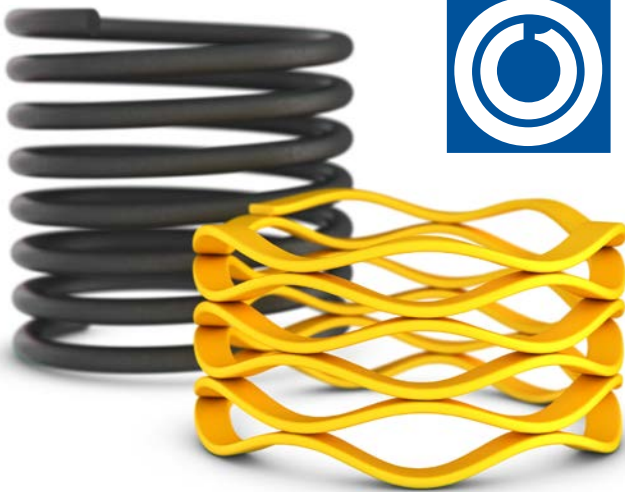
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One-shot Holding Cycle - The air circuit schematic in Figure 1 shows a single tank air-to-oil booster feeding two (2) clamping cylinders. The clamp-off position of the 4-way pneumatic control releases the clamp cylinders and simultaneously opens the pilot-operated check valve allowing oil to flow back into the tank.

Booster becomes a Pump - In Figure 2 we see how adding a magnet piston to the booster enables position sensing. Electronic sensors can then control a 4-way solenoid valve causing the booster pistons to reciprocate and pump high pressure liquid. Exhaust liquid is returned to the tank's top port from the driven device.

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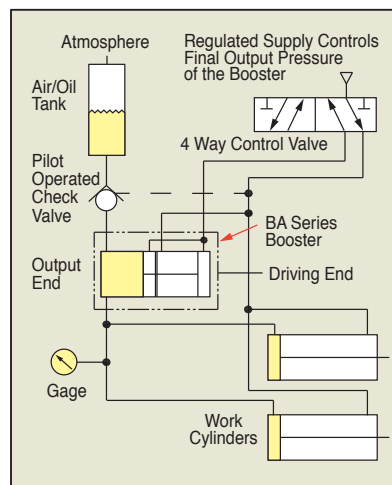


Figure 1. Booster one-shot holding circuit

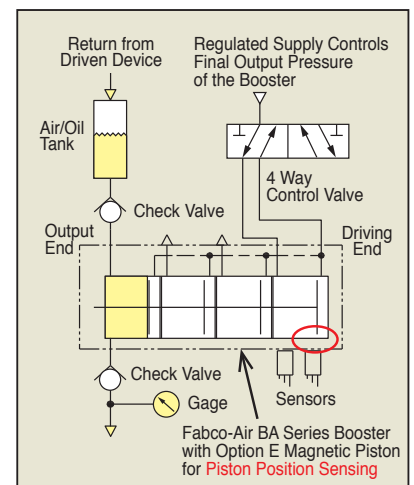


Figure 2. Booster used as pump

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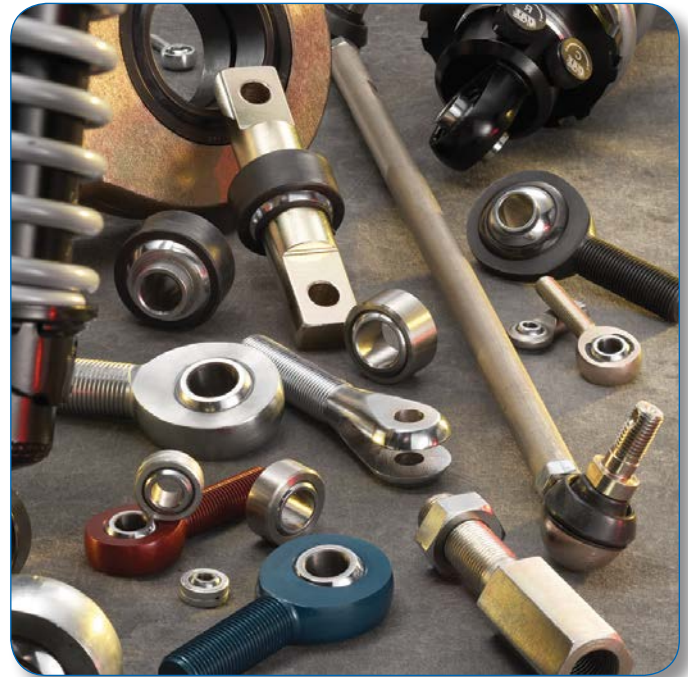
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*-Sir (Frederick) Henry Royce
British Engineer, 1863-1933*

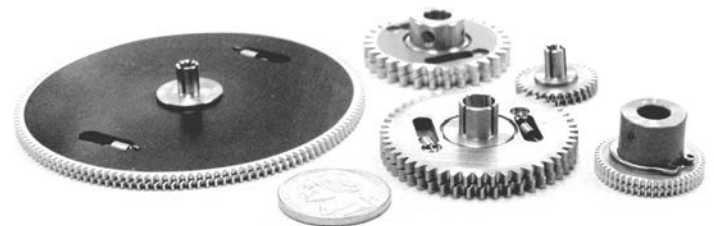
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3-D Printing and Plastic Gears

THE QUESTION

Regarding 3-D printing of gears and machine tools, etc. — does plastic gearing have a future in 3-D printing/additive manufacturing?

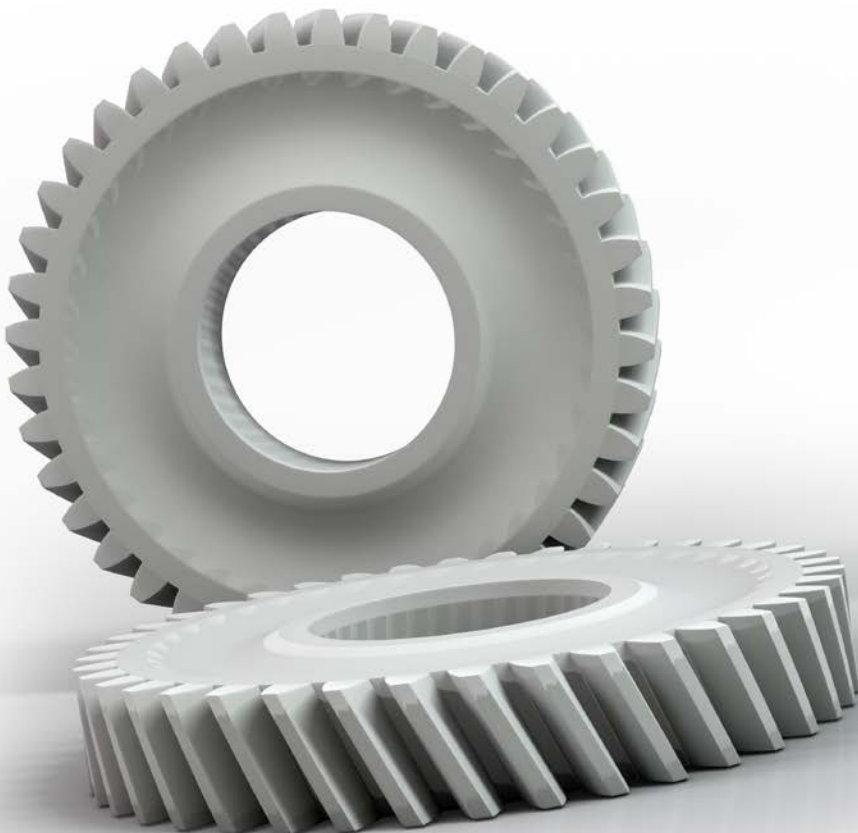
Expert response provided by Rod Kleiss, president Kleiss Gears Inc.

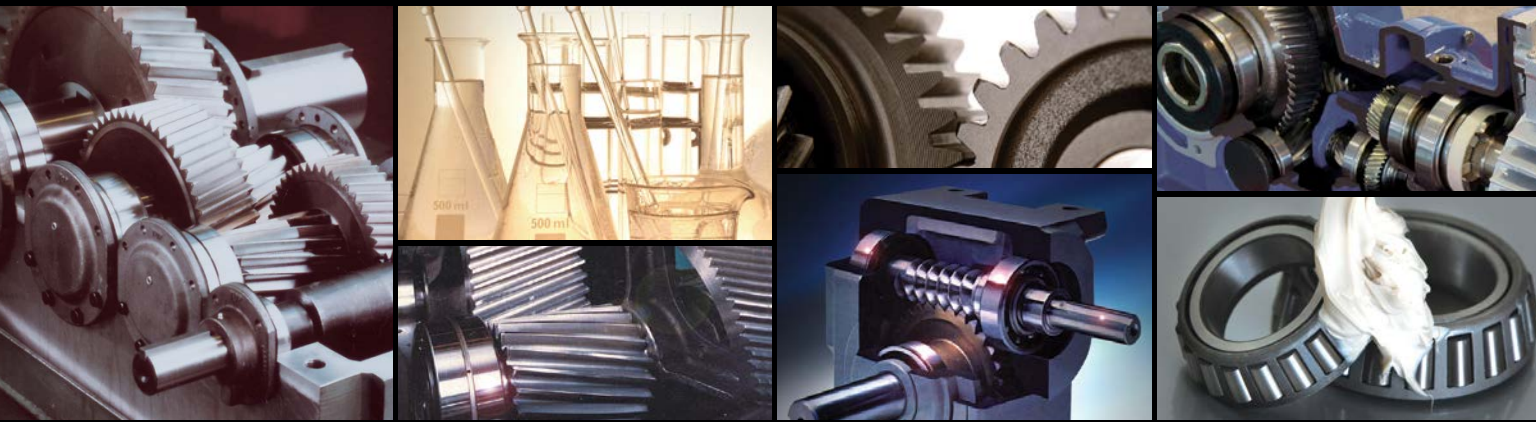
To date, 3-D printing seems to be good enough only for look and feel ideas for plastic-geared transmissions. The accuracies required for a plastic gear and the material requirements are not currently possible with that approach. Arburg, a German-based injection-molding equipment manufacturer, is introducing a 3-D printer that shows some promise in using engineering polymers, but so far has not demonstrated the necessary accuracies of 25-50 microns. For

quick and more accurate modelling, precision SLA is the preferred method presently.

Eventually 3-D printing is bound to improve in all regards, but plastic gearing will be one of the ultimate tests of its capabilities. The integrity of the plastic material is of paramount importance for proper function and service life. Building up beads of polymer on each other will create quite a challenge for material integrity as well as precision dimensional control.

Rod Kleiss's career in plastic gearing — with stops at Hewlett-Packard and Bell Aerospace along the way — began about 10 years past Graduation Day (master's degree in Mechanical Engineering from Michigan Technological University). That was when, as he tells it — "After designing some molded bevel gears for a Whirlpool self-propelled vacuum cleaner, I then began my focus on molded plastic gearing." And Kleiss has been at it ever since.





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Precision Bellows Couplings

Bellows couplings are used where precise rotation, high speeds, and dynamic motion must be transmitted. They exhibit zero backlash and a high level of torsional stiffness, offering distinct performance advantages. But proper sizing and handling are critical to their successful implementation.

Andy Lechner

Background

Bellows couplings first began to be widely used by machine tool builders in the mid-to-late 20th century. With the advent of CNC technology, machine engineers started looking to improve upon some of the negative influences traditional power transmission couplings can have on a precision rotary / linear motion system. For those seeking to enhance CNC machine performance, the flexible metal bellows offered a combination of attractive features, including natural balance, continuous symmetry, high torsional stiffness, and a low moment of inertia.

For many, using the flexible bellows as a transmission element meant not only that mechanical stiffness could be increased, but it also facilitated more aggressive servo tuning, helping machines become faster and more accurate. Throughout the 1980s and 1990s a number of manufacturers, mostly in Germany, began applying the formed metal bellows into an increasing variety of backlash free flexible coupling systems, ranging in sizes corresponding to torque ratings from roughly 0.05 to 100,000 Nm. Areas of application for the bellows coupling also expanded into servo drive systems for printing, converting, and packaging machinery, to name a few. While bellows couplings are still considered by many to be a European style technology, the worldwide market has grown significantly over the years, and they are becoming increasingly popular in North America for a still growing range of high performance applications.

Construction

With some exceptions, most bellows used in shaft coupling applications are made from one or more layers of high grade stainless steel sheet, formed and plasma welded into a seamless tube, and either rolled or hydro-formed to produce the deep corrugations (convolutions) which provide its flexibility. The resulting shape is one which is continuously symmetrical, and highly rigid about its rotational axis, while remaining flexible across all three other axes: parallel, angular and axial. Bellows are joined to the hubs by crimping, welding, or bonding. The end hubs and bellows are mounted onto a single mandrel during assembly, with the ends of the mandrel matching the respective bore diameters of the coupling hubs, guaranteeing concentricity. Bonding came into common practice in the late 1980s, with the advantage being that it allows for the bellows to be floated between the two hubs, free of stress, until the bonding agent cures. This helps to avoid deformation or stress concentration on the bellows, ensuring that it will run smoothly, with consistent output rotation, once installed. In cases where the coupling will be deployed in corrosive environments or be subjected to temperature extremes, either of which can cause the bond to break down, welded bellows-hub connections are preferred.



Misalignment

Bellows couplings are often selected in place of low-cost jaw couplings and disc pack couplings by engineers looking to benefit from their well-documented performance advantages. But they will only work well to those ends if shaft misalignment is addressed. Bellows couplings do not typically handle as much misalignment as traditional flexible couplings, but impart relatively low restoring loads onto adjacent shafts and bearings while compensating for the levels of misalignment they are designed to handle. When properly aligned, typically within 0.2-0.4mm parallel, they are fatigue resistant for an infinite service life, with no maintenance required. But if shaft alignment, especially parallel misalignment, is not considered before replacing other types of couplings with bellows couplings, failures can result. While reduced misalignment ratings can be viewed as a drawback, most experts in power transmission would agree that, regardless of the coupling style being used, proper shaft alignment always results in longer life and smoother rotation for all drive line components. Bellows couplings

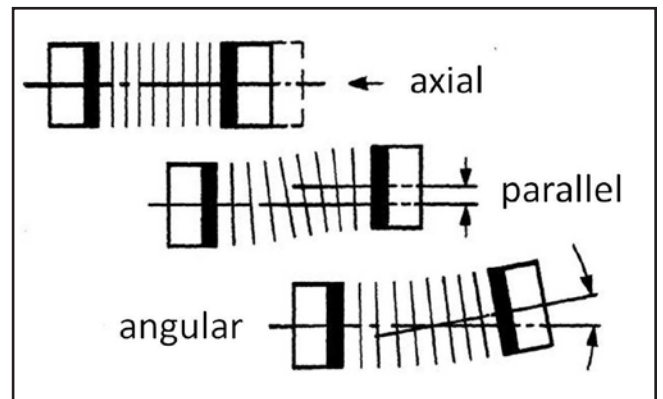


Figure A When properly aligned, typically within 0.2–0.4mm parallel, bellows couplings are fatigue-resistant for an infinite service life — with no maintenance required.

are not typically intended to compensate for gross offsets (though special high misalignment versions do exist) but rather to mitigate restoring forces between reasonably well aligned shafts, while also remaining as stiff as possible in rotation.

Where They Are Used

High-precision positioning. When it comes to rotational positioning the benefits of zero backlash and high torsional stiffness are normally fairly obvious. Lost motion from backlash is eliminated, and torsional deflection (twisting) between the input and the output of the coupling is minimized. Bellows couplings generally have the highest torsional stiffness of commercially available flexible shaft couplings. Another benefit results from its continuous symmetry. Most flexible power transmission elements have some kind of asymmetry, which means that, due to misalignment, the coupling is under different stress profiles at different points around a single rotation. To varying degrees they build up and release energy while rotating under misalignment, and have slight variations in their output speeds. In most applications this is scarcely noticeable. However in precision applications, where positional accuracy is to be optimized, the continuous symmetry of the bellows offers a measurable advantage.

Highly dynamic motion. Bellows couplings are also well suited to highly dynamic motion profiles. The high torsional stiffness translates into shorter settling times when loads are abruptly started, stopped, and reversed. As the weak link in most direct drive systems, the flexible coupling normally determines the stiffness of the entire drive axis. A coupling with higher torsional stiffness increases system natural frequency and decreases oscillation amplitude, enabling faster moves. When properly sized, bellows couplings allow designers to increase cycle rates in

camming and reversing applications. Since bellows couplings also tend to be offered in low mass moment of inertia configurations, they also play their part in minimizing load inertia.

High rotational velocity. For high rotational speeds, the same geometric characteristics come into play. Light weight, continuous symmetry, and uniform stress distribution all lend themselves to smooth, stable running at high speeds. Standard bellows couplings are rated to run at 10,000 rpm, with the limiting factor being the clamping hubs. Much higher speeds become possible through balancing of the coupling assembly. In some instances, bellows couplings can be made to run at speeds in excess of 100,000 rpm.

Resistance to temperature extremes. When machinery will be subjected to temperature extremes, metallic couplings are normally favored over elastomeric couplings, as their mechanical properties remain largely unchanged, even over a wide range of temperatures. When bonded joints are replaced with welded joints, the bellows coupling meets this requirement. The unique advantage of bellows couplings is that, unlike other types of maintenance-free metallic couplings (i.e. flexible disc couplings), bellows couplings have a high tolerance for axial movement. This allows them to absorb the axial movement which can result from thermal growth in drive shafting and other structural changes in the framework of the machine. For this reason, high torque bellows couplings are often used in drive shaft configurations for heavy equipment installed in remote areas.

Sizing and Selection

Bellows coupling sizing is generally guided by DIN 740, which is comprised of four different formulas. R+W offers a sizing calculator to help simplify the

Symbols

T_{KN}	= Rated torque of the coupling (Nm)
T_{AS}	= Peak torque of the drive system (Nm) e.g. max. acceleration torque of drive (Nm) or max. braking torque of load (Nm)
J_L	= Total load inertia (e.g. spindle + slide + workpiece + ½ of coupling) (kgm ²)
J_A	= Total driving inertia (motor [including gear ratio] + ½ of coupling) (kgm ²)
C_T	= Torsional stiffness of coupling (Nm/rad)
f_e	= Natural frequency of the two mass system (Hz)
f_{er}	= Excitation frequency of the drive (Hz)
φ	= Torsional deflection (degree)

sizing process. For reference, following is an explanation of the four key sizing formulas.

1. Selection according to torque.

Because they are normally installed in servo drive systems, bellows couplings are sized for the peak torque to be regularly transmitted. The peak torque of the application should not exceed the rated torque of the coupling. The following calculation provides a safe approximation of the minimum required coupling size, and allows for the maximum speed and misalignment to exist in the application.

$$T_{KN} \geq 1.5 \cdot T_{AS} \text{ (Nm)}$$

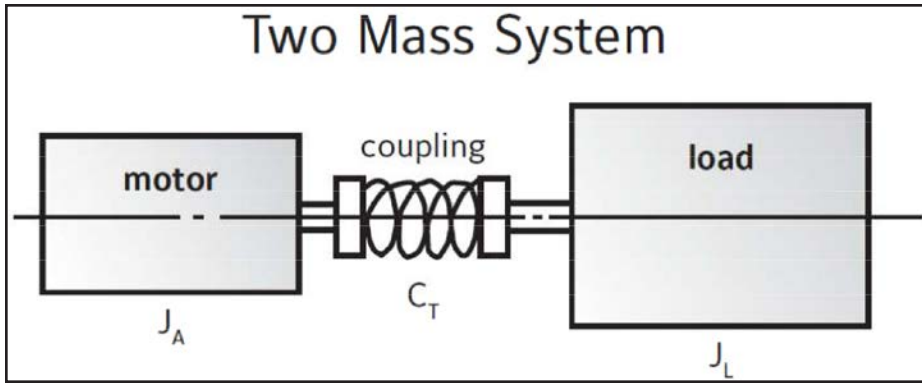
2. Selection according to acceleration torque. A more detailed calculation takes acceleration and the driving and driven moments of inertia into account. Shock/load factors ranging from 1-4 are applied, depending on the dynamics of the application. Factors in the range of 3-4 are normal for highly dynamic applications with multiple indexes per second or frequent load reversals. A favorable driving-to-driven inertia ratio diminishes the effect of the shock/load factor in the sizing calculation.

$$T_{KN} \geq T_{AS} \cdot S_A \cdot \frac{J_L}{J_A + J_L} \text{ (Nm)}$$

3. Selection according to torsional deflection. Since bellows couplings are often applied in situations where positioning accuracy is critical, the following calculation is useful in determining the transmission error as a result of torsional stress.

$$\varphi = \frac{180}{\pi} \cdot \frac{T_{AS}}{C_T} \text{ (degree)}$$

4. Selection according to resonant frequency. There are some rare cases in which the drive can pulse the load in such a way as to excite the natural



frequency of the mechanical system. In order to avoid this, the torsional natural frequency of the mechanical system must be significantly higher or lower than that of the excitation frequency of the drive. In the case of torsionally stiff bellows couplings, the torsional natural frequency should generally be significantly higher than the oscillation frequency from the motor. The torsional stiffness of the coupling generally determines the torsional natural frequency of the complete system. Therefore the torsional stiffness of the coupling becomes a critical factor in determining the natural frequency of the mechanical system. In the following two mass system calculation, a value of $f_e \geq 2f_{er}$ helps to ensure adequate stiffness for smooth, stable running.

$$f_e = \frac{180}{2 \cdot \pi} \sqrt{C_T \cdot \frac{J_A + J_L}{J_A \cdot J_L}} \text{ (Hz)}$$

The R+W bellows coupling sizing program can be downloaded here: info.rw-america.com/bellows-coupling-sizing-program

Installation and Handling

Shaft alignment. When properly aligned, theoretically infinite service life. Many types of commercial electro-

mechanical equipment have features included in the frames to help guarantee precision alignment during installation. Most commonly these are round centering pilots on motors, gearboxes and linear actuators, and highly concentric to their respective shafts and bearing journals. Driving equipment typically has a male centering pilot, and driven equipment typically has a matching female centering pilot. As the frames are bolted together, these centering pilots hold everything within sufficient alignment, and the bellows compensates for the slight misalignment that remains. In cases where the coupled equipment will be mounted to separate surfaces without integral features to help guarantee alignment, additional steps must be taken. Alignment between shafts must be checked with dial indicators or laser alignment tools, and adjustments made accordingly until the target alignment level has been reached. In those cases, bellows couplings with fully split clamping hubs are often used, since they can be installed laterally after the shafts have been aligned. In cases where precision

shaft alignment is simply not practical, special high-misalignment bellows couplings are available which can accommodate a parallel shaft misalignment of up to 1 mm.

Shaft locking. Because they tend to be used in high-performance applications, most bellows couplings are mounted to their respective shafts and flanges by frictional clamping systems. This helps to avoid the backlash and stress concentrations which result from connections made by keyway only—though in many cases keyways



Figure 1 Clamping collar hubs are most common for small and medium sizes.



Figure 2 Conical clamping hubs are used to transmit higher torque levels.



Figure 3 Flanges offer a compact precision installation.

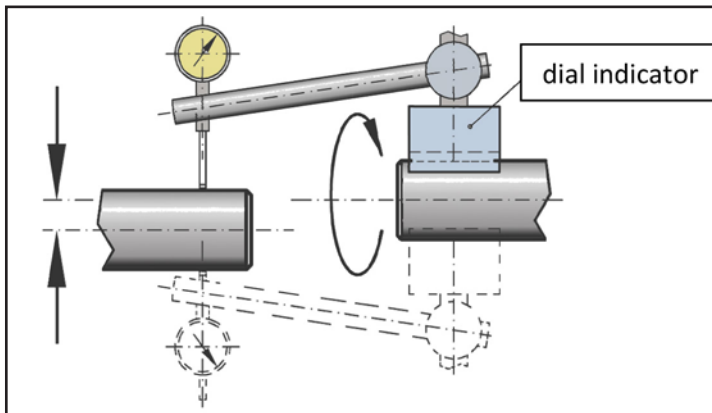


Figure B Many types of commercial electromechanical equipment have features included in the frames to help guarantee precision alignment during installation.

are still broached into the clamping hubs for a positive form fit connection. To help guarantee good shaft locking, most precision coupling bores are made to a diameter tolerance of ISO H7, which allows for zero undersizing, and oversizing by anywhere from 0.01 to 0.04 mm, with the tolerance range increasing with larger shaft diameters. In turn, most manufacturers of motors, gearboxes, and linear actuators make shafts to a diameter tolerance which allows for zero oversizing and slight undersizing. This helps to create a slip fit between the shafts and couplings during installation. When installing couplings with clamping systems, it is important to follow the installation guidelines for screw strength and tight-

ening torque values. Most bellows couplings use high-grade screws, allowing for the maximum torque and tension to be applied, helping to guarantee a secure lock onto the shaft.

Mounting options. Over the past three decades a very wide variety of sizes and mounting attachments have been developed for bellows couplings. For small and medium sizes, the most common drive attachment is the single screw clamping collar. This allows for quick and easy installation with zero backlash. For larger sizes, typically transmitting torque levels of 1,000 Nm or more, conical clamping bushings become more common, as they provide larger clamping pressure between the shaft and hub. Flanges are another popular way of attaching bellows couplings, since they tend to be very compact, and also allow for good stress distribution and a high level of frictional holding force.



Figure 4 Blind mate systems allow for “plug-in” assembly.



Figure 5 Expanding shafts help add bellows to otherwise quill mounted systems.



Figure 6 Line shaft versions span long distances between components.

Conclusion

For transmitting dynamic precision motion between two fixed shafts, flexible bellows couplings offer the benefits of high torsional stiffness, low moment of inertia, continuous symmetry, and low reaction forces under slight misalignment. When sizing, misalignment tolerances, and proper handling are addressed, they can help machines run faster and more accurately. For assistance with sizing, selection, customization and any other questions, please feel free to contact R+W at applications@rw-america.com. **PTE**

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Andrew Lechner — currently as sales manager and previously as product manager for R+W America — has since 2001 written articles on thermoplastics in coupling design and the proper selection of bellow couplings. When he's not directing R+W sales efforts or custom projects, Lechner has been a welcomed contributor to *PTE* on coupling issues.



The Modified Life Rating of Rolling Bearings: A Criterion for Gearbox Design and Reliability Optimization

Antonio Gabelli, Armel Doyer and Guillermo Morales-Espejel

Engineers typically learn that the bearing L10 life can be estimated using the so called “C/P method”—or the “basic rating life” of the bearing, a method rooted in the 1940s. Major developments have since led to the “modified rating life,” released in ISO 281:2007, which includes the a_{iso} life modification factor. In this paper a succession of equations used for bearing life ratings are reviewed, and current bearing life rating practices are discussed in detail. It is shown that—despite the introduction more than 30 years ago of the adjustment factor of the basic rating life, and the standardization in 2007 of the a_{iso} modification factor—use of these improved calculation methods are not practiced by all engineers. Indeed—many continue referring to the old model as a way of seeking compliance with existing, established practices. The result is the potential for many gearbox manufacturers to continue making design decisions based on the old ISO 281:1977 “basic rating life” standard. This paper addresses these issues in the specific context of industrial gearbox bearing design, using as an example the design analysis of a helical gearbox application. The implication of not adopting modern rating life as described in ISO 281:2007 is equivalent to disregarding 30 years of bearing technology development.

Introduction

The concepts of rolling bearing rating life and basic load rating (load carrying capacity) were introduced by A. Palmgren in 1937 (Ref. 1). At that time and until the 1950s, most bearing manufacturers listed in their catalogues the load admissible on the bearing for thousands hours of operation at five different speeds. In those days the selection of a bearing size for a given application was rather a simple matter.

The concept of a single rating factor to characterize the dynamic capacity of the bearing was new and it was initially used only within the bearing company that developed this new technology. This rating method was backed by the theory of Lundberg and Palmgren (L-P) (Ref. 2) and by the Weibull statistics (Ref. 3). It was found that it could provide a correct interpretation of the many series of endurance tests available at the time, (Refs. 2, 4 and 5). This calculation method prevailed on all the others methods used at the time and it was adopted by ISO in 1962.

Before ISO acceptance the L-P model for life ratings was independently validated by Lieblein and Zelen in 1956 (Ref. 4) of the U.S. National Bureau of Standard, using endurance test data provided from different bearing manufacturers. In total, 213 test series were

analyzed amounting to a total of 4,948 endurance-tested bearings. Furthermore, the statistical setting of the bearing life dispersion was also assessed by Tallian of the Philadelphia testing laboratories in 1962 (Ref. 5). In the Tallian investigation, a composite sample totaling more than 2,500 endurance-tested bearings was analyzed. The original L-P model constituted the foundation and it remains today the nucleus of all national and international standards for fatigue life rating of rolling bearings—including subsequent theories and developments. Basically, the L-P theory (Ref. 2) developed the basis for the calculation of the dynamic load rating and equivalent dynamic load of rolling bearings as it is applied today in the ISO 281 (Ref. 8) basic rating life equation:

$$L_{10} = \left(\frac{C}{P} \right)^p \quad (1)$$

Where

- L_{10} is rated fatigue life, at 90% reliability, in million revolutions
- C is basic dynamic load rating of the bearing for a rated fatigue life of one million revolutions
- P is standardized dynamic equivalent load of the bearing
- p is life equation exponent

The availability of a standard method for the dynamic rating of rolling bear-

ings is useful to the mechanical industry, as it allows streamlining product specifications for large-scale manufacturing and worldwide compatibility and exchangeability of rolling bearings.

The dynamic load rating allows bearing users to compare similar bearing types made by different manufacturers. Manufacturers, on the other hand, can profit from the ISO standards to rate their products, of any size and type, using just the internal nominal geometry of the bearing. Apparently the ISO standard for bearing load ratings provides a win-win situation for all parties, and this explains the widespread use of this standard in the mechanical industry.

Mechanical designers, however, need to be well informed in order to take full advantage of the opportunities offered by standardized bearing load ratings. In particular, they must be aware of the many aspects and changes that have taken place in this field through the years and how these changes have impacted gearbox performance and design practices.

In this paper we will first examine the evolution of standardized bearing life rating that has taken place after ISO 281 was first instituted in 1962. The technical justifications behind each different change will be explained, showing also the impact that variation of bearing

life ratings had on gearbox design and product performance over time.

Present use of the standard will also be discussed, showing that there are different interpretations—and some misuses—of the present standard in the marketplace. This introduces distortions and uncertainty to what should be the rather straightforward task of selecting the proper bearing size for a given application.

Methods to avoid possible misleading situations and risks are suggested and explained, using an example of a bearing design analysis of a helical gearbox application. The limitations implicit in the definition of standard load rating are also considered and discussed in detail. Finally, the concept of robust design based on the latest rating rules and the modified life, i.e., ISO 281 (Ref. 8), is introduced with reference to the performance and reliability optimization of industrial gearboxes.

Standardization and Evolution of Bearing Life

The increase of transmitted torque, the decrease in overall dimensions and weight, together with the increased reliability and service life, are undoubtedly the technical aspects that have dominated the rapid progress in the design of mass-produced gearboxes and mechanical transmissions over the last 50 years.

Previous analysis has shown that the ratio between the transmitted torque and the mass of a typical industrial gearbox has increased up to a factor of 12 since the 1950s (Ref. 6; Fig. 1).

This progress can also be assessed by looking at the power density of the gearbox that is particularly relevant in the matter of automotive transmissions. An analysis of automotive gearboxes (Ref. 7) shows that this parameter approximately doubled during the last 30 years. During the same time period the reliability of rolling bearings for gearboxes also increased by a factor of three (Ref. 7), allowing for a 70% improvement of the torque density of automotive transmissions (Ref. 37; Fig. 2).

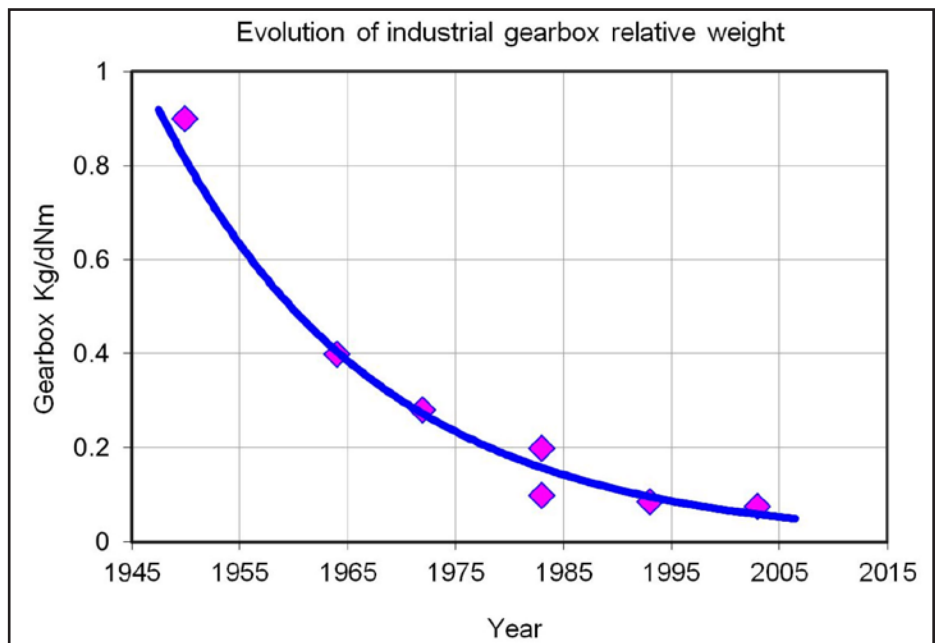


Figure 1 Typical relative weight evolution in industrial gearboxes during the last 50 years (Ref. 6).

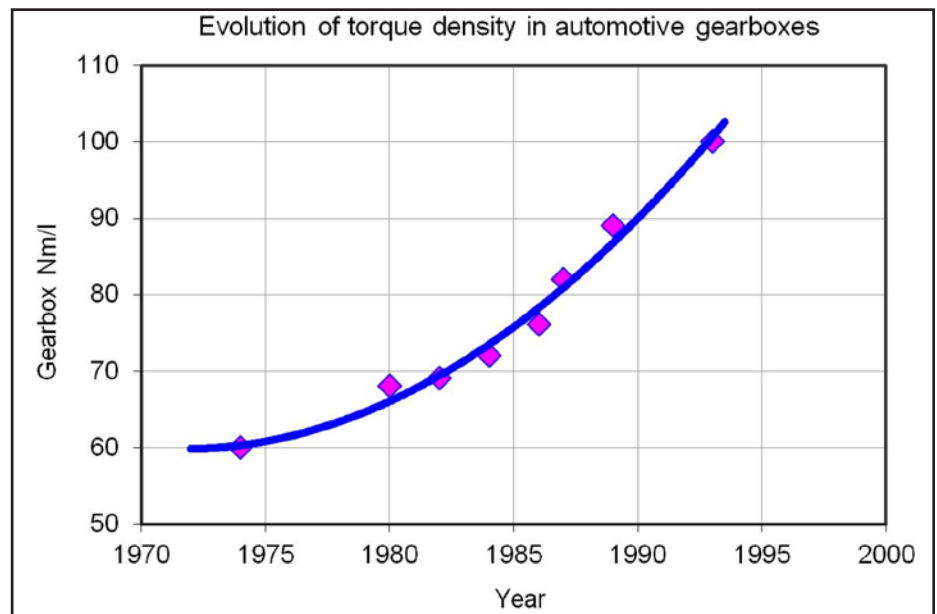


Figure 2 Progress in automotive gearbox design in terms of increased torque density (Ref. 37).

This real progress would not have taken place had gearbox designers not benefitted from the simultaneous, continuous progress in rolling bearing technology that characterized the same time period. Indeed, due to the stress concentration of the rolling contact and the number of rolling elements, rolling bearings are in general the heaviest-stressed and the highest-fatigue-cycled component of a mechanical system.

The fact that the life expectancy of an entire system depends on its weakest link makes the reliability of a few critical bearing components vital for

the reliability of the whole transmission, and it pushes for the development of bearings with an extended life. The progress achieved in increased rolling bearing reliability can be visualized in the development of the ISO 281 rated life, relative to the original ISO 281:1962 level (Fig. 3).

Figure 3 shows normalized rated lives to the initial ISO 281:1962 rating. As discussed in the introduction, the ISO 281:1962 was the direct result of a draft proposed by the Swedish delegate Palmgren to the ISO Technical Committee in 1952. This draft basically

contained the bearing rating rules developed by SKF during the previous two decades of research.

In the following period, thanks to the newly discovered elastohydrodynamic lubrication (EHL) mechanism, the effect of the lubrication quality on the expected bearing life could be addressed and an intensive research program was initiated at SKF. This research work was carried out with the prominent contribution of T.E. Tallian in Philadelphia (Refs. 9-11) and by S. Andréason in Gothenburg (Refs. 12-14). The results of this work were also made available via SKF catalogs (Refs. 15-16) and to the ISO Technical Committee for further standardization (Ref. 17). This led to ISO 281:1977 (Ref. 17). In this new version of the ISO standard, adjustment factors for the lubrication condition of the bearing, i.e., the viscosity ratio (*The viscosity ratio, κ , is defined as the ratio of the actual viscosity, v , to the rated viscosity, v_r , for adequate lubrication, when the lubricant is at normal operating temperature. To separate the bearing contact surfaces, a minimum viscosity ratio $\kappa=1$ is required. Full-film conditions exist when $\kappa \geq 4$, i.e., a sufficient hydrodynamic film is formed for adequate lubrication. $K=v/v_r$, Ref. 16), and material quality were introduced into the life rating equation. Although extensive guidelines were given, the adjustment factors were not directly provided in the standard but they needed to be specified by the bearing manufacturer.*

In the 1970s material manufacturing technology related to cleanliness made substantial progress, thanks to vacuum degassing and other techniques, to prevent or reduce the formation of micro-inclusion and defects in the steel matrix. Research to quantify the effect of material-increased cleanliness on bearing fatigue life was conducted, primarily at the two main laboratories in Gothenburg and Philadelphia, and also in the new corporate SKF Engineering & Research Center (ERC) located in the Netherlands.

This intensive effort provided hundreds of test results and a very robust experimental base to justify an upgrade of the dynamic load ratings of rolling bearings. This upgrade was introduced in the SKF catalogue of 1981 (Ref. 18)

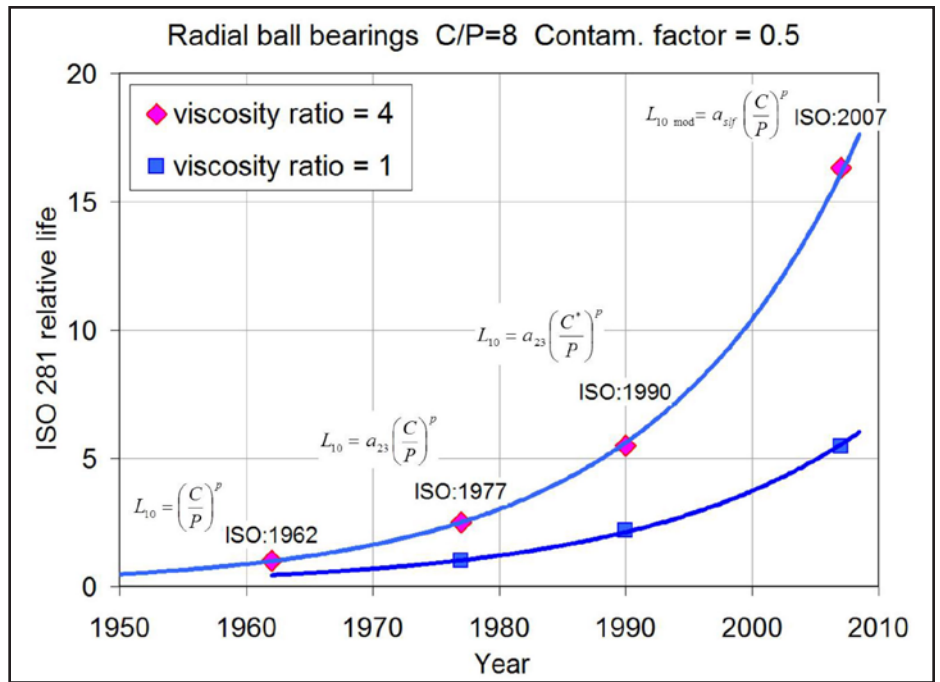


Figure 3 Typical progression of the ISO rated life of a radial ball bearing, loaded at $C/P=8$; contamination factor = 0.5; viscosity ratio of lubrication = 1 and 4.

and integrated into the ISO dynamic load rating standard about 9 years later, with ISO 281:1990 (Ref. 19).

Introduction of Modified Bearing Rating Life

In the 1980s, SKF research (Ref. 20) found that the performance of rolling bearings could no longer be accommodated with just a linear adjustment of the basic load ratings, as was done until then. Substantial modifications were required; i.e., a significant non-linear modification of the basic load rating of the bearing was developed (Refs. 20-21).

It was found that the new calculation method could introduce, under certain conditions, a change to the rated life for a factor up to 50 times (Eq. 2). Despite the groundbreaking modifications to the old calculation routines, the new methodology was introduced in the SKF catalogue 4000 in 1989 (Ref. 22) with the addition of a stress life modification factor, a_{sif} , that combines the effect of the bearing fatigue load limit and the additional stress system related to the contamination level and lubricant quality of the contact.

$$L_{10 \text{ mod}} = a_{sif} \left(\frac{C}{P} \right)^p \quad (2)$$

Where $L_{10 \text{ mod}}$ is modified rating life (at 90% reliability), million revolutions

a_{sif} is life modification factor.

In 2003 the calculation method was in use already for many years with good results, thus on initiative of the German standardization organization DIN, the SKF life rating method was adopted as DIN 281 Addendum 1:2003. Further discussions for the standardization of the new methodology were also initiated by the ISO Technical Committee.

To support this process, disclosure of the SKF theory and related experimental bases of the new method was also undertaken (Ref. 23). More than 260 test series (approx. 8,000 bearings) were tested to support the development and validation of the new method. This and other results were published (Refs. 23-24) to further sustain ISO standardization of the modified life rating calculation model. This process was concluded in 2007 and is the basis of the present ISO 281 rating standard (Refs. 25-26).

From the analysis of the evolution of ISO 281 it is evident that rolling bearing technology has made gigantic strides during the last 50 years, and this progress is an important aspect of the substantial improvement in the total efficiency and reliability of mechanical systems such as gearboxes and transmissions. This progress, however, does require the availability of a significant

amount of endurance test data for the statistical validation of the improved rating rules in the dynamic loading of bearings.

Given the high costs involved for the endurance testing of large numbers of bearings, only some large bearing manufacturers are able to financially support the investment to finance and conduct such large test campaigns. In time, this also leads to dynamic load rating standards that reflect the performance and quality of the bearing products of the main bearing manufacturers, rather than the average or lower-quality present in the market.

This implies some uncertainties for the bearing user and gearbox designer, as the ISO ratings are universally employed. In principle, the same dynamic load rating is obtained from bearings with the same internal geometry, but quite different surface microgeometry; waviness; raceway; rolling element profilometry; shape; internal precision and tolerances; material fatigue strength; and type of heat treatment. Indeed, there are many other detailed aspects of the bearing design, such as cage and seals, which are not included in the ISO 281 rating system but are known to affect the performance of the bearing in a very significant way.

To cope with this situation, main bearing manufacturers have developed in-house, advanced computer software

for the detailed modeling and simulations of rolling bearings, surrounding parts, and complete mechanical system. Advanced simulation tools include the static, quasi-static and dynamic analysis of the shaft-bearing housing system. The bearing internal geometry, mounting interface as well as shaft and housing behavior are taken into account when analyzing a bearing solution (Refs.28-29). These computer tools are maintained and updated with the most recent results of bearing performance from new product development and endurance testing.

On the other end of the spectrum, it is also found that other bearing companies that lack specific knowledge and testing facilities can simply exploit the ISO 281 simplicity of rating rules to their own advantage. Dynamic ratings of bearings based on the simple application of ISO 281 without testing and validation procedures of the product may lead to bearing dynamic load ratings that appear equal or even superior to its competitive offerings on the surface, only to fall short to a close examination or when they are in use in the actual application.

Different Practices behind Catalogue Values

As just described, it is important to verify that catalogue values are backed up with sufficient test data and that are in

line with ISO 281, by reading carefully a supplier's catalogue and technical material. This section will provide examples of misleading practices sometimes in use.

To provide an overview of the different dynamic load rating practices presently in use, roller bearings of different manufacturers were investigated and their ISO 281 dynamic load ratings were calculated and compared to their catalogue values. The result of this survey is given in Figure 4 for five samplings. This will be discussed in terms of generic rating strategies found in today's marketplace that are in current use.

For Case (A), Figure 4, bearing products of standard (std.) quality are rated according to ISO 281; the basic rating life therefore remained unchanged. For a given assumed load, lubrication and speed conditions, it is possible to have a typical ISO 281 modification factor equal to 2.5. Thus the application of such modification factor provides an increase of the rated life of 2.5 times as expected. Case (A) has also introduced a new bearing class different from the standard for extended (ext.) performance. After exhaustive testing, Case (A) found that the load rating of the new product needed to be adjusted to accommodate for the increased performance of the product. The fatigue performance of the new (ext.) product indicated a 15% increase of the dynamic load rating with the required high level of experimental confidence.

This moderate change of the dynamic load rating is then amplified by the load-life exponent, leading to a 60% increase of the basic rated life (Fig. 4). This life increase will be further magnified by the application of the life modification factor (i.e., 2.5), leading to a modified life that is four times the original ISO basic rated life of a standard product.

Case (B), following the increased rating introduced by case (A), after some product and process development, is able to match the new performance class and, with the help of validation tests, it releases a product that is also rated with a 15% increase of the dynamic load rating. In this way, Case (B) is able to match the technical challenge of the competing product to the benefit

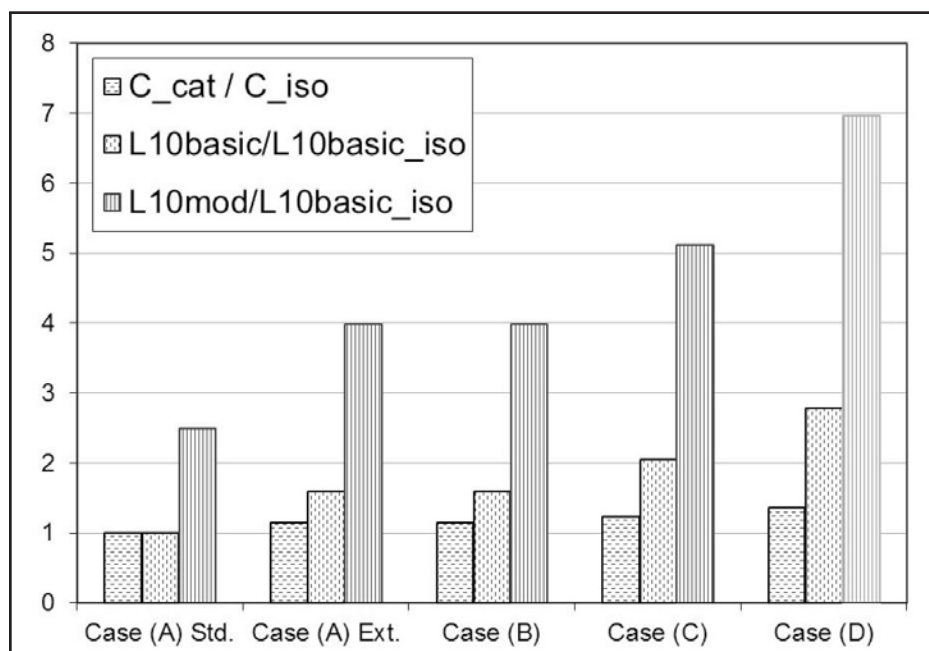


Figure 4 Overview of different dynamic rating rules found in the market place; to simplify the discussion, the life modification factor — a_{iso} — is taken for all cases equal to 2.5.

of widening consumer choice and market competition.

However, there is also Case (C), which has the goal to present the most favorable impression possible of the strength of its products, thus publishing a 24% increase above the ISO 281 ratings for some of its products—without known statistical test back-up data.

This 24% increase happens to correspond exactly to the doubling of the basic rated life of the bearing, which is quite fortunate as this can facilitate the communication with costumers and the marketing of the bearings. Note that this increase of the basic rated life is further amplified by the use of the modification factor leading to a modified rated life that is five times the original ISO basic rating.

The investigation of bearings from Case (D) revealed a rather interesting rating strategy. Similar to Case (C), this case does not seem to have any catalogue data back-up with test results. Nevertheless, Case (D) introduces a 36% increase of the dynamic load rating in his bearing catalogue.

The basic life rating associated to such an increase is 2.8 times the ISO basic rated life. Thus it seems that this case of manufacturers has simply transformed a life modification factor equal to 2.8 into a dynamic load rating of the bearing. A further investigation about the way the life is calculated by Case (D) confirms this. Indeed, contrary to ISO 281, it appears that Case (D) advises customers to apply a life modification factor that must be, at the best, lower than one. This clearly indicates that Case (D) applies a strategy to obtain load ratings that are artificially inflated just to create the perception of benefit into the buyer, and not at all in line with ISO 281 definition.

This practice might create several problems to a not-well-informed designer. Indeed, such designer, working on the assumption that the dynamic load rating declared by this manufacturer is ISO 281-compatible, will most likely introduce the declared catalogue rating in calculation routines that make use of the ISO 281 modification factor, falsely leading to a predicted life that can be up to seven times the original

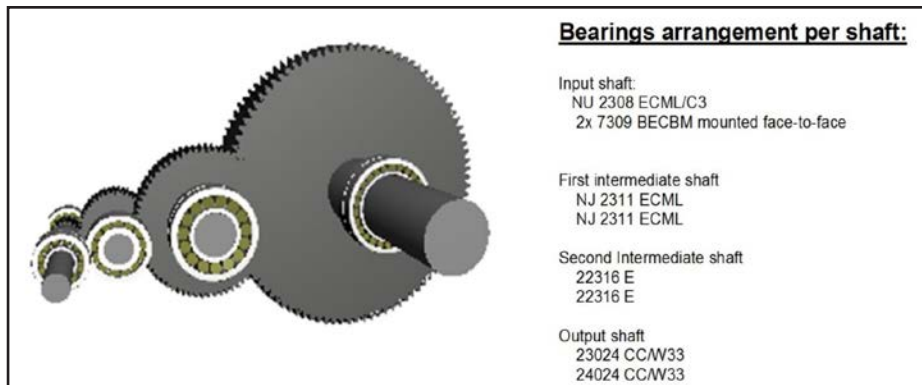


Figure 5 Schematic of a three stages helical gear unit and bearing arrangements.

ISO 281 basic life (for a 2.5 modification factor, as used for the other cases).

This significant effect on the calculated life is shown with the light gray column of Case (D) (Fig. 4), to indicate that this rated life is not compatible with the ISO 281 modification factor. Clearly, this is a misleading way of rating bearing performance, which may lead to products that, in real applications, may not be able to reach their reliability target and fail their design expectations.

The examples depicted in Figure 4 show that engineers should be skeptical of bearing manufacturers catalogue rating information, and that they should understand what is being offered in detail—even if the information is labeled as ISO 281.

A Safe Criterion for the Selection of Rolling Bearings

At the present time, making a decision based only on the dynamic load rating, (the C value) of the bearing taken from manufacturers catalogues can be a treacherous affair.

Reliance only on the declared catalogue figure of C can in some cases lead to the wrong choices. Some suppliers will always look for ways to prove the benefits of their products to the customers, and inflating the dynamic load rating C is a simple and effective way to do this. To make the most informed decision possible, users must pay attention to the details, ask hard questions of their suppliers, and always read the fine print.

Once the C value is understood and verified, the next step to do a proper design selection is to also look at the modified life rating of the particular bearing application, rather than only the pub-

lished value of C . As it will be discussed in the following gearbox calculation example, and, as general rule, it is indeed the modified rated life of the bearing, L_{10m} , rather than the dynamic load rating C , that provides the most valuable information regarding the performance of a bearing product with regard to the particular application.

The modified rated life combines the basic rating life with the stress-life modification factor. The comparison of L_{10m} will avoid hidden aspects in the particular definition of either factor. As will be shown hereafter, by using a bearing selection criterion based on the modified rated life L_{10m} , users can avoid pitfalls and arrive at informed decisions for the selection of their bearings and the optimization of their products.

Example of Newest Method for Gearbox Bearing Design

The following bearing application example was selected to illustrate that the dynamic load rating of the bearing C is less crucial as generally believed, than is the actual expected performance of a bearing application. The purpose of this example is to highlight that using modern life calculation methods provides more understanding to the designer of what issues may be faced by bearings, and consequently more chance to the designer to make adequate design choices. Comparisons of different life methods have been done by Uherek (Ref. 36) for several gearboxes. In these analyses, it is observed that contamination and lubrication were already key factors in the design.

The application example is a three-stage helical gear unit, with the following general characteristic and design:

Table 1 Calculation data and resulting basic and modified rated life

	C, kN	P, kN	C/P	Speed, rpm	Temp, °C	κ	η_c	Basic rating life, L_{10} , hrs	Life modification factor a_{SLF}	Modified rating life, $L_{10\text{mod}}$, hrs
Input shaft - A bearing 1 7309 BEP	56	1.2	47	1,400	80	4	0.5	> 1,000,000	50	> 1,000,000
Input shaft - A bearing 2 7309 BEP	56	3.9	14	1,400	80	4	0.5	34,000	30	> 1,000,000
Input shaft - B bearing NU 2308 ECP	129	12.3	10.5	1,400	80	3.9	0.43	30,500	14.4	440,000
Intermediate shaft 1 - A bearing, NJ 2311 ECP	232	31.5	7.4	443	80	1.9	0.33	29,000	2.6	76,000
Intermediate shaft 1 - B bearing, NJ 2311 ECP	232	28.1	8.3	443	80	1.9	0.33	43,000	3.1	134,000
Intermediate shaft 2 - A bearing, 22316 E	490	83.9	5.9	116	80	0.7	0.22	52,000	0.4	20,500
Intermediate shaft 2 - B bearing, 22316 E	490	105.1	4.7	116	80	0.7	0.22	24,000	0.35	8,500
Output shaft - A bearing 24024 CC	430	71.8	6	35	80	0.3	0.13	183,000	0.15	29,000
Output shaft - B bearing 23024 CC	355	82.7	4.3	35	80	0.3	0.13	60,500	0.14	8,500

- This gear unit has a reduction ratio of 40, with 3 stages
- The input speed is 1,400 rpm
- The nominal power is 66 kW, which correspond to an output torque of 18 kNm
- Lubricated with circulating oil with filters, mineral oil of 320 mm²/s @ 40°C
- The contamination level (for the contamination factor η_c) is ranked ISO -/17/14
- It is assumed that the operating temperature is 80°C
- Examining the results of Table 1 and Figure 6, the following observations can be made:
- There is no direct correlation between the dynamic load rating, i.e., basic rated life, and the actual modified rating life of the application.
- The basic rating life doesn't show the bearings that are at risk, i.e., shorter lives. Indeed the bearings that are most at risk are: the Intermediate shaft 2B and the output shaft B, both

bearings were indicated as quite safe by the basic rated life.

- The modified rating life clearly indicates that two bearings that have shorter lives, and also the technical reasons behind the reduced endurance, i.e., lubrication (low κ) and contamination issues (low contamination factor η_c). Thus surface fatigue problem can be expected rather than subsurface fatigue.

A usual procedure that is utilized when life values are found too short is to select a bigger bearing, due to its higher capacity. However, the designer must be aware that the selection of bearings with an increase of the dynamic load rating C would not solve the lubrication and contamination issue. Even if an increased capacity would show a slightly longer life (a 10% higher capacity leads to 33-37% higher life), it does not change the phenomena: the problem is surface induced stresses, originated by the surface micro-geometry and the effect of solid particles. Also in today's

gearbox, due to their high power density, the space is often limited, and it can be impossible to consider a bigger bearing size, as a solution.

These stresses can't be reduced by an increase of the dynamic load rating of the bearing. Corrective actions to improve the reliability of the intermediate (2B) and output shaft (B) bearings require not an increased dynamic load rating of the bearing but actions to improve the tribology of the surfaces in contact, (Refs.30-31). Therefore, proven EP additives in the lubricant and preventive measurements to reduce the presence of particles and debris in the oil can provide good results.

According to the analysis of the modified life rating calculation, it is possible to propose the following improvements to increase the life of the weakest two bearings:

- Use oil containing effective EP additives

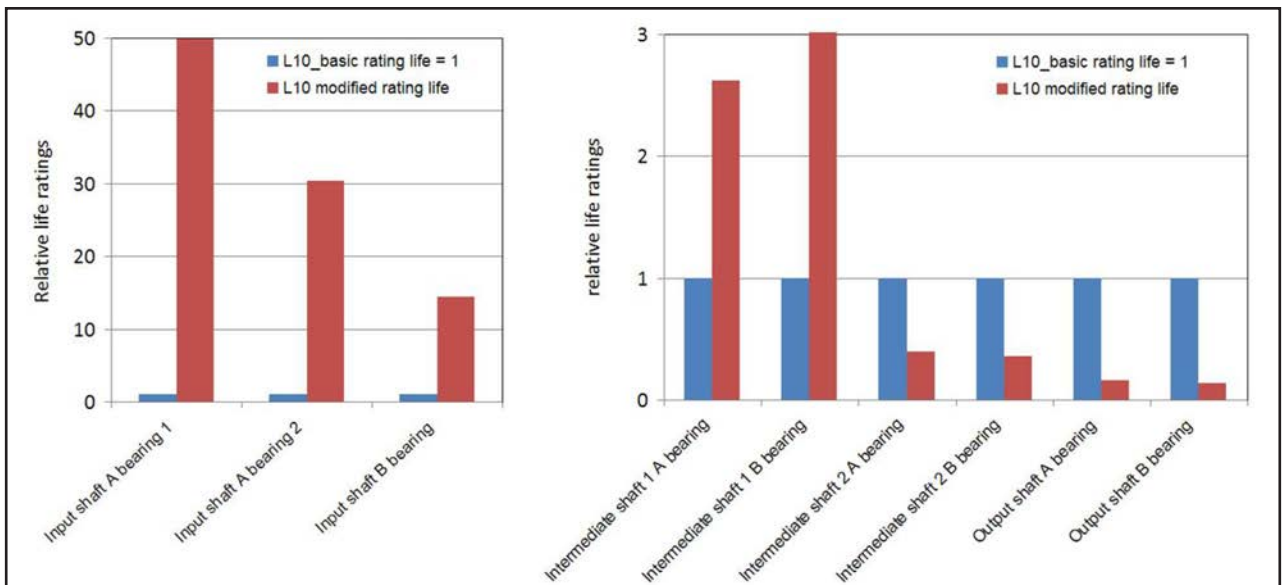


Figure 6 Overview of the modified life rating of the gearbox bearings normalized to the basic rating.

- Improve the cleanliness to ISO -/15/12 level
- Both corrective actions at the same time

Figure 7 shows the relative improvements that would be possible to achieve in relation to the original modified life rating shown in Figure 6.

- Examining the results of Figure 7, the following can be found:
- The use of oil containing proven EP additives would provide the most significant improvement—especially in the two low-speed output shaft bearings.

For the intermediate shaft bearing (2B), an improvement of 40% is obtained by improvement in the oil cleanliness. Combining this improvement with an optimized EP-additive of the oil can provide a further 80% life increase, thus enabling attainment of the required rated life for this class of applications.

This gearbox bearing calculation example shows how to use the modified rated life of bearings to improve the performance of a few critical bearings. Yet doing so will provide significant increased performance to the complete system. This transparent and simple optimization process would not be possible using the basic rating life or selecting the bearing based only on the value of the dynamic load rating *C*.

Indeed, for the input shafts A and B the dynamic load rating is quite unimportant as the size of the bearing is dictated by the required shaft size. On the other hand, for the intermediate and output shafts, the use of the basic load rating *C* would give no useful information for the improvement of the long term reliability of this gearbox. Selection of the input shafts A and B bearings based on inflated values of the dynamic load ratings *C* to reach an increased reliability for the system would fail. This is because it would not address the elimination of the surface stress system related to the low speed of the output shaft with a viscosity ratio (κ) of 0.3.

Of course the final design decision must take other parameters and constraints into account, but applying the modified life rating method allows the designer to make more informed decisions on alternative solutions with an enhanced understanding of bearing operating conditions and the expected consequences of the application performance.

Further Discussion on Selection Criteria of Rolling Bearings

The above gearbox bearing calculation example shows that the design optimization process can only be applied if the life calculation informs the designer on

potential problems and hidden risks. This should be done by looking at the modified life rating, as the basic rated life would be not able to provide such critical information.

The basic rated life and the dynamic load rating *C* basically represent the subsurface fatigue performance of the bearing. In other words, the fatigue performance at extremely high load *C/P*-2, and as such it cannot contribute much to applications normally operating at much lower loads for reliable operation and extended periods of time.

Gearbox designers that rely solely on the *C/P* parameter as a selection criterion for the bearing can also easily fall into believing that higher *C* values will ensure a higher reliability for the application. In such a case the attraction for the selection of bearings with inflated dynamic load ratings *C* will be irresistible, with possibly unfortunate consequences for the actual field performance of the application.

To explain this important issue in some detail we refer to the contact pressure and related subsurface von Mises stress field in the case of two rolling bearing contacts — one (a) with an idealized nominal smooth geometry, the other (b) with its real surface micro-geometry in contact (Ref. 27) (Fig. 8).

In the case of reduced lubrication or a presence of contamination particles, the contact (b) will exhibit a severe stress system right at the surface of the rolling contact. This stress system is the direct result of the asperities and micro-profile geometry that are not part of the ISO specification of dynamic load rating *C* (which refers to the nominal geometry of the bearing and good lubrication conditions, i.e., good separation of surfaces by a clean lubricant film).

Therefore these stresses can't be reduced by adopting a bearing with increased *C*. Note that if a bearing rated with an inflated *C*, and used under the same *C/P* conditions, will lead to the actual increase of the contact pressure and a further intensification of the surface stresses of the contact.

The problem of reducing high surface stress in the rolling bearing is therefore not by acting on the dynamic load rating, but by acting on the tribology of the contact for the restoration of the protec-

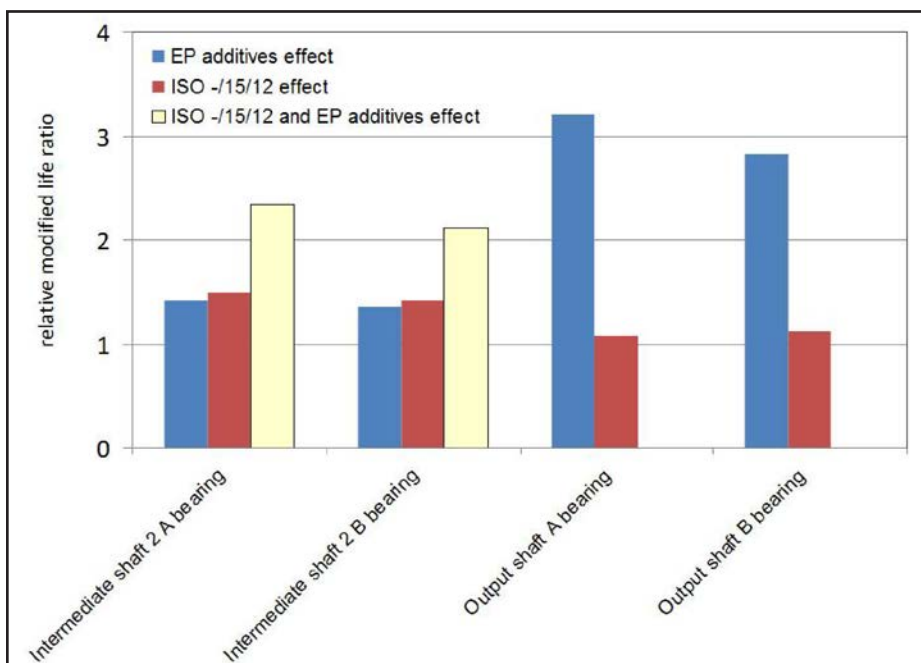


Figure 7 Relative increase of bearing life as result of corrective actions about lubricant EP additives and improved cleanliness of the oil.

tive lubricant film or reduction of geometrical imperfections. As discussed earlier in this paper, this means working with the chemistry of the lubricant and preserving the geometrical quality of the rolling surfaces by improvement of the lubricant cleanliness.

Failure Mode from the Field and Implications for Bearing Selection

There are several studies about the type of damage found in bearings that are replaced during routine maintenance work. Engel and Winter (Ref. 32) in 1979 reviewed the results of damaged bearings originated from an estimated total installed bearing population of several million bearings and arrived at the conclusion that although actual failed bearings are very small in proportion of the original population (0.05%), the predominant failure mode in the field is either lubrication- or contamination-related.

They found that lubrication and oil contamination account for 75% of all bearings failure. This same conclusion is also reported by Nierlich and Volk-muth (Ref. 35), who reviewed detailed previous data, correlating this to detailed observations and measurements of damaged bearing surfaces.

In a separate and extensive investigation supported by the German research council for drivelines technology (Ref. 33), conducted among the member companies of the FVA association, it was found that the most predominant bearing failure modes experienced in the field were inadequate lubrication and contamination. This investigation also reported and discussed in detail with other results by Gläntz (Ref. 34).

From the observation of the failure modes of field bearings, one can conclude that subsurface fatigue-initiated failure is in fact very rare. This is to be expected, as most bearing applications are selected based on a C/P design criterion, which is a good method to avoid classical subsurface-initiated fatigue failure—particularly under good lubrication conditions (Fig. 9).

However, the presence in the marketplace of artificially inflated dynamic load rating C may put in jeopardy this good record. Indeed, as observed ear-

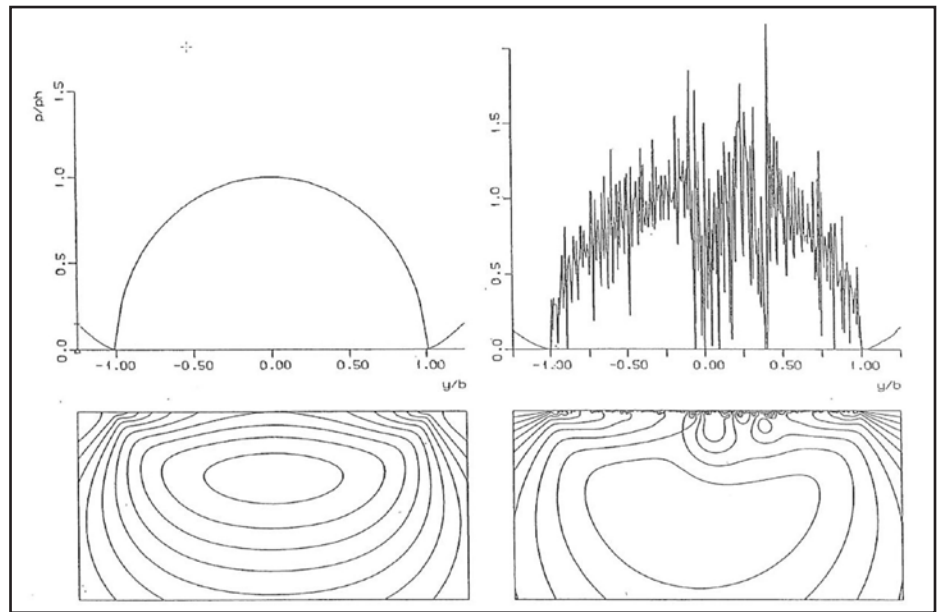


Figure 8 Example of stress field a) nominal smooth contact geometry, b) actual rough geometry (Ref. 27).

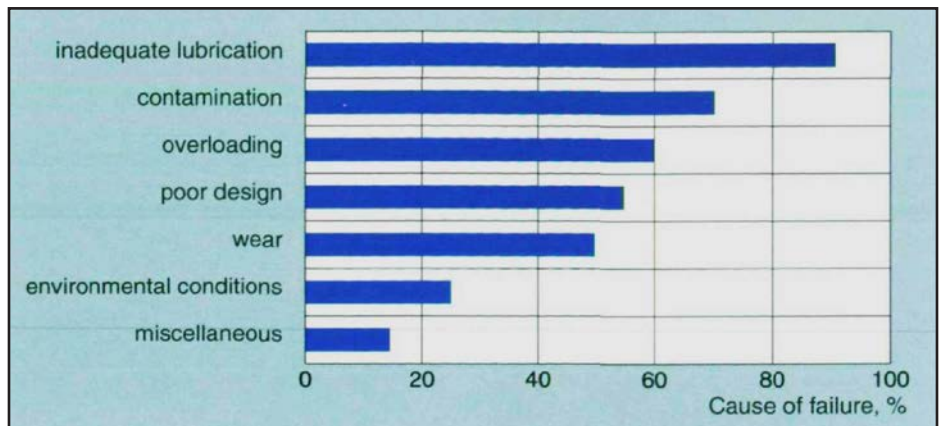


Figure 9 Causes of rolling bearing failure as percentage of responses from an enquiry among the companies of the FVA associations (Ref. 34).

lier, today there is the risk that the unusually increased C figures may correspond in reality to a lower expected dynamic carrying capacity of the bearing, leading to a reduction, rather than an increase, of the actual reliability of the application.

Conclusions

Today's gearboxes require high reliability and extended life. The trend to increased performance will continue in an effort to develop more energy-efficient mechanical systems. At present the most commonly used method of selecting a bearing for a given application is based on the dynamic load rating C . This paper has shown very clearly that this methodology has several drawbacks and may not lead to an increased reliability for the system. To avoid risk of reduced or un-

expected performance, well-informed designers should base their decision on these simple and practical rules:

- Engineers should look with critical eyes the printed C values in bearing catalogues, looking for consistency with either ISO 281 or bearing manufacturer testing practices.
- Today, the use of the modified rated life is straightforward and transparent. It is fully documented in the ISO 281 and based on physical operating characteristics of the bearing, as viscosity ratio of the oil, pitch diameter, lubricant cleanliness class, rotary speed of the bearing etc. The use of this calculation should replace current simple practices based only on the use of the C value.
- As shown in the gearbox calculation example:
 - Bearing lives based on the modified rated life can provide expected lives that can be larger

than the basic rating life. These are the bearings that are normally scrapped as not failed at the end of the gearbox life.

- There are also some bearings that are critical for the reliability of the system. The modified rating life "ISO 281" is the only public tool available to detect bearing criticality and evaluate possible corrective design modifications for performance optimization.

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Four-Point Bearings Do Triple Duty While Saving Space

Rick Burgess and Dave Van Langevelde

A four-point contact ball bearing makes it easy to simplify machine designs that combine radial, thrust and moment loads, because it can handle all three simultaneously. They are primarily used for slow-to-moderate-speed applications, or where oscillatory movement is predominant.

A single, four-point contact bearing usually makes a second bearing unnecessary, which provides some very important benefits, including:

- Space savings
- Weight savings
- Cost savings
- Rigidity and accuracy
- Faster installation
- Less maintenance
- Integral mounting holes, gears, etc.

Thanks to a unique ball path geometry that produces twice as many contact points, a four-point contact bearing can resist radial, thrust and moment loads individually, or in any combination. It has one row of balls with an inner race and an outer race. The ball grooves are generated from two centers, with each radius slightly larger than the ball radius. Contact angles are typically 35° off the radial centerline, but can be varied to suit the application.

Important Advantages

Four-point contact bearings are especially effective in applications in which the rotating element has a high ratio of diameter to axial length. Most have a large ratio of bore-to-section size: the larger this ratio, the thinner and more flexible are the individual races. Thin section bearing sizes range from 1" - 40" and slewing ring bearings range from 4" - 178" O.D.

Figures 1 and 2 show how much space can be saved by replacing two bearings with one four-point contact bearing. The rotary table design (Fig. 1) has a conventional center post supported by two bearings. Eliminating that center post (Fig. 2) reduces the height and weight of the table and frees space to be used by other components. And without a post, there is no chance of post deflection.

Similarly, having a single bearing means no runout matching, no diameter matching, and no chance of wobble from two bearings with unequal runout — all of which enhances the accuracy of the assembly.

Eliminating a second bearing also eliminates the need for adjustments to optimize its fit — and thus the expense of spacers or clamping rings (and perhaps technicians skilled in making these adjustments). In contrast, a four-point contact

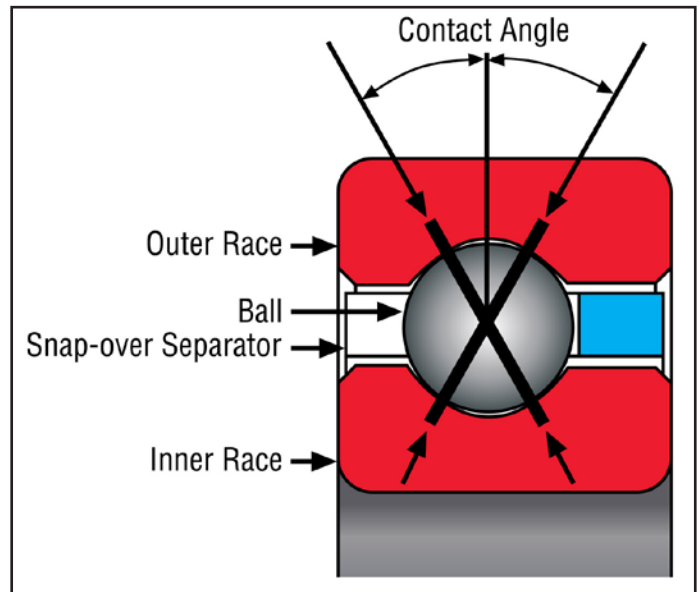


Figure 1 A four-point contact bearing can resist radial, thrust and moment loads individually — or in any combination.

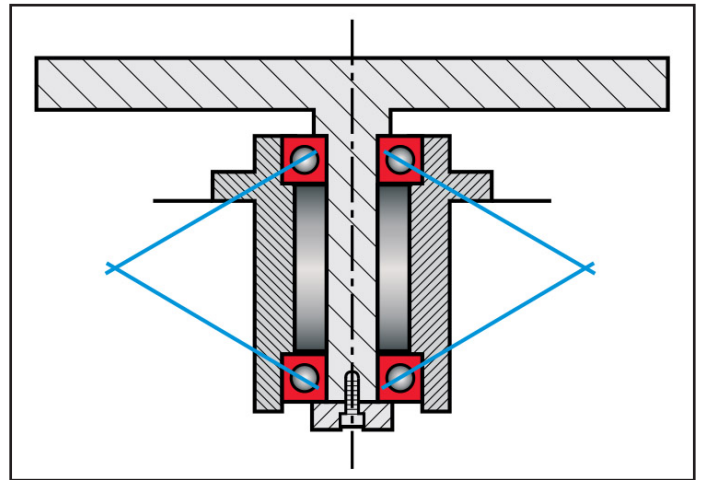


Figure 2 This rotary table design has a conventional center post supported by two bearings.

ball bearing is manufactured with the proper internal fit and is simply fastened to its mating parts.

Finally, eliminating a second bearing saves money that can be used to integrate features (gears, mounting holes, lubrication fittings) into the four-point contact bearing to further optimize performance.

Twice as accurate. Four-point contact bearings can be manufactured in accordance with ABEC precision grades and in larger sizes. In applications involving oscillatory mo-

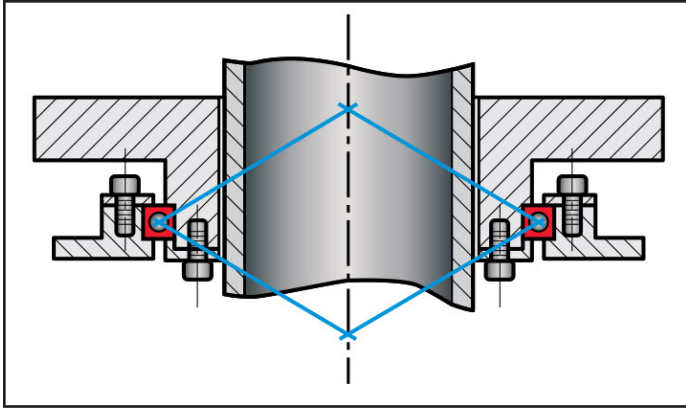


Figure 3 Eliminating the center post reduces the height and weight of the table and frees space for use by other components.

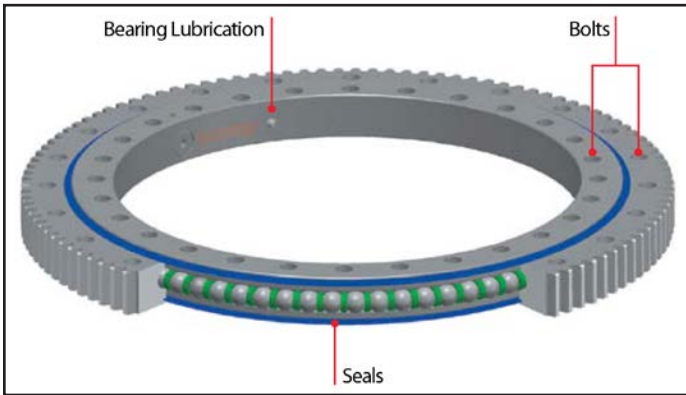


Figure 4 Holes or fittings in the bearing races facilitate lubrication when the bearings have integral seals—a possibility even in large-diameter bearings (e.g., 100”).



Figure 5 Thin section and slewing ring bearings in four-point contact configurations.

tion with limited angles of rotation — when the runout is zero for much of the rotation — an ABEC 1 bearing can sometimes be used instead of an ABEC 3 or 5. In such cases the critical requirement (axial runout or radial runout) should be specified to meet ABEC standards; noncritical areas can be left up to the bearing manufacturer.

With one row of balls instead of two, accuracy is enhanced in several ways. For example, when radial runouts in a two-row system are out of phase, the rotation will produce a wobble. Wobble can also result from structure deflection when applications require a lot of space between two rows of balls;

e.g., when high-moment load must be resisted. And if there is a pre-load difference in axial runout between the two rows, bearing friction can vary.

None of these problems will occur in a bearing with a single row of balls. Likewise, there is no matching of housing bores and shoulders, or of shaft diameters and shoulders. All other factors being equal, the accuracy of a four-point contact bearing may be twice that of a bearing with two rows of balls.

Choice of Materials

Four-point contact ball bearings are typically manufactured of conventional anti-friction bearing materials but, like other bearings, materials decisions are ultimately dictated by the application. High-carbon 52100 alloy and 440C stainless steel are common choices for through-hardening. When selective hardening is needed, such as when a bearing has integral features, like flanges and gears, options include carburizing or induction hardening. Alloys such as 8620, 4340, 150, and 1552 are utilized for this purpose. All can be hardened to Rc 58 for 100% bearing capacity and maximum service life. (At Rc 50, capacity drops to about 50% and at Rc 45, to less than 30%.)

When corrosion resistance is important, races and balls can be made of precipitation-hardened stainless steels or coated with a thin — yet dense — chrome, such as Endura-kote plating.

Limiting Speeds

Four-point contact bearings are primarily used for slow-to-moderate-speed applications. Under combined loads, some of the balls are loaded across both sets of contacts. Since they cannot roll about two axes simultaneously, they tend to rotate about one axis. This leads to more skidding or slippage on the other set of contacts, increasing friction and wear — especially at high speeds.

Maximum allowable speeds vary with bore size, section size, ball size, retainer type, type of lubrication, and type of loading. As a rule, this type of bearing performs best at pitch line velocities under 1,100-feet-per-minute. However, the variable effects of preloading, lubrication and simultaneous individual loads can overcome this limitation. For applications requiring higher speeds, the bearing manufacturer should be consulted.

Under a single loading (radial or thrust), speed is no more a factor for a four-point contact ball bearing than that it would be for a conventional radial bearing or an angular contact thrust bearing.

Lubrication and Maintenance

In most applications, four-point contact ball bearings need no more maintenance than any other anti-friction bearing. Often, they need even less.

Grease lubrication is typical, since so many applications involve low speeds or oscillating motion. If the application involves full rotation, two grease fittings—mounted 180° apart—should allow sufficient access. But if a design calls for heavy loads as well as full rotation—or if the bearing is located near other moving parts that must be lubricated with oil—oil lubrication is used instead.

While many bearings are pre-lubricated at the factory, the lubricant must nevertheless be replenished and replaced as needed. The incorporation of holes or fittings into the bearing races facilitates this, which is especially true when the bearings have integral seals—a possibility even in large-diameter bearings (e.g., 100 inches).

Separators. Separators should always be used in four-point contact bearings, the style varying with the application. Material options include steel, stainless steel, bronze, phenolic, nylon, Teflon, and stainless steel wire (spring-type). The most common style is the retainer found in a Conrad deep-groove bearing, which can be inserted into the bearing from the side through the gap between the race lands.

A full, one-piece retainer is usually the strongest option, but inserting it into a four-point contact bearing requires splitting one of the races or providing a loading plug. This is not practical in light-section bearings because the race is too thin to split and cannot be reassembled with rivets or screws.

When a thin section bearing application demands maximum capacity in a slow-speed bearing and separation of the balls, a wire separator is a good choice. Spring-type separators are used in low-frequency, oscillating, or slow, full-rotational applications where low, uniform bearing torque is important. The springs act as free-floating bodies to keep sliding friction very low.

Conclusion

Today's design engineers are challenged to simplify designs in order to reduce cost and weight. In many applications, four-point contact ball bearings—which do the job of multiple bearings by handling radial, thrust and moment loads simultaneously—are an ideal solution. **PTE**

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The Four-Point Bearing: How it Works

As the inner race rotates, a downward thrust load is transferred to the ball at point B, and then transmitted through the ball (typically at a 35° contact angle) to point D. From there it passes into the outer race and support structure. Deflection of the ball in the race grooves along the load-transmission line relieves the ball at contact points A and C and allows the ball to rotate smoothly around an axis perpendicular to line BD.

Moment load is much the same, passing a thrust load from the inner race at point B, and to the outer race at point D. At the same time, a thrust load 180° opposite is passed from the inner race at point C to the outer race at point A.

Radial resistance occurs 180° from the point of application (assuming much larger thrust load than radial load) and the radial load is resisted equally across the lines of contact CA and BD. The relationship of the individual loads determines whether the reactions are large or small.

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David VanLangevelde

is Kaydon's product engineering manager for slewing ring bearing products.



Rick Burgess is Kaydon's senior engineering manager responsible for thin-section and custom bearing products.



A wireframe funnel, resembling a time machine or a wormhole, is positioned vertically in the center of the page. At the top and bottom of the funnel are two Earths, representing the past and the future. The background is a vibrant, red and black nebula with scattered white stars. The text is overlaid on this background.

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Global Industrial Outlook: Oil Slick, Currency Headwinds Challenge Growth

By Brian Langenberg, CFA

End market conditions for the power transmission industry have arguably worsened since our last column. In December we stated that with two armed conflicts underway impacting economic performance in Eastern Europe and the Middle East our stance was “Buy on the Sound of Cannons... Selectively” while cautioning PTE readers not to be sanguine.

Three factors are challenging growth:

Oil	Currency	War
		

What has changed?—Oil price.

Simply put, in December WTI oil stood at about \$75 and was down (about 25%) despite two conflicts owing to excess supply. At that range it made sense to assume cuts to upstream exploration (drilling new wells) and production (keeping older, high cost rigs working), while mid-stream activity (pipelines, infrastructure) and downstream (refining) spend would hold up fairly well.

With U.S. oil price hovering at \$50-\$52 per barrel—(down 50%)—all bets are off because industry cash flow is driven, like all businesses, by revenue—expenses. When your unit price plummets (50%), cash flow gets killed, capital preservation becomes paramount, and capital spending budgets are slashed. Recently announced spending cuts (selected):

Chevron	13%
British Petroleum	20%
CNOOC	35%

The general consensus is about a (25%) reduction in 2015 capital spending, which seems right but can worsen in 2016 should oil price not recover.

To be clear—very, very few industrial companies (i.e. your customers) have publicly acknowledged it will have a

significant impact on them. This is called self-delusion; with *Caterpillar* a notable exception.

Currency has become a challenge. Remember in 2011 when the U.S. dollar was supposedly going to plummet when S&P downgraded? Wrong! See chart below. The mighty greenback is at its highest level in over a decade as the U.S. has become a better growth proposition (by default) due to weaker Japanese yen (on purpose), Euro (weak economy) and flight to safety (Fig. 1).



Figure 1



Figure 2



Figure 3

Japanese construction equipment manufacturers are in turn using the weaker yen to fight with price in the Middle East and Latin America; we are already seeing it in revenue and margin (Fig. 2).

In turn the Euro has plummeted on economic weakness, conflict (Ukraine) and fears of a Greek exit. The result: lower international profit for many companies (Fig. 3).

War is a threat to global growth. The war between ISIS, coupled with lack of U.S. leadership, is a threat to the development and sustainment of oil supplies directly in Iraq and Libya in the near-term. One can make the case, and I do, that U.S. foreign policy will be feckless, continue to embolden ISIS, Iran, and Hamas over at least the next two years and, in a worst-case scenario, potentially threaten the stability of the Saudi regime.

Outlook

Here is our outlook for key geographic regions and end markets:

- **U.S. remains best growth spot.** Non-residential construction, consumer durables (auto, housing) and gradually improving employment will offset weaker commodity-based demand.
- **Europe.** Taking a marginal hit (Nordics, resource-related parts of German economy) by conflict in Eastern Europe. The bigger question is geopolitics and the Euro. Russia's Ukraine gambit (combination invasion and "rebel" support) will not lead to broader war because Russia is economically weak and Germany is a geopolitical weakling. With respect to the Euro, it has weakened at least partially on fears of a Greek exit from Europe. I think if Greece exits, the Euro rallies because it is really the old German Deutschemark with baggage. Losing Greece = less baggage.
- **Middle East.** Oil & Gas activity should remain strong — even with production cuts — because mature fields require more capital and the region is seeking to capture more of the value stream. Increased Japanese construction equipment competition is a negative for U.S. manufacturers.
- **Latin America.** Oil & Gas will remain weak (Petrobras, Brazil) and your construction equipment customers are

facing increased competition from the Japanese, given the weak yen. Auto-related investment, particularly in Mexico, remains strong.

Oil & Gas: Oil is now at \$52 not \$75 — look out below. This will hit construction equipment and anything tied to energy-related activity — particularly

in upstream — but the spending cuts will spread. The "consensus" is for a (20%-25%) cut in 2015, accelerating into the second half and possibly further cuts in 2016. Bad for construction equipment, land-based power generation (small p not BIG P), and ancillary products and services.

Mining: Still awful; aftermarket is now stabilized, despite cash burn at coal companies.

Power Generation: U.S. power generation remains weak; owing to efficiency gains throughout the economy and lack of regulatory support for new construction. Globally the industry looks good, including coal and gas.

Transportation Infrastructure: More pot hole filling — no major infrastructure upgrade anytime soon. While I've heard rumblings of a multiyear highway bill, reality suggests other factors including 2016 Presidential election, ObamaCare disruptions, etc., would make for a "status quo" or "status quo with certainty" outcome vs. a big infrastructure rebuild. I would love to be proven wrong. I doubt I will be wrong.

Machinery: Nobody is feeling the love outside replacement demand for U.S. trucks along with modest incremental demand from non-residential and residential construction markets (cement mixers). United Rentals is calling for flat capital spending in 2015, which pretty much tells you the construction equipment outlook. Weakening farmland prices, declining farm cash receipts signal the AG outlook.

Consumer (auto, appliances): Old cars = continued U.S. strength. Auto-related end markets will remain solid. Auto investment in Latin America, particularly Mexico, continues to increase. U.S. residential recovery is on track and will further support construction equipment demand.

Aerospace/Defense: Strong commercial build rates, coupled with two significant wars and depleted U.S. inventories, will continue to support a continued recovery in aftermarket activity. Long-term, we expect a U.S. defense recapitalization — but not before 2017, authorization given the current Administration. Foreign policy matters — and messes — will remain to be cleaned up.

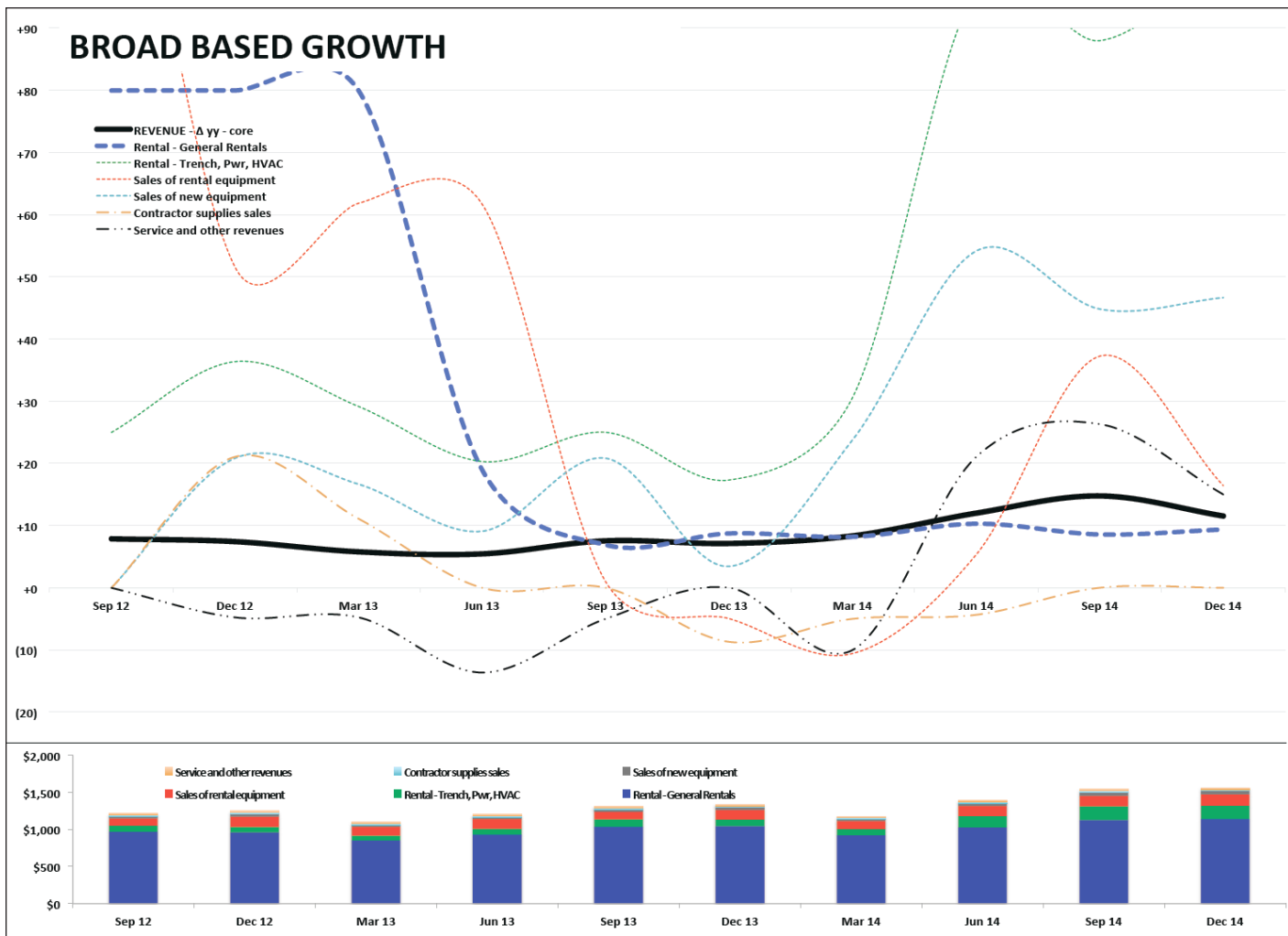


Figure 4

Focus Companies: United Rentals (URI)

There is no better company to track if you wish to monitor the North American construction equipment market than industry leader United Rentals (URI).

URI is the rental equipment industry leader, not only in size but also innovative asset utilization strategies that are driving more activity with less capital investment. For example, while total U.S. construction equipment activity is slated to rise about 8% this year, and URI expects to continue taking market share, their planned capital investment in 2015 is expected to be flat. This is good for them, bad for you. Be aware of that trend (Fig. 4).

In the big scheme of things you can look forward to flattish demand in 2015, despite oil patch weakness as improving non-residential construction activity, along with improved housing demand, continue into 2015.

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Brian K. Langenberg, CFA, has been recognized as a member of the Institutional Investor All-America Research Team, a *Wall Street Journal* All-Star, and *Forbes/Starmine* (#1 earnings estimator for industrials). Langenberg speaks and meets regularly with CEOs and senior executives of companies with over \$1 trillion in global revenue. His team publishes the *Quarterly Earnings Monitor/Survey*—gathering intelligence and global insight to support decision-making. You can reach him at Brian@Langenberg-llc.com or his website at www.Langenberg-LLC.com.





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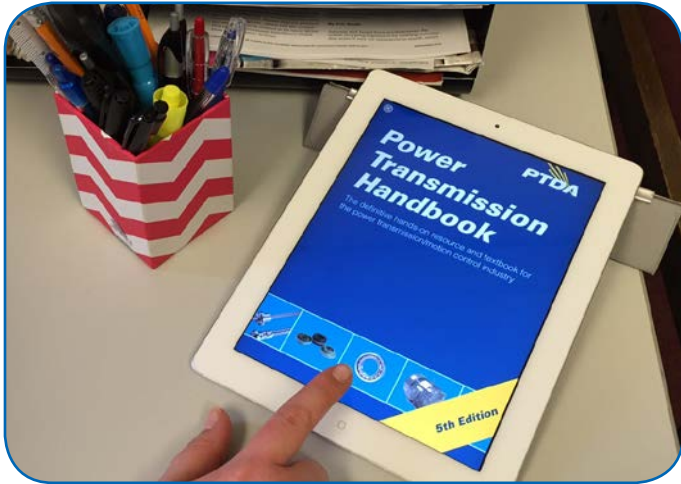
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The book has been adopted by industry professionals as well as educators and students in universities, community colleges and technical and trade schools. The Handbook eBook is currently available in both Apple and Kindle formats as searchable, bookmark-able, transportable content for busy people on the go.

First published in 1969 and recently updated, PTDA's Power Transmission Handbook is a comprehensive primer on the products, technology and concepts that move the industry.

The information contained in the book is suitable for inside/outside salespeople, experienced employees and customers. The publication has been formatted for ease of reading and features nearly 400 pages of vetted content, graphics and application examples.

Chapters touch on topics like adjustable speed drives, bearings, clutches and brakes, controls and sensors, linear motion and motors.

Thomas W. Rouse

NAMED PRESIDENT OF C&U AMERICAS

C&U Americas, LLC, the North American subsidiary of The C&U Group, recently named **Thomas W. Rouse** as its new president.

The announcement was made by XianLiang Zhou, chairman of C&U Americas, who noted that Rouse will be



responsible for managing all aspects of the C&U Americas' operations, including new business, sales, marketing, engineering, customer service, warehousing operations, and administration. Rouse succeeds William A. Childers, who is retiring.

"We are delighted to have Tom Rouse on our team," Zhou stated. "He brings a wealth of expertise as well as top-level management experience in the bearing business to the C&U Americas organization. His proven ability to deliver excellent sales results and his exceptional leadership qualities are precisely the attributes that we need to continue to grow the C&U Americas business in the U.S. and build an even stronger brand in the NAFTA market."

Rouse comes to C&U Americas after serving Precision Gear Holdings, LLC and Merit Gear, LLC as president and chief executive officer since December of 2009. He held full responsibility for P&L, manufacturing, and all department functions of both organizations.

Prior to Precision Gear, Rouse enjoyed a 20-year career at NSK Corporation. During his tenure as president and COO from 2004 to 2009, he was responsible for all industrial, after-market and automotive business segments, five manufacturing locations, and 1,500 employees.

During his time at NSK Corporation (1989 to 2009) Rouse also served as president and general manager of NSK Precision America, director of information management and business planning, and senior automotive marketing manager.

From 1983 to 1989, Rouse was a sales engineer and market analyst for steering and suspension products at TRW Automotive, Inc.

Rouse also served as a board and executive committee member of the American Bearing Manufacturers Association. He holds an MBA from Wayne State University and a B.A. in business from Michigan State University.

C&U Americas offers a full line of bearing types and styles for use in original equipment manufacturing, aftermarket replacement, and MRO operations. The C&U portfolio includes over 30,000 types of bearings in a wide range of specifications and sizes ranging from 1.5 mm ID to 4,000 mm OD.

North American Robotics Market

HAS STRONGEST YEAR EVER IN 2014

Robot orders and shipments in North America set new records in 2014, according to the Robotic Industries Association (RIA), the industry's trade group.

A total of 27,685 robots valued at \$1.6 billion were ordered from North American companies during 2014, an increase of 28% in units and 19% in dollars over 2013. Robot shipments also set new records, with 25,425 robots valued at \$1.5 billion being shipped to North American customers in 2014. Shipments grew 13% in units and six percent in dollars over the previous records set in 2013.

The automotive industry was the primary driver of growth in 2014, with robot orders increasing 45% year over year.

Non-automotive industries also performed well throughout the year, growing seven percent in total over 2013. The standout non-automotive industries in 2014 in terms of order growth were plastics and rubber (25%), semiconductor and electronics (21%), and metals (16%).

According to Alex Shikany, Director of Market Analysis for RIA, the fastest growing applications for robot orders in North America in 2014 were Arc Welding (+58%), Spot Welding (+57%), Assembly (+16%), and Material Handling (+11%). RIA estimates that some 230,000 robots are now at use in United States factories, placing the U.S. second only to Japan in robot use.

"This is an extremely exciting time to be involved in the robotics industry," said Jeff Burnstein, president of RIA. "Record sales performance, groundbreaking innovation, and increasing consumer interest all make the robotics industry so dynamic."

Burnstein noted that the RIA and its parent group the Association for Advancing Automation are seeing the impacts of the growth in demand for automation in events like the upcoming Automate 2015 trade show.

"With six weeks to go, the exhibit floor at Automate 2015 is already over 70% larger than our 2013 event," he said. "This growth is attributed to the fact that leading automation companies are reaching out to small and medium sized customers, many of whom are just now beginning to explore automation. This group makes up the core of the Automate 2015 attendee base, and early indicators are that the attendance in 2015 will be more than 50% higher than two years ago."

Polygon Solutions

JOINS NATIONAL ASSOCIATION OF MANUFACTURERS

Polygon Solutions Inc. recently announced it is joining the National Association of Manufacturers (NAM). The Florida company manufactures rotary broaching tools, used in CNC machines to make bone screws and accurate aerospace fasteners.

Polygon Solution is only four years old, but has won the nationally recognized ML100 award for Innovative Enterprise and regional awards for Market Problem Solving and Technology Transformation. Polygon also continues to re-



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lease new rotary broaching products every year, increasing in size and employees.

The National Association of Manufacturers is a co-producer of the Manufacturing Day event. NAM represents 11,000 companies, and is the nation's largest industrial trade association, representing small and large manufacturers in every industrial sector and in all 50 states. Manufacturing Day is designed to open the doors of manufacturing facilities to students and the public, and help them to see the opportunity they have to join a more modern manufacturing experience than in years past.

Polygon Solutions has participated in Manufacturing Day every year since it began. It has partnered with Lee County High School in Southwest Florida to bring students into their facility for a manufacturing presentation and tour. Attendance for the event has nearly doubled every year.

The joint effort is helping other businesses too. Neighboring Paver Motorcycles decided to join Polygon's tour this year. After learning about innovative rotary broach tools, students were directed next door to learn how custom motorcycles are made. Most students admitted afterwards that although they hadn't considered a career in manufacturing, they were more likely to after the tour.

Polygon credits much of its success to the relationships they've developed with various manufacturing associations. Other affiliations include the Precision Machined Products Association (PMPA), the Southwest Regional Manufacturer's Association (SRMA) and the National Tooling and Machining Association (NTMA). The broach manufacturer is now expecting to make further gains in exporting, tax issues and workforce development with the help of the National Association of Manufacturers (NAM).

Kent Furst

NAMED MANAGER OF FREEDONIA GROUP'S POLYMERS AND MATERIALS GROUP

Kent Furst was recently promoted to manager of the polymers and materials group at The Freedonia Group, Inc.

Furst has worked as an industry analyst since 2005 and is a member of the Society of Plastics Engineers. Furst graduated from Case Western Reserve University with a BS in Polymer Science & Engineering.

He recently was the keynote speaker at the 2014 International Silicone Conference and is currently involved in research on the polyethylene, fluoropolymer, and graphite industries.

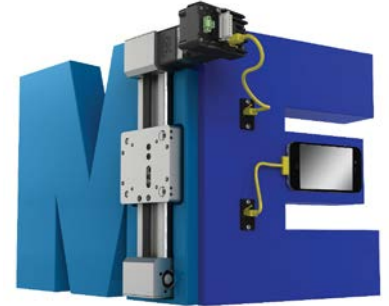


PBC Linear and Moons' Industries

ANNOUNCE JOINT VENTURE

PBC Linear and Moons' Industries recently announced a joint venture together to develop and deliver integrated mechatronic solutions for linear motion applications.

For over 30 years, PBC Linear has been a developer and manufacturer of linear motion solutions for a broad range of applications while developing a market in North America. In the last 20 years, Moons' Industries has grown to become the fourth



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largest stepper motor manufacturer in the world with a base in Asia and Europe. Combining in a joint venture, PBC & Moons' bring experience in manufacturing precision linear rails, multiple bearing types and drive options, and creating robust linear actuators along with experience in stepper and smart stepper motors, control solutions, and network connectivity to provide a global, simplified approach to integrated mechatronics for single axis robot modules and multi-axis systems.

The PBC and Moons' combination addresses the markets merging of multiple technical disciplines, trims down and consolidates the proliferation of vendors and companies to deal with, and simplifies the complex design and architecture of a mechatronics solution.

Motion Industries

ANNOUNCES EXPANSION TO ALASKA

Motion Industries, Inc. a wholly owned subsidiary of Genuine Parts Company, recently announced the purchase of Oil & Gas Supply, located in Anchorage, AK. The acquisition was finalized on February 2, 2015.

Oil & Gas Supply has two locations in Alaska – Anchorage and Kenai – providing industrial and hydraulic fluid power hoses, fitting and repair services, as well as tank truck parts to the oil and gas industry. The purchase of Oil & Gas Supply expands Motion Industries' Northwest footprint, serving industries including mining, construction, and fishing, in addition to oil and gas.

"The addition of Oil & Gas Supply provides an expansion of products, services, and value for customers in Alaska, an important area for our company's 49-state coverage," said Tim Breen, Motion Industries' president and CEO. "We are happy to have Oil & Gas Supply as part of the Motion Industries team."

With annual sales of \$4.5 billion, Motion Industries is a leading industrial parts distributor of bearings, mechanical power transmission, electrical and industrial automation,

hydraulic and industrial hose, hydraulic and pneumatic components, industrial products, safety products, and material handling.

Motion Industries has over 550 operations including 15 distribution centers throughout North America and serves more than 150,000 customers from the food and beverage, pulp and paper, iron and steel, chemical, mining and aggregate, petrochemical, automotive, wood and lumber, and pharmaceutical industries.

Sercos

CELEBRATES 25TH ANNIVERSARY

Sercos International, supplier of the Sercos automation bus, recently celebrated its 25th anniversary as well as 10 years of Sercos III technology.

Digital intelligent drives offer the highest precision and speeds for numerically controlled machines, at the same time minimizing equipment costs. In order to benefit from these advantages, an efficient digital interface is required for control. Although Sercos was originally designed as such an interface, over the course of the last two decades Sercos has developed into a universally deployable real-time interface for all automation applications.



In 1988, the concept was established, along with the clock-synchronous transfer concept, the most important profiles and the desire to offer an ASIC as the basis for the master and slave interfaces. So in 1990 Fördergemeinschaft SERCOS interface (FGS) was founded. Its members undertook both financing the Sercos concept and also supporting it for the future. Today, this syndicate collaborates on an international basis under the umbrella of Sercos International e.V.

The first generation, which was presented to the public for the first time at the EMO show in Hanover in 1989, supported 2 and 4 Mbit/s transmission rates and initially was used mainly in demanding tool machine applications. In the following years, Sercos was deployed in a wide variety of applications around the globe and in a wide variety of applications and industries. In 1995, Sercos was recognized as IEC standard 61491.

In 1999, the second generation of the standard followed. The transmission rate was increased to 8 and 16 Mbit/s, a new ASIC was developed, and the service was expanded to include asynchronous data transmission. Since 2001, this technology has been available based on the SERCON816 ASIC, with backward compatibility with the first generation ensured.

The recipe for success of Sercos III, the third generation of Sercos, which was launched into the market with initial prototypes in 2005, is: "Use of the transmission medium and the protocol of Ethernet while preserving the tried-and-tested Sercos mechanisms."

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Greater Columbus Convention Center, Columbus OH. Presented by the Precision Machined Products Association, and co-presented by Production Machining and Modern Machine Shop, PMTS is the only show in North America dedicated to the Precision Machining industry. With more than 260 exhibitors displaying equipment, products and services to more than 5,000 attendees, PMTS is an international gathering of the manufacturing professionals who are moving the industry forward. For more information, visit www.pmts.com.

April 29 – SMMA Presents: An Overview of Various Electric Motors and Motion Control Technologies

Villas of Grand Cypress, Orlando, FL. This new SMMA Motor & Motion College course will provide fundamental concepts of electric motors and their electronic control methods. Intended for non-technical professionals such as sales and marketing, middle and upper management, and application engineers who want to learn fundamental principles and basic knowledge, course content covers electromagnetic torque production theory, construction and operation of all motor types, their relative differences, as well as electronic hardware topologies, field oriented and sensorless control algorithms, and servo system theory in clear and concise explanation without using lengthy equations. The instructor for An Overview of Various Electric Motors and Motion Control Technologies is Dal Y. Ohm, PhD, president of Drivotech, Inc., a technical consulting firm specializing in the design and development of motor control, drives, and renewable energy converter systems. Dr. Ohm has more than 25 years of industrial and academic experience in research and product development in motor drives, servo systems, and power converters. For more information, visit www.smma.org.

April 29-May 1 – 2015 AGMA/ABMA Annual Meeting

The Meritage Resort and Spa, Napa Valley, CA. This year's Annual Meeting will address the key issues facing manufacturing and offer opportunities to network, make memories, forge relationships, and build on future partnerships. Napa Valley provides much to explore and many attendees will bring a spouse or guest. In lieu of the golf tournament, the planning committee opted to keep open the second afternoon for exploration of this unique location. For more information, visit www.agma.org.

May 4-6 – 2015 Gearbox System Design: The Rest of the Story... Everything but the Gears and Bearings

Sheraton Sand Key Resort, Clearwater Beach, FL. This course focuses the supporting elements of a gearbox that allow gears and bearings to do their jobs most efficiently. Learn about seals, lubrication, lubricants, housings, breathers, and other details that go into designing gearbox systems. This seminar starts with the basics including some history of design and the varied environments to which gearbox systems are built. It continues by teaching detailed design layout. And it then will focus on individual pros and cons of types of housing construction, drawing practices for housings and related components and

selection and role of gearbox accessories, such as breathers, filters, screens, sight gages and other level indication devices. For more information, visit www.agma.org.

May 6-7 – Design-2-Part Show Schaumburg Convention Center, Schaumburg, IL. Manufacturers nationwide rely on Design-2-Part Shows as the most efficient place to meet high-quality, reliable American job shops and contract manufacturers. In just a few hours you can find cost effective, quality suppliers, learn about new technologies and materials, see and compare parts and components, and quote jobs and evaluate quality price while getting delivery on the spot. Finding trustworthy contract manufacturers who can provide flexible, cost-effective solutions and scale up growing organizations is critical. There is no better way to identify new outsourcing partners than spending even one half-day at this show. The modern elegance of the Schaumburg Convention Center (Schaumburg, IL) provides the perfect location for people to work hard and still enjoy a day out of the office. For more information, visit www.d2p.com.

May 18-21 – AWEA WINDPOWER 2015 Conference & Exhibition

Orange County Convention Center, Orlando, FL. Wind energy's premiere industry gathering is a concentration of expertise and innovation that draws thousands of professionals from around the world to trade knowledge, experience and best practices across all industry segments. And in 2015, WINDPOWER will address what you can do now to meet the challenges of today, while preparing for tomorrow. The WINDPOWER 2015 cutting-edge program presents and examines the technical developments and evolving issues that are transforming the industry and increasing the competitiveness of wind power. AWEA has assembled top industry experts for this conference, who will present deep-dive sessions on a variety of relevant topics. Targeted tracks provide the opportunity to network, collaborate and advance your tactical understanding in areas that impact you most. For more information, visit www.windpowerexpo.or.

June 22-25 – 2015 Automation Summit

Aria Resort, Las Vegas, NV. The Summit will again feature the popular Connect Event, where attendees can network in-person and virtually with Siemens employees, solution providers, integrators, distributors and end users. Siemens will offer hands-on training sessions, featuring work stations with equipment, led by technical experts, and will provide updates on recent product enhancements, including the PCS 7 Version 8.1, SIMATIC WinCC V7.3 process monitor; WinCC/ Web UX; SIMATIC HMI Mobile Panels and Outdoor Panels 2nd generation; SIMATIC IPC347D; SIMATIC ET 200SP Open Controller; SIMATIC S7-1500 Software Controller; and INOX devices. Innovator and business futurist Nicholas J. Webb will provide the keynote address. Webb, author of "The Innovation Playbook" and "The Digital Innovation Playbook," is a successful inventor with a wide range of patented technologies including one of the world's smallest medical implants and the popular Hanz line of educational toys. For more information, visit www.industry.usa.siemens.com.

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3-D PRINTING IS HERE! AND THERE! AND OVER THERE!

Jack Mc Guinn, Senior Editor

Necessity is the Mother of Invention, goes the bromide, but this 3-D printing thing is taking manufacturing to an entirely different—yes—dimension.

I mean, you've read the bordering-on-science-fiction articles, attended the seminars, sat through the webinars. And to cite the legendarily titled, unfinished, unreleased Orson Welles film—*It's All True*. (Allowing of course for obligatory flak-speak).

3-D print technology—and this is a most-basic explanation—fashions parts, modules, etc., from a “blank page” by pan-caking thin layers of materials on top of each other—as specified (designed) by blueprints via computer display. Acknowledged advantages thus far for this nascent technology include faster production, increased flexibility, i.e.—the ability to create components in shapes impossible to accomplish through standard methods—and, one of 3-D printing's most attractive capabilities for the power transmission game—rapid prototyping of complex, expensive parts (tools, gears, etc.).

Easily the shiniest, newest thing for most of us to ponder who follow manufacturing, 3-D printing gains more attention – and investment capital—in real time as one after another of its manufacturing wonders is unveiled in the trade press.

For example, a recent *Bloomberg News* report, that likens Sandvik's 3-D gambit to Siemens AG in exploring 3-D printing, states that, “Sandvik AB is boosting research spending on 3-D printing as the world's largest maker of metal-cutting tools expands capabilities in a market set to grow nine-fold—to \$21 billion in a decade.” That's a lot of folding money for a technology that some continue to treat like a redheaded stepchild. (In fairness, the whiz-bang technology process is not manufacturing-extensive; there are limitations having to do with cost ef-

fectiveness and repeatability issues, to name just two.) What's more, the report adds, the toolmaker is adding staff expertise to operate a new 3-D printing research and development center in Sandviken, Sweden. There they will “unify 3-D initiatives across the business and examine how the technology can be used in its production of everything from mining drill rigs to fuel tubes for nuclear power plants.”

Another wonder of 3-D printing—or additive manufacturing, as it is interchangeably known—is how it can work with extruded plastic to create solid objects that can include moving parts—even though they are first created as a single/solid component. One such wonder is this 3-D-printed peristaltic pump (shown)—the brainchild of a blogger. What makes it truly wondrous is that this thing was printed from a 3-D-printed *planetary gear bearing*.

Pump people know peristaltic pumps are designed to apply constant, steady pressure on fluid-filled tubing that is coursed through the interior perimeter of a planetary gear. Meanwhile, intermediate gears directly apply pressure as they are tracking. These pumps are used in medical devices, clean rooms and many other environments and in equipment where controlled fluids delivery is critical. They also have a place in the sizeable home & garden market, where they are used in gardens, fountains, ponds, etc.

Not to party-poop, but shiny and new can get old and in the way in a hurry. What's the application-specific service life for a piece of 3-D-printed equipment such as this? Its blogger maker says it is wear-and-tear-resistant, but what does *that* mean, exactly? So in this case expectations are key and certainly more testing is/would be



needed—dependent upon what those expectations—or mandated requirements—actually might be.

That aside, you have to admit that the fact that one can *print* a set of *working, moving*, parts is like taking the “fi” out of “sci”—like *Iron Man 2*, for instance, writ true-to-life. And you can bet your stock portfolio there will be other applications dovetailing with the rotary functions of 3-D print-friendly planetary gears and other iterations.

Like, the aerospace industry is at the forefront of 3-D printing in the manufacturing industry (peristaltic pumps for example?), according to *Bloomberg*, reporting that “General Electric has said that from 2016, its new Leap aircraft engine will include 19 3-D-printed fuel nozzles, designed to last five times longer than traditionally made components (see service life comments above); and “Siemens uses additive manufacturing to repair gas turbine burners that's accelerated the repair time from 44 to four weeks, and the process has also hastened the time taken to prototype new metal components to as little as 48 hours.”

And did we mention they are already 3-D-printing replacement parts up at the ISS (International Space Station)?

Saddle up folks. Mars, Hoooooooooooooooooooo! **PTE**

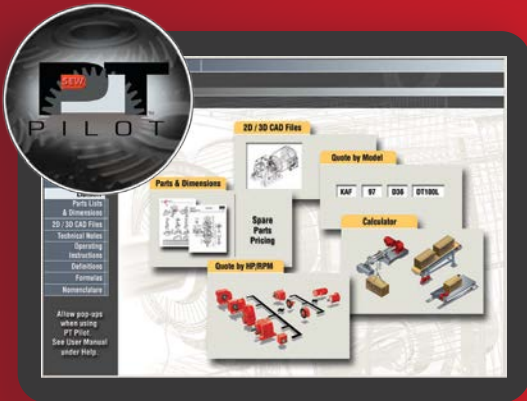


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