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APRIL 2014

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Power Play

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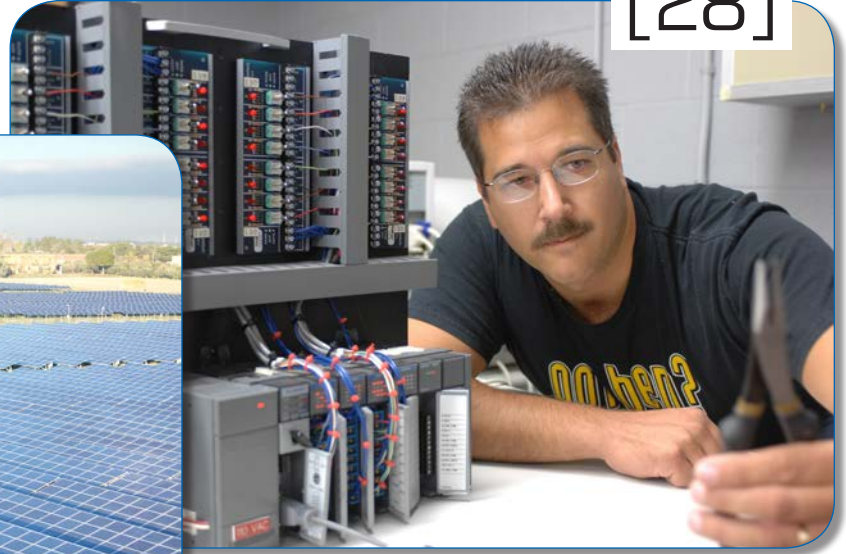
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Power Transmission Engineering

VOL. 8, NO. 3

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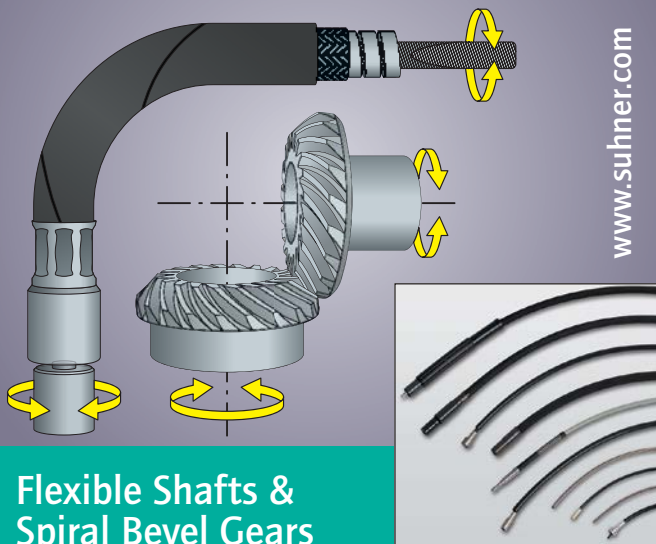
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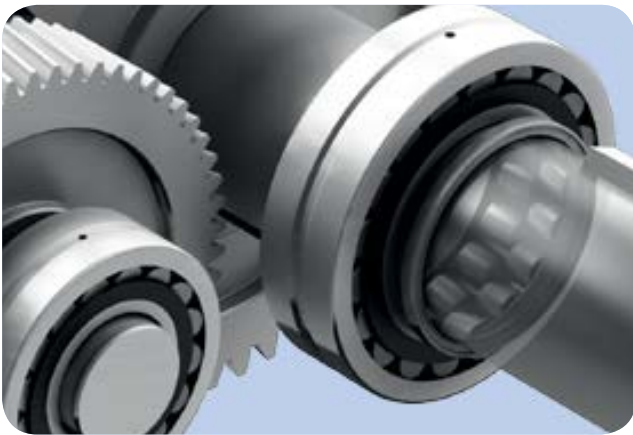
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PTE Videos

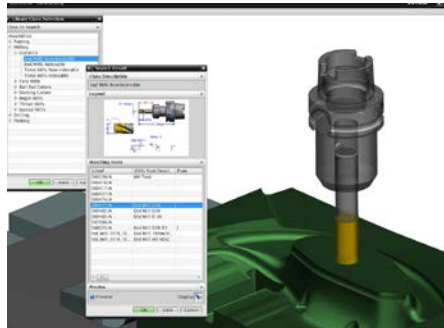
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Gearboxfailure.com is a resource for designers, technicians, operators, and owners of geared machinery. The site provides information on gear and bearing failure modes, how to identify the failure mode, how to prevent additional failures, and perhaps most importantly, what can be done to prevent failures from occurring in the first place. The website was created by **Rob Budny** with content contributed by Bob Errichello.



LinkedIn: Siemens' NX software, the company's flagship solution for integrated 3-D computer-aided design, manufacturing and engineering analysis (CAD/CAM/CAE), is now available in a cost-effective private cloud environment. Learn more on our LinkedIn page: (www.linkedin.com/groups/Power-Transmission-Engineering-PTE-2950055)



E-News: Recent E-news topics for *Power Transmission Engineering* include articles on "Specifying a Gear," "How to Spec a Mill Gear," and the "Influence of Gear Loads on Spline Couplings." To subscribe to our monthly newsletter visit www.powertransmission.com/newsletter.

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Randall Publications LLC
1840 Jarvis Avenue
Elk Grove Village, IL 60007
Phone: (847) 437-6604
Fax: (847) 437-6618

EDITORIAL

Publisher & Editor-in-Chief
Michael Goldstein
publisher@powertransmission.com

Managing Editor & Associate Publisher
Randy Stott
wrs@powertransmission.com

Senior Editor
Jack McGuinn
jmcguinn@powertransmission.com

Senior Editor
Matthew Jaster
mjaster@powertransmission.com

Editorial Consultant
Paul R. Goldstein

ART
Art Director
David Ropinski
dropinski@powertransmission.com

ADVERTISING
Advertising Sales Manager & Associate Publisher
Dave Friedman
dave@powertransmission.com

Materials Coordinator
Dorothy Fiandaca
dee@randallpublications.com

CIRCULATION
Circulation Manager
Carol Tratar
subscribe@powertransmission.com

RANDALL PUBLICATIONS STAFF
President
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Motor Appreciation



When I woke up this morning, my house was a comfortable 68°F, despite the fact that overnight temperatures in the Chicago area were close to freezing. I don't often think about the blower motor that helps circulate the warm air from my furnace throughout my house, but today I was grateful for it.

Similarly, I take for granted the exhaust fan in my bathroom, even though I use it every day to keep the mirror from steaming up during my shower, which comes in handy when I want to comb my hair and shave. I don't really have to think about the electric motor that powers the fan. I just flip the switch and go about making myself beautiful.

The point is, electric motors have a much bigger impact on our daily lives than most of us realize. They quietly hum in the background, making our lives better. When I poured cold milk on my Wheaties this morning, I didn't have to think about the evaporator fan on my refrigerator or the electric motor that powers it. I just enjoyed the cold milk.

In fact, it's only noon, and I've already made use of or been assisted by at least a dozen electric motors: My garage door opener, my windshield wipers, the automatic drawer that opens at the drive-through lane at my bank, the printer on my desk, the fan and DVD drives inside my computer.

Even my two fish benefit from motors. Elvis and Albus (don't ask, my kids named them) would be swimming in pretty filthy water if not for the little pump motor that powers the water filter on their tank.

According to the U.S. Department of Energy, electric motors account for more than 50% of all electricity use in the United States, which means that my fish and I are not unique in our dependence upon them. But whereas they're an important part of everyday life, they're even more significant in the nation's industrial activity.

Because of the importance of motors in the overall economy and in the energy consumption they require, enormous effort has been spent on increasing the energy efficiency of motors used in the United States. I encourage those interested in learning more to visit www.motorsmatter.org, the website of Motor Decisions Matter, a national public-awareness campaign sponsored by a consortium of electric utilities, industry trade associations and motor manufacturers. The site contains tools and information for better understanding the costs associated with electric motors and their use.

Also, this issue of *Power Transmission Engineering* includes a focus on electric motors, with a special section, beginning on page 22, which includes some of the latest technology from the world's leading manufacturers. Motor designers continue to find ways to provide greater power in smaller packages, increase energy efficiency, reduce noise and provide ever increasing levels of control. If you are a buyer, specifier or end user of electric motors, it behooves you to stay up to date on the latest technology. We've done our part by gathering information in this special section.

And if you're interested in learning more about how motors work, we invite you to read Dan Jones' latest article, beginning on page 46, which explores the basics of step motors.

After half a day of taking a conscious inventory of my electric motor usage, I have a much better appreciation for just how much benefit we derive from them every day. I'd love to hear your feedback about the electric motors you rely on. Perhaps there are some that I used today without even realizing it.

In the meantime, I think I heard the microwave beep, which means my lunch is ready. Thank goodness the one in our office has a rotary turntable in it. Otherwise I'd have to take the food out, stir it and heat it some more. I can't imagine how people survived before they put electric motors in microwave ovens...

A handwritten signature in black ink that reads "Randy Stott". The signature is written in a cursive, flowing style.

Hunting For High Quality Gears? Forest City Gear Leads the Way

US Navy MH-60S Seahawk helicopters patrolling for mines out ahead of surface vessels use a powerful and precise Carriage Stream Tow and Recovery System (CSTRS) to quickly raise and lower mine-hunting and destruction equipment. Very high-precision gears from Forest City Gear help to ensure that the mission goes as planned. In this and many other aerospace and defense applications, Forest City Gear is helping customers meet their gear challenges – no matter how difficult to detect.

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Bosch Rexroth

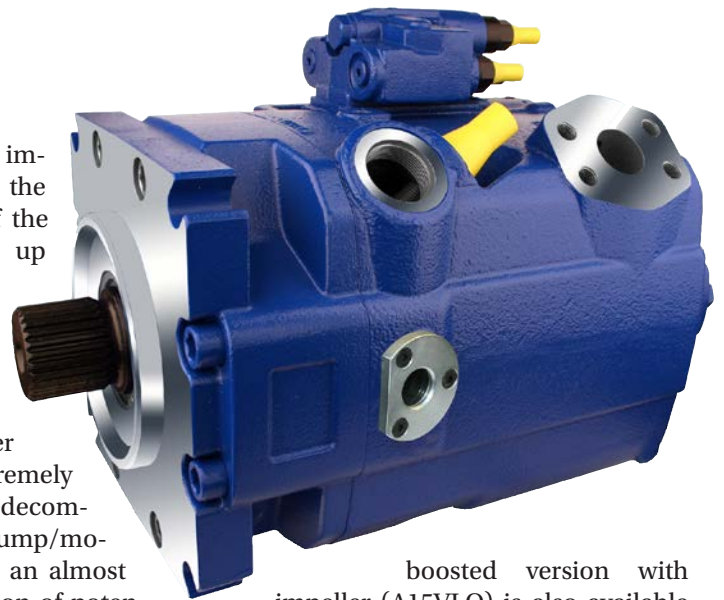
INTRODUCES HIGH-PRESSURE AXIAL-PISTON PUMP

Rexroth combines significantly lower noise emissions with further improved efficiency in the new A15VSO hydraulic axial-piston pump for stationary applications in open circuit operation. It can meet pressure requirements to 420 bars and recover potential energy during pump/motor operation almost completely. This enables innovative regeneration concepts that can improve the efficiency of machines and systems. Equipped with a universal through drive, the A15VSO seamlessly integrates into the Rexroth line of products and simplifies the process of combining different pumps. Rexroth developers used state-of-the-art simulation tools in all design stages.

The one-piece housing eliminates numerous sealed oil paths, allowing designers to move closer to the goal of a leak-free design. The housing structure, optimized for minimum sound emissions, reduces noise considerably. Subsequently, the airborne noise level has been reduced in average by up to two dB(A) at full flow operation and up to three dB(A) during pressure holding periods (high-pressure standby). In addition, the development engineers shifted the operating noise to a frequency range that is perceived as sonorous and more agreeable to the human ear.

Further design improvements bring the overall efficiency of the axial-piston pump up to 93 percent. The swivel range, for example, has been expanded to ± 100 percent to enable complete over center operation for extremely fast and efficient decompression. In the pump/motor operating mode an almost complete regeneration of potential energy is possible, for instance during lowering of a load or braking of a moving mass. This opens up new opportunities for maximizing the energy efficiency of machines and systems, whereby the robust and stable swivel action ensures highly dynamic performance with reduced response times.

The A15VSO is available in sizes 110, 145, 175, 210 and 280 cubic centimeter (cc) at a nominal pressure of 350 bar and a maximum pressure of 420 bar. The standard 280cc pump can run at 1,800 rpm with flooded suction. The new compact housing, which features an optimized layout of flow channels and better use of installation space, simplifies the process of fitting the pump even in very tight spaces. A



boosted version with impeller (A15VLO) is also available for up to 20 percent higher operating speeds. The universal through drive increases flexibility for customized drive solutions and can easily be used to connect axial-piston, gear, and other hydraulic pumps out of the comprehensive line of Rexroth pumps. Numerous hydraulic and electric controllers (also for remote control operation) enable efficient, highly precise control of power, pressure and flow, as well as load-sensing functions.

For more information:

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Ovako

STEEL RINGS IMPROVE PROCESSES AND LOWER COSTS

Production of near-net-shape rolled and forged stainless steel rings by Ovako, using closely managed hot-rolled ring mill techniques, is helping customers to reduce process costs and cut down on waste. Rolled and forged steel rings are vital components for applications in the rolling bearing, heavy vehicle, automotive and machine tool manufacturing industries. Yet machining can be costly with issues of weight and generation of waste materials.

A leading producer of high quality rolled and forged rings for nearly a century, Ovako has recently invested

heavily, and further expanded its capabilities, to deliver rolled and forged rings that are extremely close to customers' final component sizes.

This allows customers to focus on their assembly or final targets with reduced needs for further machining and the associated costs and material waste, such as polluting dust. Some surfaces may even



SCHAEFFLER



Bearing Replacement Costs Digging into Your Profits?

Time to Split!

In the mining & aggregate business, if you're not digging, you're not making money. Bearing replacement, while necessary, stops your machines in their tracks.

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And less downtime means more profits.

Maybe you should split, too!

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Ovako strictly controls its whole production chain from the initial melt, carefully managing oxygen levels to manufacture exceptionally clean steels through to the precision rolling of the rings. On completion every ring is inspected for surface defects, discrepancies in their inner and outer diameter, width, height and squareness utilizing an inventive inspection system.

Cleaner steels can enable longer operational lifespans for products with higher wear and corrosion resistance, and reduce maintenance and lifecycle costs.

The near-net-shape rings have very tight tolerances for minimal deviation from each client's desired net dimensions, with small allowances to accommodate waste reduction targets. They can be heat treated before delivery – including normalized, soft annealed, quenched and tempered and more.

To facilitate individual customer requirements, Ovako can manufacture virtually any ring profile shape in dimensions of 170-4,000 mm and weight ranges between 7-5,000 kg. All the rings are of stable quality with tests carried out on every batch, and batch deliveries are adaptable to suit each customer's unique requirements.

Expanded production capacity

Ovako has opened a new hot-rolled ring mill at its works in Hofors, Sweden. This will increase its manufacturing capacity by 75 percent from around 30,000 to 55,000 tonnes, equivalent to more than 3.5 million rings manufactured per year. The company prides itself on processes that few ring producers can match in terms of consistent quality from delivery to delivery.

For more information:

Ovako AB
Phone: (803) 802-1500
www.ovako.com

Igus

RELEASES BEARING MATERIAL SAMPLE KIT

Plastics specialist Igus has announced the release of its dry-tech box, a sample kit designed to help engineers find the right material bearing for their application. The box contains a set of state-of-the-art card overlays, which filter the bearing choices by criteria – similar to the Igus online configurator. The dry-tech sample box includes a complete array of Iglide bearings, ranging from Iglide H, which is suitable in corrosive environments, to Iglide A350, which can withstand temperatures up to 356°F, and are utilized for the food industry. The box also contains a user-friendly bearing guide that highlights the key properties of each bearing making the search for the perfect bearing simple and precise. All Igus bearings have dry-running properties, making them lubrication-



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- 2-Side Worm Support

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- Low Backlash
- 1 and 2 Stage Ratios
- Lubricated for Life

Servo Worm Gearheads



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- Capacity: 10-7000 Nm
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TorqSense

PROVIDES IN-LINE TORQUE METER

Manchester University's School of Chemical Engineering and Analytical Sciences is leading world class developments in energy efficiency in the process industries. Researchers have incorporated TorqSense transducers into a test rig that is analyzing losses in in-line mixers. The energy consumption involved with in-tank mixing processes is well researched and understood. But with in-line rotor-stator mixers the flow is often controlled independently of the rotor speed and collecting sufficient data to accurately model the process has to date required a large number of experiments. Now researchers Dr. Mike Cooke and T. L. Rogers at Manchester University have developed two simplified methods of obtaining the necessary information for particular stator-rotor mixers: one uses torque measurements, the other heat balance.

Dr. Cooke explains that high shear rotor-stator mixers are widely used in process industries, including the manufacture of many food, cosmetic, healthcare products, fine chemicals and pharmaceuticals. Rotor-stator devices provide a focused delivery of energy, power and shear to accelerate physical processes such as mixing, dissolution, emulsification and deagglomeration. "To reliably scale-up these devices from laboratory size to industrial scale, we need to understand the relationship between rotor speed, flow rate and the energy dissipated," he says. "The first step is to link the energy dissipation rate to desired process results."



The scientists created two mixing experiments and set about measuring the torque profile and heat balance. In the first experiment torque was measured by a Sensor Technology's TorqSense in-line torque meter fitted to the drive shaft. There are two main sources of potential error when measuring the torque on the rotor shaft, time-based zero-drift and bending moments on the shaft, both of which are easily counteracted with the TorqSense. Other corrections also have to be made for bearing losses, temperature fluctuations etc.

TorqSense proved a good choice for this work because its non-contact operation meant extra drag forces were not added to the system and also allowed rapid assembly and disassembly during the experiments. It uses two piezoelectric combs which are simply glued to the drive shaft at right angles to one another. As the shaft turns it naturally twists along its length very slightly and in proportion to the torque, which deforms the combs changing their piezo-signature. This change is measure by wirelessly by a radio frequency pick up and used to monitor the torque.

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ABB

PRESENTS OFFSHORE DRIVE AND CONTROL SOLUTIONS

Modular liquid-cooled drives and PLCs from ABB have been included in Vard Electro's innovative, application-specific propulsion and thruster power solutions for offshore supply vessels. The electric motor propulsion technology designed by Vard Electro is used on a series of six platform-supply vessels (PSVs) — the first two of which currently are being built in Japan.

Twenty years ago, in response to growing global competition and demands for ever-more sophisticated propulsion performance, the innovative shipbuilding group Vard decided to bring their systems integration function in-house. Vard established a fully owned daughter company, Vard Electro, specializing in system integration and development and providing

tailor-made marine electronics solutions for offshore specialized vessels worldwide.

Vard Electro looked for a drives and control supplier that could provide a highly configurable drives platform, and chose drives from ABB's ACS800 range, with control provided by ABB's AC500 PLCs. The high degree of modularity of both the controller and drives, the availability of sophisticated PLC development tools in the form of ABB's Automation Builder engineering software suite — together with valuable local programming and HMI capabilities of the drives themselves — provided the economy and versatility of platform that Vard Electro was looking for. These system components also provided a number of tangible performance advantages for this particular motor control application. They include fast real-time control updates and low harmonics power conversion of the drives, and compactness that comes from liquid cooling — an extremely valuable feature for the packed OSV engine rooms housing the main engines and thrusters.

For each vessel of the six PSVs which are being built in Japan, ABB is supplying five PLC-controlled variable-speed drives to control a total of over 6 MW of power: two 2 MW drive systems for the main engines, two 730kW drives for bow thrusters, and one 730kW drive for a dual-fed bow thruster that is able to survive the failure of either of the vessel's two power generators.

The ABB drives and controller system are now part of Vard Electro's new SeaQ Power intelligent power systems range, which was created during the past year. To support the development process for the new propulsion power offering, ABB initially supplied the company with a small-scale version of the PLC-drive-motor package, plus development tools. Supplying the complete control and drive package ensured that there were no integra-





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tion problems. ABB's AC500 is also one of the fastest PLCs on the market, and Vard Electro also chose a version of the PLC with one of the fastest processor options — the PM590-ETH — to ensure very good real-time control performance. The PLC is connected to the drive using Profibus DP fieldbus communications.

Vard Electro's control logic for the propulsion system includes all of the standard control features, as well as numerous variations to optimize performance in a number of situations, including a Vard Electro "ride through" specification to overcome power supply glitches smoothly, seamless switchovers for dual-fed supply arrangements, and rich local status, alarms/diagnostics and control possibilities on each of the drives — provided via the addition of a touch-screen HMI located on each cabinet's front panel. For this latter task, Vard Electro chose to install large CP660 HMI panels from ABB's state-of-the-art CP600 series, which meet DNV standards — to display information to operators in very clear and detailed forms.

The integration of all these components was simplified by the use of ABB's integrated *Automation Builder* software, which provides a common development tool for the spectrum of automation components used in this application: PLCs, drives, HMIs, fieldbus, networks and web services.

Before delivering the new electric power propulsion control system, Vard Electro performed detailed testing on the PLC and drive combinations at its test facility in Søvik, Norway. These trials were also witnessed by Vard Elec-

tro's Japanese shipyard customer. The integrated control system passed all of its tests and Vard Electro now has shipped the propulsion systems for the first two vessels. The very first vessel with this technology will be launched in mid-2014, and will be destined for use in platform supply applications.

"By combining ABB's high quality drives and PLCs with Vard Electro's

specialist system integration know-how, we have been able to deliver a propulsion solution offering state-of-the-art performance," says Tommy Damm, a drives specialist with ABB Norway.

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Trelleborg Sealing Solutions

INTRODUCE INNOVATIONS AT IFPE 2014

In facilitating the advancement of fluid power, motion control and power transmission applications, Trelleborg Sealing Solutions presented its “Trelleborg Solution,” advanced delivery services and customized packaging as well as its array of innovative products including Turcon, Glyd Ring II, Zurcon Glyd Ring D and high performance rotary seals during IFPE 2014. With a focus on increasing the Total Value of Ownership (TVO) for customers and supplying not just the highest quality of products, but also services, the “Trelleborg Solution” from Trelleborg Sealing Solutions helps accelerate customers’ business processes and delivers seal application and design for even more efficient manufacturing. When coupled with its advanced delivery services, Trelleborg Sealing Solutions can help empower fluid power component manufacturers through vendor-managed inventory and supply chain solutions, such as value-added packaging and handling services. These give customers the ability to customize packaging and labeling for a more simplified stocking and handling operation.

Peter Hahn, president, Trelleborg Sealing Solutions Marketing Americas, says: “Our value proposition to our customers is a significant cost savings proposal through a radically different concept in helping our customers to not only *rethink their profitability* but actually deliver the solutions to help achieve it. As a forward-thinking company, we not only intend to bring business accelerators to the forefront for our customers but also to help them to implement and achieve increased business value.”

In addition to demonstrating its service approach, Trelleborg Sealing Solutions displayed these new products at their booth:

Turcon Glyd Ring II is a double-acting, rod or bore, bi-directional seal for reciprocating and static applications offering lowered friction and yielding a longer service life.

Zurcon Glyd Ring D seal is produced from a completely new Zurcon material and engineered to extend seal life in high-pressure hydraulic sealing applications. It is well suited for machines, equipment and motors filled with hydraulic cylinders.

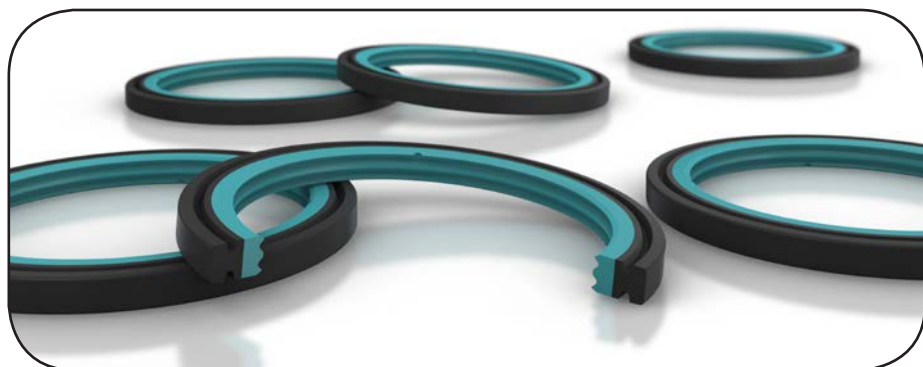
Rotary seals from Trelleborg Sealing Solutions extend product life while improving safety and performance in extreme environments in power transmission and motion control applications. Featured rotary seals are as follows:

CSL1500 is a radically new cassette seal design for agricultural and construction equipment that maximizes performance. These seals have been proven in lab and field to outlast conventional cassette seals.

A new line of standard inch size radial oil seals is made to meet advanced design standards. These seals offer sizes and styles that are available to fit a full range of applications. Heavy duty mechanical face seals are designed for severely contaminated environments. They are available in cast iron or bearing steel to give the best performance in every application.

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Siemens is offering conveyor technology for material handling, to all builder, system integrator and end-users of both discrete and process manufacturing markets. An integrated drive system with Siemens motion control and drives products, along with communication protocols, is available. It spans the range of drives, motors, gear motors and automation technology, plus machine safety, power supply and circuit protection. As a longtime supplier to the global conveyor and material handling industry, Siemens brings this offering to the North American market with the full support of its global network of engineering, sales, service and technical support.

Advantages for machine builders

Siemens brings a flexible and field-tested portfolio of products and software services to the builders of material handling equipment in all industries. Free design tools allow a more efficient process in customer design, configuration and product selection, plus communication and energy calculation. When a large or multi-unit system is needed, the advantages of Siemens distributed control and common DC bus afford many with an economical solution to material handling. This translates to a lower installation and commissioning cost.

Advantages for system integrators and end-users

Whether a greenfield project or brown-field expansion of an existing material handling machine or full production line, Siemens integrated drive systems bring a full portfolio of products and automation solutions to the task. In the field, fast commissioning is provided by a team of qualified personnel, resulting in quicker start-up and less downtime.

The preventive maintenance and remote diagnostics software combine to keep equipment running more productively. The recent expansion of our popular drives platform to include Profinet, Profibus, Ethernet/IP and AS-interface allow Siemens drives to com-



municate with other brands of existing products or new components on the customer's line, resulting in cost savings and greater efficiencies.

Siemens can satisfy an array of typical material handling scenarios, as it supplies a full range of products and services to create the ideal solution for the customer. Siemens products for material handling applications include:

Gear motors

Recently established in Greenville, S.C. to better serve the North American market, the Simogear gear motor facility assembles energy-efficient gear motor units commonly found in material handling. Simogear can be combined with Sinamics drives to suit a broad range of applications—from the low-speed uses (0.1–1,000 rpm) to the most challenging, high-torque demands.

Siemens is in the forefront of the evolution from worm to helical bevel gear motor utilization in the material handling world, as this technology means less motor power is needed to produce the same output torque and speed. This translates to smaller units with higher efficiency and overall lower cost.

Drives

The complete family of Siemens Sinamics drives means a single source for a broad assortment of product solu-

tions, globally recognized and capable of controlling virtually every application in material handling, from basic roller tracks to multi-axis, high-bay racking units, all with high-dynamic performance.

Central and decentralized drives are highlighted by the Sinamics V20, G120C and G120D. All are space-saving and offer a variety of communication, programming and control capabilities. In addition, the decentralized Sinamics G120D can be machine-mounted and is suitable for tough environments.

Controllers, I/O and Software

Simatic S7 PLCs offer both PAC and PLC reliability in their performance with modular and PC-based options.

Distributed I/O from Siemens is useful in all conveyor, sorting and assembly operations, plus is offered in space-saving compact or modular form factors.

Simatic software includes operator control and monitoring systems with a single software environment for every automation task. Totally Integrated Automation (TIA) means over 100,000 Siemens products share a core intelligence.

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Solar Power Turns a Corner

ABB Sees Significant Market Potential Moving Forward

Matthew Jaster, Senior Editor

According to GTM Research and the Solar Energy Industries Association (SEIA), photovoltaic (PV) installations increased 41 percent from 2012 to 2013. Additionally, 410 MW of concentrated solar power came online in 2013. Solar was the second-largest source of new electricity generating capacity in the United States, exceeded only by natural gas. By the end of the year, there were more than 440,000 operating solar electric systems in this country.

“Perhaps more important than numbers, 2013 offered the U.S. solar market the first real glimpse of its path toward mainstream status,” said Shayle Kann, senior vice president at GTM Research. “The combination of rapid customer adoption, grassroots support for solar, improved financing terms and public market successes displayed clear gains for solar in the eyes of both the general population and the investment community.”

“Solar is the fastest growing source of renewable energy in America, generating enough clean, reliable and affordable electricity to power more than 2.2 million homes,” said SEIA president and CEO Rhone Resch. “We’re just beginning to scratch the surface of our industry’s enormous potential.”

“The impact of the solar market on ABB’s success in 2014 will be quite significant,” said Bob Stojanovic, director of Solar Power North America at ABB. “The role of the solar market in current and future growth is so important that ABB made a \$1B investment in Power-One. The investment was made in order to fully participate and capitalize on the long term global growth of the PV market. We expect that ABB’s growth in solar for 2014 will significantly exceed the market growth levels.”

Power-One is one of the largest providers of solar inverters in the world. The company, based in Camarillo,



California, supports every step in the refinement of utility-grade AC into the various DC voltages required to power high-availability infrastructure systems at the site, system, and semiconductor levels. Late last year, ABB completed the acquisition of Power-One, a move that made sense according to ABB CEO Joe Hogan. “The acquisition of Power-One expands our renewable businesses and provides substantial opportunities to create value for our customers, employees and shareholders. The combination of Power-One and ABB is fully in line with our 2015 strategy and creates a global player with the scale to compete successfully.”

In recent years, economic strife has made it difficult to gauge where U.S. renewable energy’s strength and market future stands (just ask those that invested significantly in wind, solar, hydro or geothermal power around 2008 or 2009). “There will be short-term volatility in various regional markets as incentives change or phase out, however over the long term solar will grow at a rate that is far superior to the general economy,” said Stojanovic. “The transition period during the phase out of the 30 percent Solar Investment Tax Credit (ITC) will certainly have an impact;

however I expect that the market will recover from the expected dip in 2017 installations. Solar power has a lot of things going for it that will ensure its growth for a long time to come. Aside from the fact that solar PV has demonstrated a steady history of cost reduction, it is predictable, flexible, scalable, available everywhere, and it has an overwhelmingly positive perception by the general public. That cannot be said about many other forms of energy production.”

The U.S. solar market has been a source of reassurance for the global players, while the European markets have endured periods of extreme volatility as a result of very generous Feed In Tariff (FIT) policies, according to Stojanovic. “The fact that utility scale developers have to compete for power purchase agreements (PPAs) ensures market level pricing, whereas a FIT as implemented in other markets establishes an artificial market rate on a first come, first served basis which does nothing to ensure that rate payers are not overpaying for solar power. The steady long term growth of the U.S. market has allowed companies to create longer term product roadmaps and business strategies necessary in order

to further reduce costs and increase efficiencies to make the business sustainable.”

The Solar Investment Tax Credit will not go away completely, but is being reduced from 30 to 10 percent after December 31, 2016. Adds Stojanovic, “The reason the 30 percent ITC was implemented was to draw private tax equity to the solar power market during a time of extreme economic uncertainty when cash and credit were very tight as a result of the great recession.”

A tax credit reduction will reduce investment in solar power short-term, but long-term growth will most likely continue. “While the ITC is an incentive to get cash off the sidelines for larger projects, it is not the primary market mechanism that drives utility scale solar development. Utility scale solar power development is primarily driven by legislation at the state level to fulfill renewable portfolio standard goals set by the state.”

Stojanovic continues, “Very recently a few developers have been signing long-term PPAs at historically low rates (5-6 cents/kWh). These facts, combined with the necessary scale in the market and the advancements in technology and efficiencies, leads me to believe that by the end of 2016 Solar Power will be competitive without the 30 percent ITC.”

Still, renewables here in the United States seem to have a harder time gaining ground in the market for a variety of reasons. “The greatest challenge for solar power today in the United States is addressing the soft costs (government regulations, local, state and federal). The latest studies illustrate how far behind the U.S. is, compared to other major solar markets in soft costs. Soon soft costs can be as much as 50 percent of the cost of a solar installation if we don’t change the way we do things.”

Stojanovic believes by the end of 2016 rooftop PV will be competitive with retail utility rates in most of the high population density centers in the United States, especially if the issue of soft costs is addressed.

“This means that it has a definite place in our future energy mix. Solar power is a unique source of power that has the ability to allow anyone to



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be energy independent as long as the sun shines in that local geography. It has its own unique set of advantages and limitations. It is generally available everywhere on the globe and very predictable; however its output is variable. The constant drive toward lower costs and higher efficiencies will ensure its place in the energy mix, thus it will allow the efforts on energy storage to continue. The question really goes beyond solar, and really becomes an overall energy resource and delivery planning strategy discussion." **PTE**

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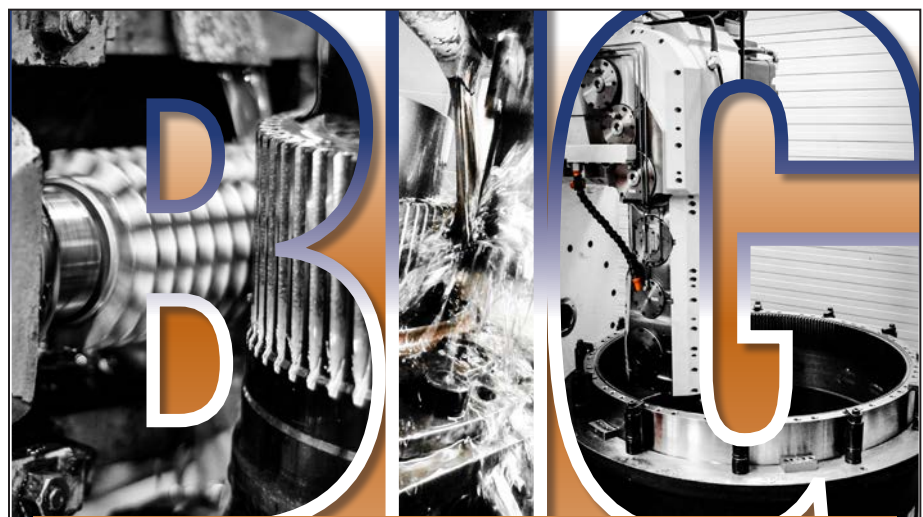
With a promising future for solar power, *Power Transmission Engineering* takes a look at wind, hydro and geothermal developments in 2014.

Wind Energy

American wind energy generation has outpaced the growth in new wind power capacity thanks to innovative technological advancements. Over the past five years, U.S. wind energy capacity grew from 25,000 megawatts (MW) to over 61,000 MW, a 140 percent growth rate, yet electricity generated from these wind turbines grew at a rate of 200 percent, exceeding capacity growth and making wind energy cheaper than ever. Operational improvements have also contributed to increased production. More informed operations and maintenance strategies have led to the highest performance levels ever seen in the U.S. wind industry. The entire wind industry will gather in Las Vegas, Nevada for AWEA Windpower 2014 Conference & Exhibition on May 5-8, to discuss technology improvements and unveil the next fleet of wind turbines.

Hydropower

Linda Church Ciocci, executive director of the National Hydropower Association (NHA) recently made a statement following President Barack Obama's 2015 fiscal budget plan. "Hydropower is the nation's most affordable and reliable renewable electricity resource and NHA applauds President



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Barack Obama's FY 2015 budget proposal for recognizing the crucial role that expanding hydropower will play in the country's diverse energy future," Ciocci said. "The budget continues and improves vital investments in water power research and development. We also applauded the president for his commitment to grow hydropower and other renewable energy generation by recognizing the need to provide long term financial certainty to developers through permanent tax incentives."

Geothermal

Representatives from 24 countries came together with Washington leaders for the GEA International Geothermal Showcase in Washington D.C. in April. The Showcase examined the outlook for the geothermal market and the policies driving geothermal development. The Geothermal Energy Association released the results of its new annual U.S. and International Market Update exclusively to attendees. The event was hosted by the Geothermal Energy Association and made possible by Green level sponsor Power Engineers/Galena Advisors. "This Showcase is an opportunity to bring global geothermal leaders from government and industry together to review accomplishments, expand collaboration and discover new opportunities," said GEA executive director Karl Gawell. "Much of the world is rapidly expanding efforts to harness the Earth's energy and they continue to see America as

world geothermal power leader with strong technological know-how."

Countries represented at the event included the Philippines, Nicaragua, India, Belgium, Germany, Nigeria, Colombia, Fiji, Iceland, Commonwealth of Dominica, Tanzania, Japan, Switzerland, Uganda, Kenya, Taiwan, New Zealand, Ethiopia, Indonesia, Romania, Turkey, Italy, United States and Slovakia. Additional country participation is anticipated. GEA's new U.S.

and International Market Update reported that the international geothermal power market is booming, with nearly 700 geothermal projects under development in 76 countries. And after a recent lull in production, the United States is poised to experience significant growth from new initiatives in Nevada, California and Oregon.



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SUPPLIES STROS WITH DRIVE TECHNOLOGIES FOR INTERNATIONAL PROJECTS

Stros, the largest manufacturer of construction hoists in the Czech Republic, supplies customers all over the world. Three systems ship per week. Eight of the high-rises at “Moscow City,” a major construction project in Russia, are being built or have already been completed with Stros hoists. The hoists reach heights of 300 m or more and have to withstand wind speeds of up to 20 m/s. Safety is therefore fundamental. Stros has been working with Nord Drivesystems as its single-source drive supplier for more than 15 years.

Stros specializes in rack-and-pinion mast-climbing equipment, which allows for extended service heights and can be quickly installed. The gearbox output shaft is fitted with a gear that meshes with a rack attached to the guide mast. This robust drive method withstands extreme environmental conditions over long time periods. Apart from building construction companies, Stros frequently supplies power plants, industrial plants, and offshore facilities. Completed projects include locations beyond the Arctic Circle and in the tough climatic conditions of the tropics. The NOV se-

ries of personnel and material hoists reaches maximum lifting speeds of 100 m/min and load capacities up to 3,200 kg.

Moscow City construction project

The highest hoist to date was erected at the “Moscow City” construction site. The complex consists of several high-rise buildings, eight of which are equipped with Stros hoists. One of the hoists serves the Mercury City Tower, which at 340 m is currently the tallest building in Europe. The NOV 2032 hoist has a 350 m lifting height, a 2-ton load capacity and a 70 m/min rating. With a control panel that allows the operator to select the floor number, the hoist provides the same level of control comfort as a standard elevator in an apartment block. The drive unit consists of three helical bevel geared motors with external braking resistors. “The motors are equipped with electromagnetic disc brakes which can be released by hand,” says Zdenek Coubal, chairman of Stros. “This is a custom solution from Nord Drivesystems. And it exemplifies our cooperation: whatever new challenges we meet, Nord provides consulting and tests and develops a solu-

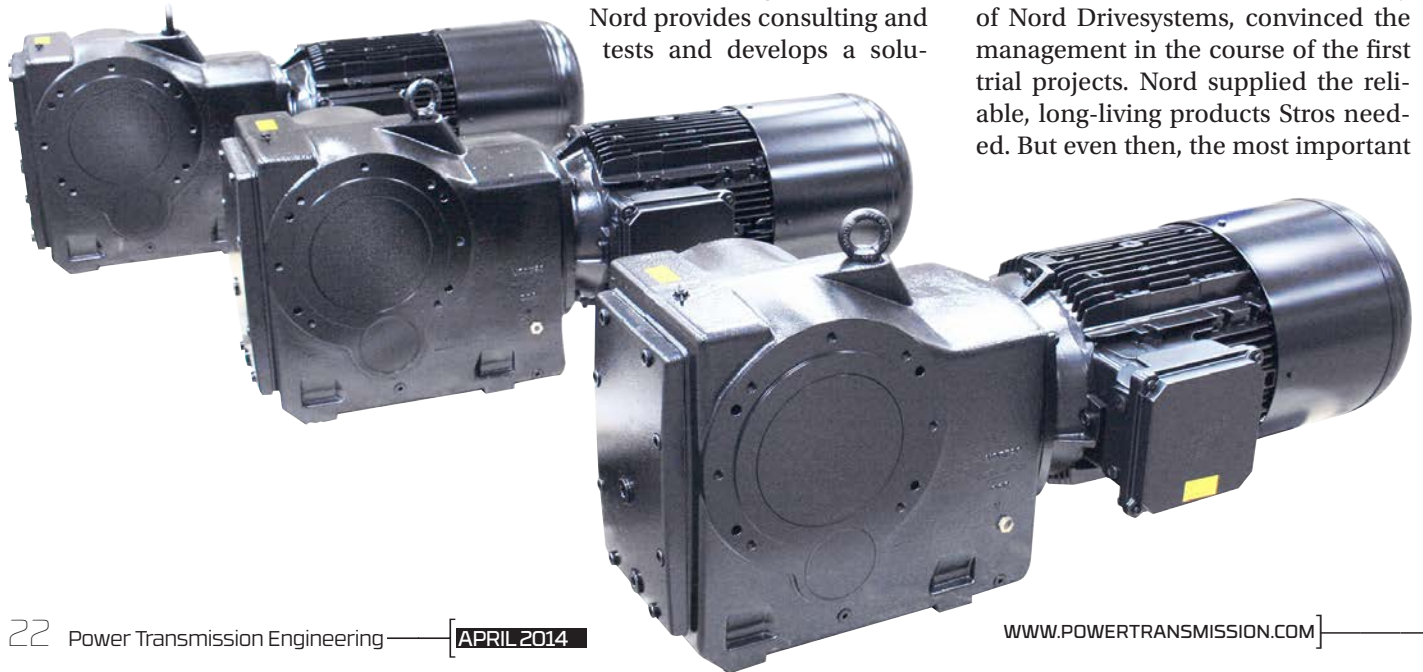
tion.” A control cabinet inverter with hoist function controls all three motors. It enables soft starts and stops and high leveling precision. Coubal says, “We are working very closely with the construction companies. They say that our technology saves time and money.”

Patented safety device

The Stros engineering team has designed a mechanism to safely stop hoist cages in the event of a failure. If the nominal lowering speed is exceeded, the safety device will trip and engage its pinion with the rack to gradually stop the hoist cage. The centrifugal mechanism is individually set for each machine model. The Stros safety device is certified by the internationally recognized German technical testing authority TÜV SÜD.

Cooperation with Nord

The cooperation with Nord as their sole drive supplier began in 1997. At that time, Stros’ predecessor company made the first serious foray into international markets. Nord Poháneckí Technika, s.r.o., the Czech subsidiary of Nord Drivesystems, convinced the management in the course of the first trial projects. Nord supplied the reliable, long-living products Stros needed. But even then, the most important



factor for Stros was Nord's ability to guarantee service even in remote locations. Coubal says, "Nord is very good as a one-stop supplier. They suggest the best solution for any application that crops up in our everyday business. For example, we are not limited to standard gearboxes. The units are assembled exactly to fit the requirements. And Nord customizes drives for us when we need it, supplying reinforced bearings or special gear case materials, or ATEX and NEC-compliant drives for refinery applications."

Higher requirements

Initially, Stros only used geared motors. As the manufacturer built only relatively slow hoists at that time, start and stop control via the motor switch was fully sufficient at speeds up to 40 m/min. But with the growth of the customer list, the projects grew accordingly. Stros started building hoists for higher and higher buildings. Consequently, the cages had to travel faster to decrease waiting times. New models have rated speeds of 55 to 100 m/min

and are always equipped with variable frequency drives. In addition to geared motors, Nord supplies control cabinet inverters that control motor speed and enable precise braking. Sophisticated positioning and safety functions such as STO and SS1 for safety requirements up to SIL3 are also available.

Another diversification: special and permanent elevators

The 2008 collapse of the construction industry severely affected suppliers such as Stros. To survive, the company sought applications for its technology apart from construction hoists and branched into hoists for permanent use on buildings, chimneys, or technological equipment. This new field makes up a large part of Stros projects today. For example, the company built a 150 m high permanent elevator on a chimney at the Siekierki power station in Poland's capital Warsaw. The NOV 514 elevator has a load capacity of 500kg and a rated speed of 46 m/min. The elevator was equipped with a frequency inverter, which ensures soft

starting and braking and includes a POSICON position control. The project was immediately followed by a contract for a second, 200 m high elevator for another chimney at the same plant.

Conclusion

If a hoist does not work, the entire construction site will come to a standstill. Therefore, the drive must never break down under any circumstances. The Nord concept for Stros hoisting equipment with up to three autonomously working drives prevents costly downtimes. Looking back on 15 years with Nord as their sole drive supplier, Stros Chairman Coubal says, "Nord technology is reliable, and the service is excellent." And how is the outlook? "According to the trend in the USA, Canada, and Russia, we can expect more demand for greater-performance drives and inverters due to increasingly larger cages, load capacity, and speed. We have our work cut out for us."

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Portescap

RELEASES MINI MOTOR APP

Portescap has released the *MotionCompass*, a web-based application designed to provide mini motor solutions based on unique motion requirements for various applications. The input parameters (speed and torque) generate motor recommendations across multiple product technologies. A wealth of self-contained data is available on recommended options, including electrical and mechanical specifications, speed vs. torque curves and performance charts. All data is dynamically generated in real-time and provides the ability to select a solution based on specific application needs. Users can choose product(s), review performance metrics and confirm the optimum solution for the application.

A unique feature of the *MotionCompass* is the ability to assign weights to four key performance parameters (speed, efficiency, power and current), which directly impact motor recommendations. The intelligent algorithm, developed based on years of experience and application know-how, recommends a set of ideal motor solutions to maximize application performance.

ETEL

OFFERS CAGELESS, HIGH PEAK TORQUE MOTORS

ETEL is proud to offer cageless and high peak torque motors — called the TML and TMM series — within its line of high performance, zero maintenance motor technologies. Both series provide the advantages of direct drive technology, an ETEL specialty, while being offered in a low weight, low-priced package with diverse and easy to utilize mounting options.

When an application does not require a motor to be in a caged structure, the TML and TMM motors are lighter, lower cost alternatives to ETEL's better known TMB model, yet still provide a direct drive technology option. And mounting is easy with both series as the TML has the lugs located along its outer diameter which provide a simple mounting method contributing to its lower cost. The TMM is even lighter and is designed to be directly glued

Additional motor parameters, such as diameter, bearing type, efficiency and current requirements, feedback options, etc., are available to further narrow down recommended options that meet specific application needs.

“The *MotionCompass* puts the power of product configuration and selection in the hands of the user. Real-time product recommendations based on user inputs provide the ability to evaluate a multitude of options and determine the optimal motor for the application. Users can fine tune application parameters and evaluate performance impact online without ordering samples to test in live application – elimi-

nating the iterative qualification process. Hours of pouring through catalog data has been replaced by minutes of time spent online, with a depth of data not previously available, to enable faster decision making,” says Dave Beckstoffer, project manager at Portescap.

Portescap provides local application support and expertise to assist customers in optimizing motor selection for their applications.

For more information:

Portescap
Phone: (610) 235-5499
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into the machine structure.

The TML/TMM motor series is an ideal solution for any applications that have less demanding continuous torque requirements. Despite this, they are able to provide the same peak torque as the famous TMB range with up to 5,000 N-m and reach speeds of up to 2,100 rpm. The TML/TMM both come in multiple standard sizes which vary in diameter, length and power, and each model offers different types of coil winding providing more performance variations.

The TML/TMM motors are design specifically for direct drive applications which offer the following advantages over transmission-based

devices including fewer parts requiring lower overall costs, stable performance all along machine lifetime due to zero maintenance required on the motors, no backlash, allowing for better accuracy and repeatability, smooth, precise, and efficient motions and compact design.

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NEMA

PUBLISHES MOTORS AND GENERATORS STANDARDS

The National Electrical Manufacturers Association (NEMA) published three standards in its MG series: NEMA MG 2-2014 Safety Standard for Construction and Guide for Selection, Installation and Use of Electric Motors and Generators; NEMA MG 3-1974 (R1995, R2000, R2006, R2012) Sound Level Prediction for Installed Rotating Electrical Machines; and NEMA MG 10-2013 Energy Management Guide for Selection and Use of Fixed Frequency Medium AC Squirrel-Cage Poly-phase Induction Motors.

NEMA MG 2-2014 gives recommendations for the selection, installation, and use of rotating electric machines as it applies to the practical safeguarding of persons and property. It may be downloaded at no cost or purchased in hardcopy for \$91 on the NEMA website.

NEMA MG 3-1974 (R1995, R2000, R2006, R2012) delivers a method

for estimating sound pressure levels of installed rotating electrical machines. It may be downloaded at no cost or purchased in hardcopy for \$54 on the NEMA website.



National Electrical Manufacturers Association

NEMA MG 10-2013 conveys practical information concerning proper selection and application of polyphase induction and synchronous motors, including installation, operation, and maintenance. It may be downloaded at no cost or purchased in hardcopy for \$77 on the NEMA website.

For more information:

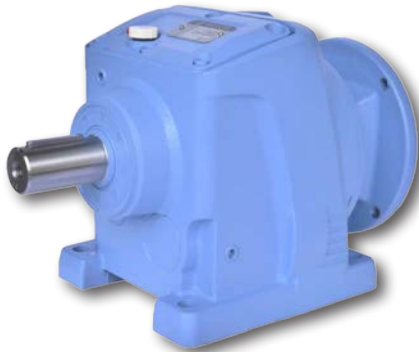
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oil (flooded in hydraulic oil). The power rating depends on the surrounding medium and amounts to 220W in air and, due to the much higher heat flow, 480W in oil. They are designed for ambient temperatures of more than 200°C and atmospheric pressures of up to 1700 bar. The Ø32mm motors must also be able to withstand vibrations of up to 25 G_{rms} as well as impacts of up to 1,000G (1,000 times the acceleration due to gravity at the earth's surface). As an example, a Formula 1 vehicle is exposed to approximately 2G and fighter jets are exposed to approximately 13G. The motors feature high efficiency (up to 89% in air, more than 80% in oil), making them ideal for use in battery-operated applications. With their detent-free running properties, they have excellent control character-

istics and are suitable for high-precision positioning tasks in outer space, even at low speeds.

The EC-4pole 32 HD is ideal for use in environments with extreme temperatures, subject to high vibration, or under ultra-high vacuum. This means the motors can also be used in aerospace applications, e.g. for gas turbine starters, for the generators of jet engines, for regulating combustion engines, or for exploration robots. For the use of the motor in conjunction with a gearhead, maxon offers the GP 32 HD, a powerful and robust planetary gearhead.



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REDUCES LEAD TIMES WITH GENERATION II SIMOTICS 1FK7 SERVOMOTOR

In response to increased market needs and always seeking to exceed customer expectations, Siemens Industry, Inc. announces a further reduction in lead times for Generation II of its Simotics 1FK7 servomotors. Highly-configurable to suit a wide variety of applications, this popular line features seven shaft heights, Quick-Connect power connectors and high-accuracy 20- and 24-bit field replaceable encoders in 10 styles, all combined with a three-week lead time, that began January 1, 2014. This new Siemens service applies to all motor models in the line, when ordered without gearbox.

The 1FK7 Generation II servomotors offer three inertia versions — standard, high-dynamic for rapid acceleration jobs and high-in-

ertia for maximum smooth running. These motors are designed for operation without external cooling, and the heat is dissipated through the motor surface. With 10 styles of field-replaceable encoders, the 1FK7 Generation II servomotors provide easy maintenance in the field, with reduced downtime and operating cost savings. A 10 percent improvement in continuous (S-1) power is achieved, since the encoders are mechanically and thermally decoupled from the mo-

tor. The mechanical decoupling also means the encoder is more resistant to vibration conditions on the machine. In addition, there is no need for battery back-up on the absolute encoders.

Further, these 1FK7 Generation II servomotors provide users with 3x overload, 2.5 percent torque ripple, cross profiling for easier mounting, Siemens Drive-Clq interface for easier field commissioning and unit recognition with the Siemens Sinamics S120 drive family, plain shaft or keyway design, three IP ratings and are supplied with or without holding brake. The full application engineering assistance and service of the global Siemens network supports this new line of servomotors.

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Train to Maintain

Industrial Maintenance Another Lost Art?

By Jack McGuinn, Senior Editor

“Job skills gap.” We’ve all heard about it. But what exactly is it? The respected NFP American Society for Training & Development (ASTD) defines a skills gap as “A significant gap between an organization’s current capabilities and the skills it needs to achieve its goals. It is the point at which an organization can no longer grow or remain competitive, because it cannot fill critical jobs with employees who have the right knowledge, skills, and abilities.”

Fair enough. But we might wish to consider a corollary to that condition and its definition when the topic is industrial maintenance, and that would be a *will* gap. A gap in the will to *train*, and a gap in the will to *be* trained. At least that remains the general and arguably correct perception of the state of U.S. industrial maintenance today—whether it’s a growing, yet unmet need for technicians inspecting the local hydro-electric power plant down the road or checking the fail-safe mechanisms for the nuclear control rods at the nuclear facility out in the bay.

Now, un-closed gaps like that can get a little scary.

But, hope lives. And, more importantly, people are out there working to make hope happen. That would be those who fill the administrative and training roles in the schools that exist around the country for the kind of maintenance training that is dearly needed—almost to the point of it being considered a matter of public safety and national security in some extreme but real cases (see above).

This is an issue with a dual demographic. On one hand is the group of, say, eager, 40+ “displaced” i.e.—canned workers. On the other, we have kids just out of high school with no college plans—for them “the halls of ivy” might as well be the name of an 80s hair band. The dilemma is getting trained those who desperately want to be trained (40+), and luring in

those who should be at least *considering* it as a career path (kids).

How challenges like that are being met and much more were asked of: Micah Statler, technical training program manager for Advanced Technology Services (ATS); Lisa Goetsch, director of workforce development & continuing studies, Kent State University at Trumbull; and Steve Straub, dean of Fox Valley Technical College’s (FVTC) manufacturing and agricultural divisions.

One of the first issues addressed was the aging workforce—not the aging workforce looking to retire; the older but still capable workers looking to hold on to a decent quality of life. So we asked: In this economy, are you seeing older applicants?

“We do see several older applicants in the field of maintenance in general, says Micah Statler of ATS. “With regard to jobs, recovering from the recession has kept more workers in the market longer. Particularly, we see many applicants from the Michigan region who were affected both by the recession hitting their retirement funds as well as early displacement from jobs around the auto industry.

“With respect to training, the older workforce is having to adapt from the requirements of single trade expertise to that of multi-skilled, which is now more prominent—both due to staffing efficiencies and heavy integration in more modern automation.”

At Kent State, located in the bedrock manufacturing state of Ohio, Lisa Goetsch sees it a bit differently.

“Not necessarily an increase,” she says. “We have always served a large number and percentage of older students. These adults are either (a) seeking skills to advance their careers within the maintenance field, or (b) seeking skills to *enter* the maintenance field (whether they are currently working or are unemployed).”

At FVTC they are taking the get-‘em-while-they’re-young long view—an approach that many who have closely followed the subject are in full agreement—including Steve Straub.

“Innovative partnerships with K-12 systems are front-and-center when it comes to changing the way our society looks at the value of higher education. The new economy calls for skill; it is no



FVTC trainers closely assess students’ development in order to gage their ideal skillset based upon knowledge, preference and life experiences (photo courtesy FVTC).

longer as dependent on four-year degrees, for the most part.”

Youth must be served, however. But are they stepping up to the table? (This reminds of the saying, paraphrased):

“Those who refuse to step up to the table, run the risk of ending up *on* the table.”

“Not only do we expect (an increase), but it is happening regularly,” says Straub. “As the older workforce has retired, there is a vacuum in those available to back-fill; this is the ‘skilled labor shortage.’” Unfortunately, it’s not just the lack of apprenticeship programs that is a leading contributor, but the relative lack of primary education in the fields of electrical, mechanical, and fluid power theory and practice. We are seeing an influx of younger (workers) in the maintenance arena.

“This younger generation may have the aptitude, but (also) lack the formal training, at fundamental levels, to begin to grasp the concepts and integration of today’s modern factory equipment.”

Kent State’s Goetsch — aware of the serious ramifications of continuing to ignore this — is all about making high-skill training opportunities available to these kids — but they have to want it.

“Yes—we would love to see more young people considering skilled trades such as industrial maintenance and taking classes,” she says. “This is a national problem! In our region (NE Ohio) we have been working to increase awareness of manufacturing careers and opportunities to increase the number of youth enrolling in training programs. This includes bringing high school educators and guidance counselors to manufacturing facilities, having manufacturing workers speak to high school students about opportunities, and much more.

“We have been working with companies throughout the U.S. who are facing this issue. Employers are beginning to recognize that they need to be an active partner in solving the problem. They can no longer sit back and wait for the education system to produce the quantity and quality of workers that they need. What employers are doing (or should be doing) to make an impact is: working collaboratively with education partners (high schools, techni-

cal schools, community colleges, and universities); sharing information with educators such as hiring requirements, job descriptions and skill requirements; hiring forecasts and levels of demand for occupations, etc.; and partnering with educators (providing internships and other hands-on learning opportunities for students, referring students to training/education programs, interviewing/hiring program graduates, do-

nating equipment/resources, speaking to classes/students, etc).

And while Fox Valley’s Straub reports that the average age of his applicants has dropped, he’s puzzled that the actual class numbers aren’t higher.

“We should be attracting more young people because of the great employment outlook for people with these skills, and the rewards involved in this type of work.”



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Then of course there's the old "be careful what you wish for warning." With basic manual skill sets—hammer a nail; change a tire; saw a piece of wood—of the young at perhaps its nadir—being in the industrial maintenance training business must have its challenges. Add to that finding and keeping quality instructors—and trying to get through to the minds of probably the most distracted generation since the invention of television. According to a study by the Pew Research Center, 87% of teachers in the study—performed in conjunction with the College Board and the National Writing Project—said digital technology is creating an "easily distracted generation with short attention spans." And 64% of teachers (from middle and high schools) say today's digital technologies "do more to distract students than to help them academically."

"It has been quite difficult to address this challenge, which is more than providing technical knowledge and know-how," Statler of ATS allows. "We have been plagued culturally with educational institutions that have painted the factory portrait as a destination for delinquents, behavioral or learning impaired individuals; as evident by the general population in any remaining high-school shop classes. To this respect, we find that many who enter the factory work force, while potentially

competent, may also lack the fundamental skills of mathematics, general physical sciences, communications, and basic reading and interpretation skills. This makes it difficult to train individuals where these fundamental understandings are an implied given of primary education. Those others that do have the fundamentals, and even some secondary education, carry a stigma of being above the core skills (electrical, mechanical, and fluid power), and are often placed in work environments and training situations that are beyond their current skill-levels. To this we answer with assessments that focus on providing a "30,000-foot-view" of fundamental and core skills. This provides us with the opportunity to address the areas of needed improvement so that the student and the company get the greatest return of investment: immediate and sustained skills application."

Finding and retaining skilled, dedicated instructors is another longstanding problem. It is really no different than job shops looking for good machine operators.

"From a core training perspective, we look to those who are known subject matter experts," says Statler. "Most often, these are seasoned maintenance professionals that have climbed the ladder to or above the maintenance specialist level or reliability engineer.

We have a great relationship with retiring professionals, who out of respect to the trade want to help us overcome the skilled labor shortage. These individuals have the knowledge and skill to pass along, but also the freedom to remain semi-retired.

"Internally, through train-the-trainer programs, we identify strengths in the same manner that we identify opportunity for assessment-based improvement. For the highly skilled, the ability to train is an additional part of their career path."

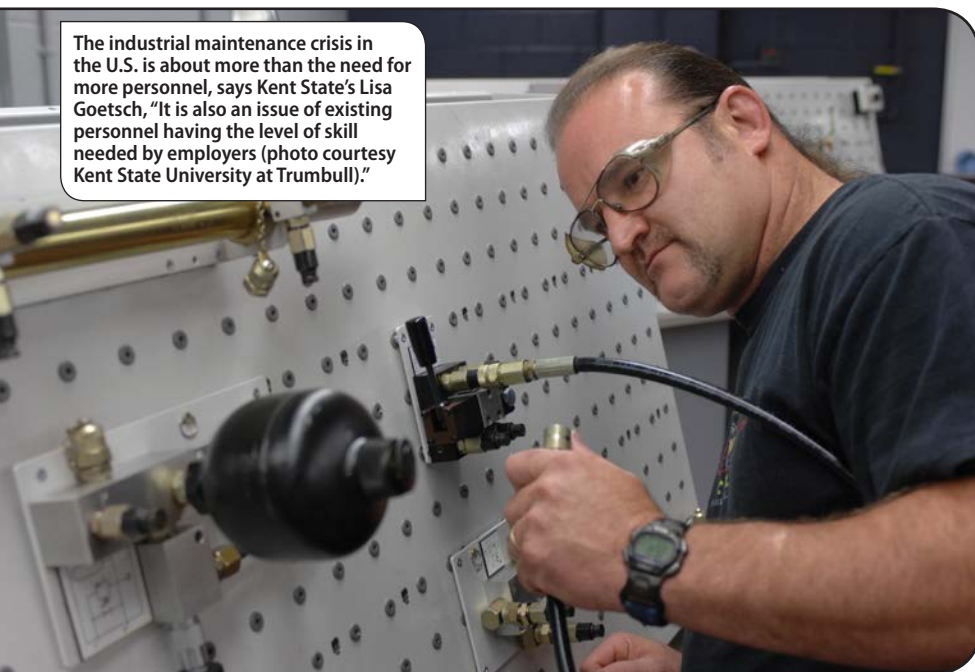
"Yes, (recruiting trainers) can be a challenge," says Goetsch. "Retirees and/or individuals seeking a second career away from the plant floor provide a great pool of candidates. We also utilize working employees for evening or Saturday training. And we partner with a variety of professional associations and other training providers to best utilize available resources."

"We recruit instructors from industry," says FVTC's Straub. "We need instructors who have recent experience in the field in which they teach. Indeed it is sometimes difficult to find people with the technical expertise required along with an aptitude and desire to be a good teacher."

"Industrial maintenance" certainly covers a lot of territory—requiring differing levels of training and education. With virtually no previous exposure to these skillsets, how do young students decide on which area to pursue?

"We focus internally on providing multi-skilled technicians on the factory floor, but the breadth of expertise required to specialize in all fields is insurmountable," Straub concedes. "Through our assessments we are able to identify areas of strength as well as areas for improvement. We view a technician's development much like a college would a major and minor. Assessment will tell a manager or trainer clearly where an individual technician's skillset is, based on knowledge, preference and life experiences. What we strive to do is provide these technicians with development that enhances their strengths and minimizes their weakness to at least a point of competence in the core theories and application of skill. This strategy has proven to

The industrial maintenance crisis in the U.S. is about more than the need for more personnel, says Kent State's Lisa Goetsch, "It is also an issue of existing personnel having the level of skill needed by employers (photo courtesy Kent State University at Trumbull)."



be beneficial in the troubleshooting of complexly integrated and automated equipment and fosters the teamwork that is often required in troubleshooting, ensuring that everyone is able to speak the same fundamental language.”

“Employers use a variety of titles for maintenance mechanics, but predominantly they are considered maintenance technicians as they are required to have strong technical skills,” says Goetsch. “There are typically three classifications of maintenance technicians: 1) Maintenance Technician Mechanical (MTM); 2) Maintenance Technician Electrical (MTE); and 3) Maintenance Technician Multi-Crafted (MTMC) (both electrical and mechanical). That being said, there are also “specialty” areas that students might pursue—for example, welding or ironworker. But these occupations are more dependent on regional employment trends and over the last 10+ years, most manufacturers have moved away from “specialties”—maintenance technicians must have a broad range of skills. For industrial maintenance there are really only two primary choices: mechanical and electrical. When advising students (young or old), we focus on the region and types of positions available, the level of demand for the jobs, the hiring requirements, what background/strengths they may have, and their goals/interests.”

For those incoming students having already done their “homework,” Straub simplifies it to, “The primary areas are electrical and mechanical maintenance. The choice is usually based on interest of the student. Aptitude and interest often are directly correlated.”

Two hot areas in industrial maintenance these days are predictive maintenance and condition monitoring. They are both relatively new, and some schools are probably scrambling for funds and instructors to teach them.

“Predictive maintenance is included in our training,” says Goetsch. “As noted previously, most students—including those currently working in maintenance—do not have the level of “basic” skills needed. We need to start with a strong foundation and work up to predictive skills. For example, you

need to understand hydraulic components; how they work; how they are impacted by other components and drive systems; how to troubleshoot problems; fix the problems; determine what is causing the problem; preventing the problem from recurring; THEN apply predictive maintenance techniques and measures to control the process and eliminate problems from recurring. Most employers would like their maintenance technicians to be involved with predictive maintenance,

but typically it is being done by plant engineers and/or highly skilled maintenance supervisors.”

Finally, given that there indeed exists an industrial maintenance crisis in the country, we asked each of our participants which area of the industry they felt to be most in need.

“There is a need for people who are well versed in industrial control technology, such as Programmable Logic Controllers,” says Straub. “People with this skill are needed to design, build, trou-



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bleshoot, and repair automated manufacturing systems. Most manufacturing in the U.S. is highly automated, and the trend will continue in that direction.”

Says Statler, “Often this question is answered with a ‘can’t see the forest for the trees’ explanation of whatever technology is being employed at a given facility – Robotics, CNC, Laser Technology, PLC Programming, etc. However, I am greatly of the opinion that the leading areas for improvement are in the mathematics and physical sciences. Math and Science provide all of the tools for troubleshooting technological problems. There is a deficiency in these fundamental skills, yielding a deficiency in troubleshooting and problem solving, which cannot be overcome from a systems oriented training. The common rebuttal to this predisposition is that the military does a great job of providing technical experts with regard to each piece of equipment and process that is available. This is true, yet the military can control the configuration, programs and processes of each type of equipment and develop SOPs and troubleshooting flow charts dedicated to the units. In a factory environment, there is no standardization, a century’s worth of equipment iterations, and each piece of equipment is performing its own specific process.”

“It is not just an issue of ‘more’ maintenance personnel, it is also an issue of existing personnel having the level of skill needed by employers,” says Kent State’s Goetsch. “Even when manufacturers are fully staffed with maintenance technicians, they face a number of problems. This includes longer equipment downtimes due to limited troubleshooting skills, decreased production and profitability due to downtime, limited or lack of preventive or predictive maintenance – resulting in ongoing breakdowns/problems, hiring of outside contractors to handle specialty fixes/problems, inefficient use of engineers and/or supervisors time handling maintenance tasks, etc. The critical skill gaps that are hindering manufacturers appear to be related to (a) root cause analysis and effective troubleshooting, and (b) advanced technology skills in electronics/PLCs.” **PTE**

Furthermore...

As the less-than-full-employment condition continues to fester right along with the ongoing skills gap dilemma, bad news continues.

According to a still relevant 2012 McKinsey Global Institute report, “The World at Work: Jobs, Pay, and Skills for 3.5 Billion People,” predicts a potential global shortage of 38 to 40 million high-skills workers in 2020 (13 percent of the demand for such workers) and 45 million middle-skills workers (15 percent of the demand).

But the report also includes mention of an idea long on promise but, to date, short on execution. It speaks of a coast-to-coast information “pipeline” to keep all involved and interested parties apprised of the latest employment news, needs, and developments:

“While both targeted training and education are necessary for closing the nation’s skills gaps, these efforts have minimal long-term impact when treated as isolated events. It is incumbent upon the entire pipeline to identify job openings and skills needs and work together to meet these deficiencies.

“The mid-skills gap in Middle America identifies four essential stakeholders critical to informing, funding, advocating for, and building successful public-private partnerships to enhance the skills pipeline: 1) Government (via policy decisions,

agencies and flexible mandates); 2) private sector businesses and industry associations, educational and training institutions; 3) (K-12 and two- and four-year colleges); and 4), non-profit intermediaries (Source: 2012 McKinsey Global Institute; ASTD).

What matters most is that everyone pulls from the same end of the rope.

Critical Workforce Development for U.S. Manufacturers

The Manufacturing Extension Partnership (MEP), within the National Institute of Standards and

Technology (NIST) and housed within the United States Department of Commerce, is tasked with helping small and medium-sized manufacturers — those with fewer than 500 employees — understand how investments in workforce development pay off and how to implement corporate training that helps them become successful high-tech innovators.

With support and encouragement from the highest levels of the U.S. Administration, MEP supports and encourages innovation and growth for small manufacturers, and collaborates with many partners, such as other U.S. federal agencies, community and technical colleges, manufacturing collaborations, and professional associations (2012 McKinsey Global Institute; ASTD).

For more information:

Micah Statler
Technical Training Program Manager
Advanced Technology Services
8201 N. University
Peoria, IL 61615
Phone: (309) 693-4000
Fax: (309) 693-4164
info@AdvancedTech.com

Chris Jossart
Manager of Media Relations
Fox Valley Technical College
P.O. Box 2277
Appleton, WI 54912
Phone: (920) 735-5738
Mobile: (920) 574-1161

Lisa Goetsch
Director, Workforce Development & Continuing Studies
Kent State University at Trumbull
4314 Mahoning Avenue NW
Warren, OH 44483
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Working in AutoCAD

THE QUESTION

How does one draw and mesh involute gear teeth in AutoCAD?

Expert response provided by Jamie Pears, head of project management for Romax Technology Ltd.

Involute gears are the most commonly used types of gears and are those in which the gear tooth profiles are **involute**s of a circle.

When two involute gear teeth mesh, they always have a single point of contact and, as the gears rotate, the point of contact moves along a straight line. This straight line is tangent to the **base diameters** of the two gears. Additionally, the direction of the force generated between the contacting teeth is in the direction of this straight line, which is known as the **line of action** of the gear pair.

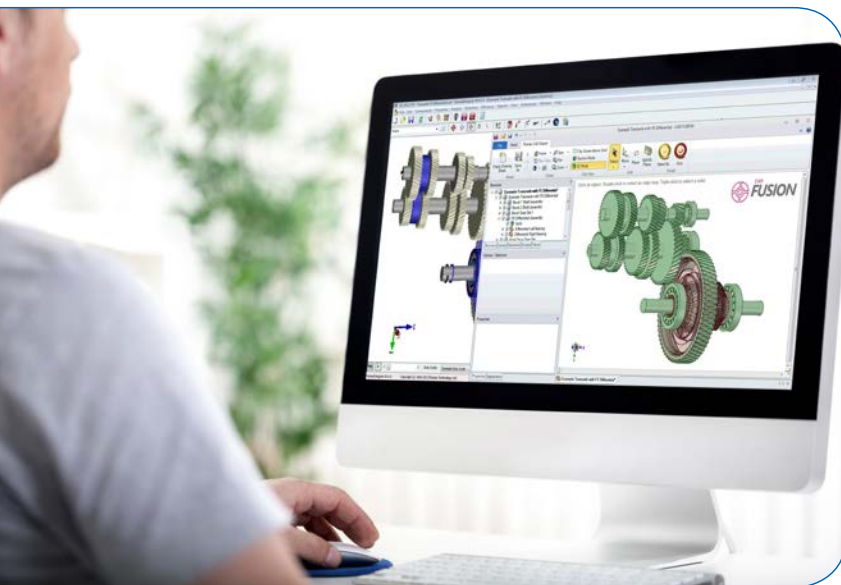
An involute profile is most commonly illustrated by the unwrapping of a string from a solid cylinder — the path that the end of the string traces is the **involute profile**, and the diameter of the cylinder is the **gear base diameter**. Using simple trigonometry, the generated curve can be calculated to be defined with a parametric equation, with the x and y coordinates being a function of a common parameter.

There are many videos on the internet that illustrate this process; simply Google “AutoCAD involute gears.”)

While the reader’s question is quite a basic one, it highlights an issue that designers have when creating accurate CAD models of 3-D meshing gears — especially bevel and hypoid gear sets.

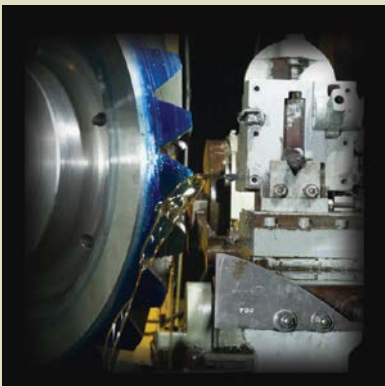
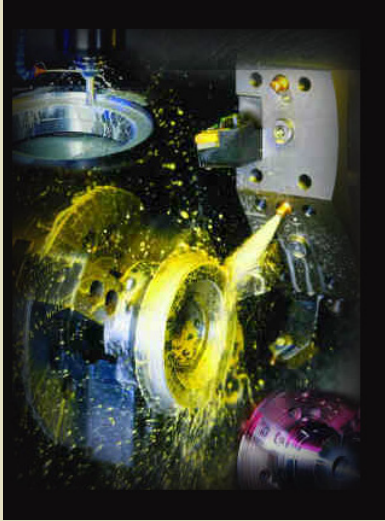
The ability to automatically create 3-D models of gear sets from the analysis tools used to design them is therefore of great benefit and Romax Software tools are one example of where this is possible. In a matter of minutes, detailed models of meshing gears can be exported from a Romax analysis model and then easily be incorporated into a 3-D CAD model, therefore saving designers many hours of modelling. It is this line of thinking that also led Romax to create a new whole gearbox design tool aimed specifically at powertrain architects and designers. Launched last year, *Concept* not only allows designers to quickly design, rate and optimize gears, but also entire gearbox concepts, before being able to seamlessly share data with CAD systems.

Dr. Jamie Pears is the head of product management at Romax Technology. He holds MSc and Ph.D. degrees in physics from Nottingham University, U.K. Pears joined Romax Technology in 2000 as a software developer working on the *RomaxDESIGNER* analysis code developing the *RomaxNVH* software. Since then he has been involved in engineering projects as the NVH Team Leader, providing consultancy for many worldwide customers. Pears is now back, beginning with development as R&D manager, and currently as software team manager. For more information, please visit www.romaxtech.com.



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Gear Lubrication: Long-Term Protection for Wind Turbines

Steve Mazzola, Michael Hochmann and Julian Wald

The chemical and physical properties of gear oils may change, depending — more or less — upon their formulation and the environmental conditions under which they are used.

This is why — after three years of use in a wind turbine — a gear oil was examined to determine if indeed changes were evident and if the protection of the gears and rolling bearings still met the same requirements as would be expected of fresh oil. Our findings revealed that the existing gear oil — as well as its ability to protect the gears and rolling bearings — had degraded very little compared to fresh oil.

Introduction

An oil condition analysis (OCA) was performed to find out if the chemical and physical properties of the used oil were still within acceptable limits. For this purpose, its viscosity, oxidation, and the water and element contents of the additives and impurities respectively were measured. Ideally, oil condition analyses should be performed at certain intervals to determine a trend with regard to oil aging. The changes of chemical and physical oil properties can serve to estimate the appropriate moment for an oil change based on empirically established figures. However, the question whether gear oils maintain their ability to protect gears and rolling bearings in a gear unit over a longer period of time remains unanswered.

The gear oils of today are expected to protect gears and rolling bearings against damage such as wear or micropitting even under critical lubrication conditions and during the entire oil change interval. Gear oils are normally tested in standardized mechanic-dynamic test procedures using fresh oil. In contrast to this, a high-performance gear oil was tested after three years of use to find out if chemical or physical changes were evident and if the protection of gears and rolling bearings would still be as high as with fresh oil.

Typical Gear Failures

Figure 1 shows typical limits of the load-carrying capacity for case-hardened gears according to Niemann (Ref. 12). In the range of slow and medium circumferential speeds, the micropitting risk is increased, compared to very low circumferential speeds where the risk of slow-speed wear prevails. Tooth fracture is not influenced by the lubricant.

Micropitting failure of gears. Micropitting is a type of fatigue failure occurring on hardened tooth flanks of highly loaded gears (Ref. 12). This failure consists of very small cracks and pores on the surface of tooth flanks. Micropitting looks grayish and causes material loss and a change in the profile form of the tooth flanks, which can lead to pitting and breakdown of the gears. A typical micropitting gear failure is shown (Fig. 2). In this case, misalignment was the reason for micropitting formation.

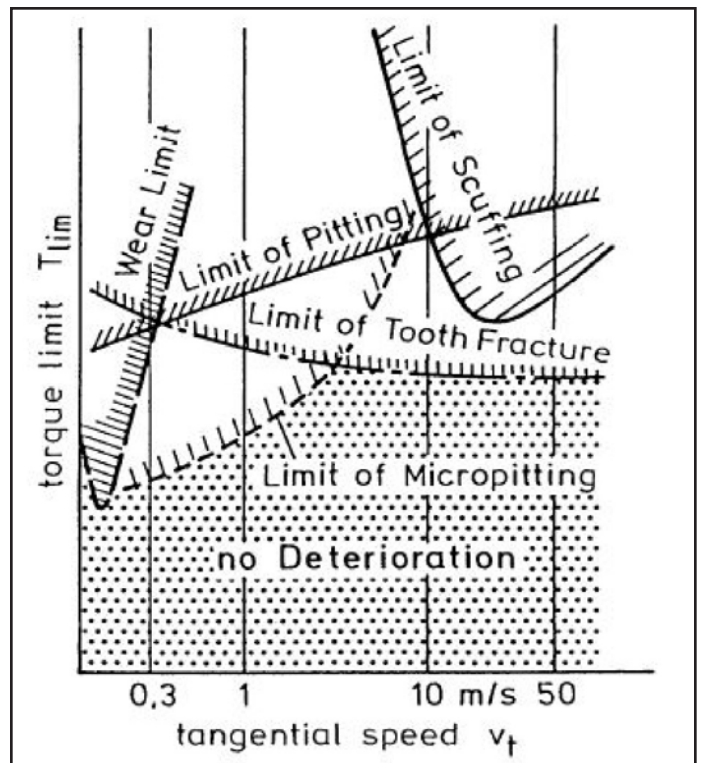


Figure 1 Typical limits of load-carrying capacity for case-hardened gears.

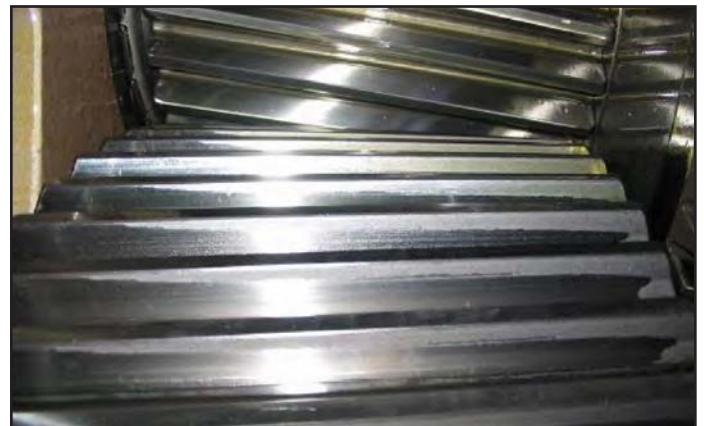


Figure 2 Example: micropitting gear failure.

The formation of micropitting depends on different influences; besides material, surface roughness and geometry of the tooth flanks, it is the lubricant and the operating conditions that have a major influence on micropitting formation.

In modern gearboxes, the gears are often highly loaded and run under conditions of mixed lubrication. In such cases the tooth flanks of the mating gears are not fully separated by the lubricant film, and the additives of the lubricant have to protect the tooth flanks against micropitting formation.

Scuffing failure of gears. Scuffing occurs at failure of the surface protection at excessive temperatures in the tooth contact (Ref. 11). With this failure the tooth flanks of pinion and wheel weld locally and are torn apart immediately. The tooth flanks are partially destroyed, which could result in breakdown of the gears. A typical scuffing failure on the tooth flanks of a gear is shown in Figure 3.

The scuffing load-carrying capacity depends on different influences; particularly high sliding, vibrations and non-optimized flank surfaces — low manufacturing quality or missing running-in, for example — increase risk of scuffing (Ref. 3). In addition, lubricant and operating conditions have a major influence on scuffing.

Wear failure of gears. Wear is an abrasive material removal occurring on the tooth flanks of gears. This failure proceeds continuously, causing material loss and a change in the profile form of the tooth flanks, thus leading to breakdown of the gears. Typical wear on the tooth flanks of a gear is shown (Fig. 4).

What's more, the wear behavior depends on different influences. Besides the surface hardness, material, and geometry of the tooth flanks, it is again the lubricant and the operating conditions which have a major influence on wear behavior.

Failures of rolling bearings. Gear damage is also often caused by high rolling bearing wear or premature fatigue of rolling bearings (Ref. 15). Failures based on material or production mistakes are very seldom. However, type, condition, and quantity of lubricant have a major influence on bearing failure, as well as hard or liquid contaminations (Ref. 14; Fig. 5).

The additives contained in gear oils may have a decisive effect on rolling bearing damage.

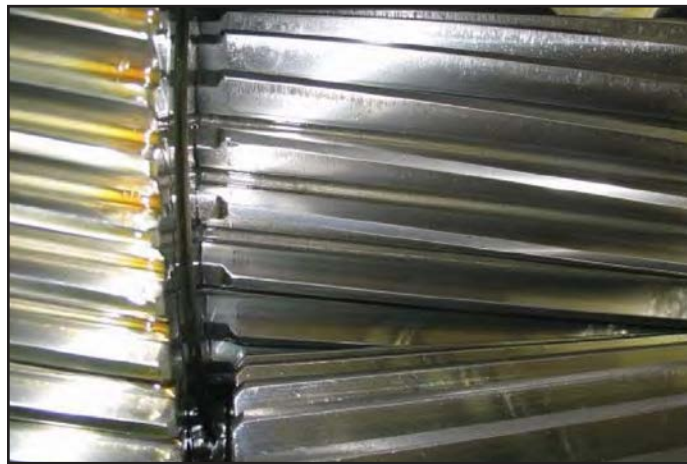


Figure 3 Example: scuffing gear failure.

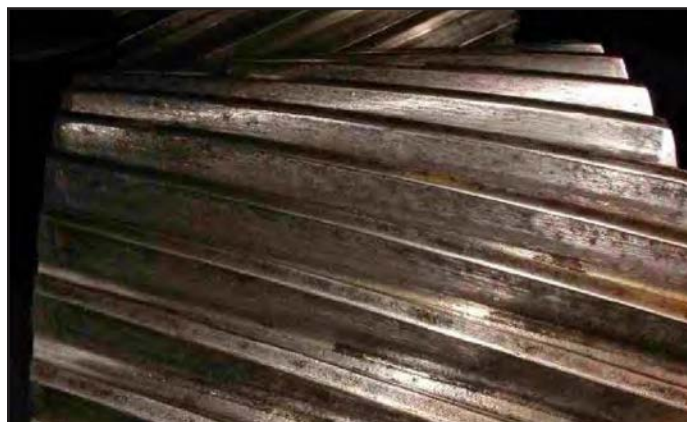


Figure 4 Example: wear gear failure.



Figure 5 Example: typical rolling bearing failures.

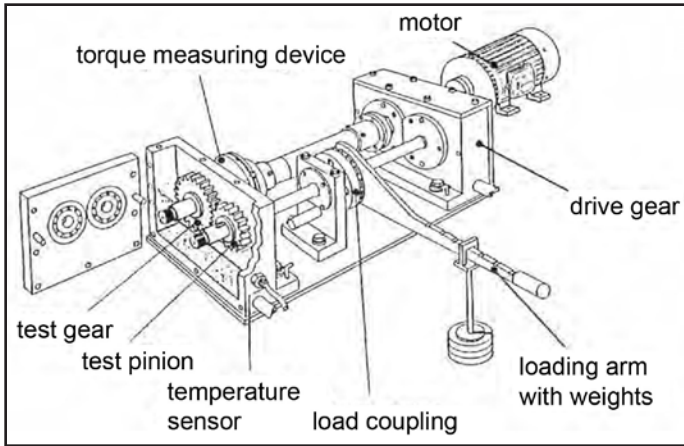


Figure 6 FZG back-to-back gear test rig.

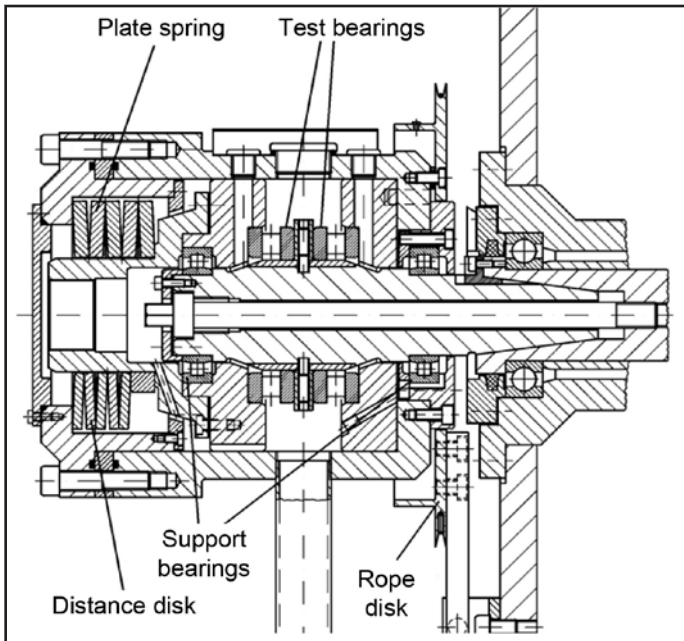


Figure 7 FE8 bearing test rig.

Test Equipment

Investigation of micropitting load-carrying capacity and wear behavior of gears. The test runs conducted to determine the micropitting load-carrying capacity and the wear behavior of gear oils on gears were performed on a FZG back-to-back gear test rig (Ref. 7; Fig. 6).

The FZG back-to-back gear test rig utilizes a recirculating power loop principle — also known as a four-square configuration — in order to provide a fixed torque (load) to a pair of test gears. The test gearbox and drive gearbox are connected with two torsion shafts. One shaft is divided into two parts and contains a load coupling used to apply the torque (load) through the use of weights hung on the loading arm. Heating and cooling elements are used to control the oil temperature, as required by the operating test conditions.

In order to investigate the micropitting load-carrying capacity, test gears type C-GF of the standard micropitting test, according to FVA 54/7 (Ref. 10), are used. The slow-speed wear behavior is investigated by using test gears type C-PT, according to DGMK 377-01 (Ref. 2). The geometric data and manufacturing details of the test gears type C-GF and type C-PT are given in FVA 54/7 and FVA 2/IV.

Investigation of the wear behavior of rolling bearings. The test runs conducted to determine the wear behavior of gear oils on rolling bearings were performed on an FE8 bearing test rig (Ref. 5) required for lubricating oils CLP, according to DIN 51517-3 (Ref. 4; Fig. 7). The wear behavior of rolling bearings according to DIN 51819-3 (Ref. 5) is investigated with test bearings type-D (81212, according to DIN 722).

Investigation of the foam behavior of gear oils. The foam behavior of gear oils is determined on the foam test apparatus, according to ISO 12152 (Ref. 6) developed by Flender. The test apparatus (Fig. 8, Ref. 9) comprises a sealed gear unit housing to receive the gear oil sample to be tested. A pair of

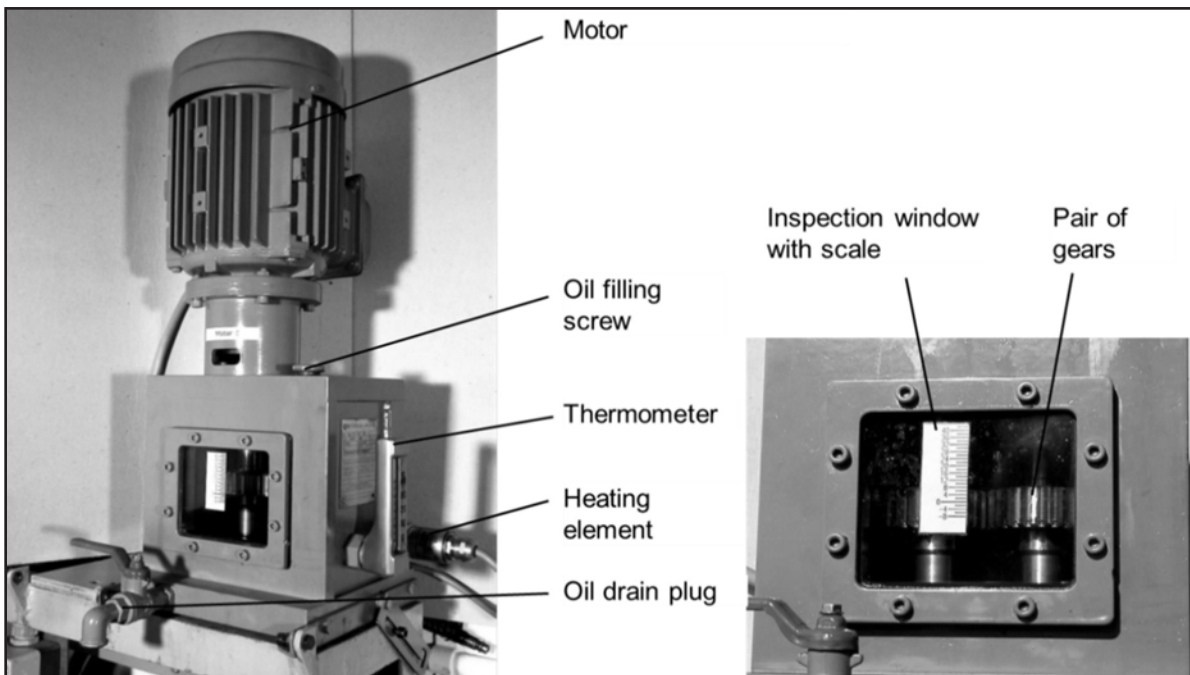


Figure 8 Foam test apparatus.

test gears is mounted on two vertically arranged shafts in order to mix 1.0 liter of the gear oil with air and generate foam.

Test Procedures

To determine the performance capacities of gear oils with regard to the prevention of micropitting and wear, they are today subjected to standardized tests under critical lubricating conditions and temperatures that are commonly encountered in practice. The micropitting resistance in gears is analyzed on the FZG micropitting test according to FVA 54/7 (Ref. 10) at an oil temperature of $\vartheta_{oil}=90^{\circ}\text{C}$. Meanwhile, it has become increasingly common to conduct micropitting tests also at a reduced oil temperature of $\vartheta_{oil}=60^{\circ}\text{C}$ in order to determine if micropitting can be reliably prevented at these lower temperatures, which are encountered, for example, in wind turbine gearboxes. The standard scuffing test according to ISO 14635-1 (Ref. 7) is conducted at a circumferential speed of $v_t=8.3\text{m/s}$. In order to intensify the requirements of a gear oil, the scuffing load-carrying capacity is tested at an increased circumferential speed of $v_t=16.6\text{m/s}$. The slow-speed wear behavior of gears is analyzed in the FZG wear test according to DGMK 377-01 (Ref. 2) at oil temperatures of $\vartheta_{oil}=90^{\circ}\text{C}$ and 120°C . The influence of temperature is thus taken into account — albeit on a rather high level. The wear behavior of rolling bearings is examined in the FE8 wear test according to DIN 51819-3 (Ref. 5) at an oil temperature of $\vartheta_{oil}=80^{\circ}\text{C}$. The foam behavior is analyzed according to the foam test of ISO 12152 (Ref. 6).

FZG micropitting test (GF-C/8.3/90 or GF-C/8.3/60). The micropitting test GF-C/8.3/90 or GF-C/8.3/60 according to FVA 54/7 consists of a load stage test and an endurance test performed on a FZG back-to-back gear test rig (Ref. 7). Test gears type C-GF run at a circumferential speed of $v_t=8.3\text{m/s}$ and an oil temperature of $\vartheta_{oil}=90^{\circ}\text{C}$ or 60°C . The load and the test periods are varied.

In the load stage test, the load is increased stepwise from load stage LS5 to load stage LS10, with a running time of 16 h per load stage. After the load stage test, an endurance test with a running time of 80 h in load stage LS8 and 5×80 h in load stage LS10 is performed. The pinion torque and the corresponding Hertzian pressure of the different load stages are given in Table 1. In load stage LS10, the test gears are highly loaded; the endurance limit of the material is about $\sigma_{Hlim}=1,400\text{N/mm}^2$.

At the end of the load stage test and the endurance test with the first test

gears, the load stage test is repeated with new test gears to check repeatability.

After each test period, the test gears are disassembled and the profile of the tested flanks is measured using a 3-D measurement system.

In the load stage test, the failure criterion has been reached once the mean profile form deviation due to micropitting exceeds the limiting value of $7.5\text{ }\mu\text{m}$. The load stage in which the failure criterion is reached is called “failure load stage.” An overview regarding the classification of test results obtained in the micropitting test is given in Table 2.

Lubricants with a high micropitting load-carrying capacity reach the failure criterion of a profile form deviation of $7.5\text{ }\mu\text{m}$ due to micropitting in load stage $\geq\text{LS }10$ of the load stage test (GFT-high) (Figs. 9, 10).

Table 1 Load stages of the micropitting test

Load stage	Pinion torque, T1, Nm	Hertzian pressure, pc, N/mm2
LS5	70.0	795.1
LS6	98.9	945.1
LS7	132.5	1093.9
LS8	171.6	1244.9
LS9	215.6	1395.4
LS10	265.1	1547.3

Table 2 Classification of test results of the micropitting test

Description	Failure load stage	Micropitted area	GF-class
Low micropitting load-carrying capacity	$\leq\text{LS }7$	Sometimes more than 50%	GFT – low
Medium micropitting load-carrying capacity	LS8 – LS9	About 30%	GFT – medium
High micropitting load-carrying capacity	$\geq\text{LS }10$	Less than 20%	GFT – high

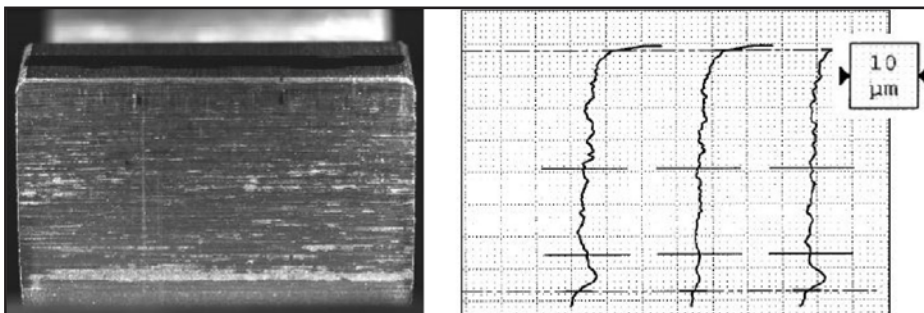


Figure 9 Pinion type C-GF; with measurement of the profile, nearly no micropitting failure.

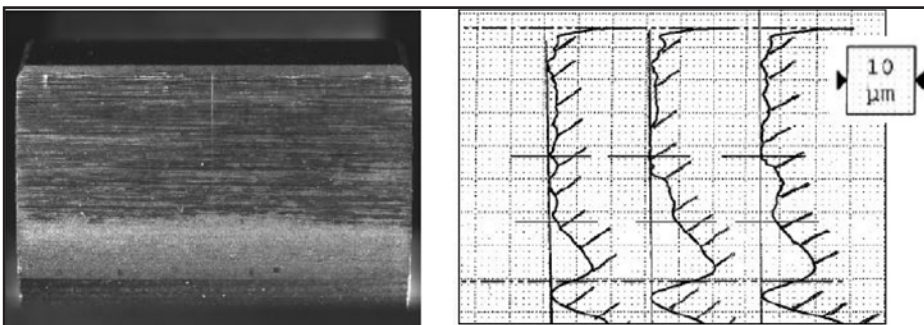


Figure 10 Pinion type C-GF; with measurement of the profile; micropitting failure in the range of the failure criterion.

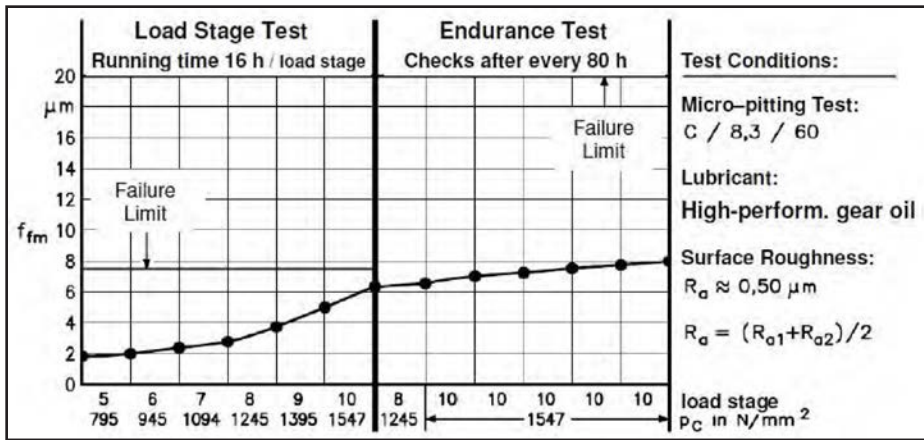


Figure 11 Micropitting test of a high-performance gear oil; measurement of the profile form deviation.

In the endurance test, a stagnation of micropitting formation compared with the micropitting area at the end of the load stage test is preferred but not required. For high-performance gear oil with a high micropitting performance, a test result is given (Fig. 11) showing the profile form deviation due to micropitting. The profile form deviation of the pinion is below the failure criterion for the whole load stage test (GFT-high). In the endurance test, the profile form deviation stagnates compared with the step test.

FZG scuffing test (A/16.6/90). The scuffing test A/16.6/90 according to ISO

14635-1 is performed on a FZG back-to-back gear test rig. The test gear type A runs at an increased circumferential speed of $v_t = 16.6 m/s$ and an oil start temperature of $\vartheta_{oil} = 90^\circ C$. Per stage the test lasts approximately 7.5 min due to a revolution of $n = 21,700 min^{-1}$ (Ref. 7). The load is increased stepwise from load stage LS1 to load stage LS12, and additionally up to LS14. The pinion torque and the Hertzian pressure of the different load stages are given (Table 3). In load stage LS12, or even LS14, the test gears are highly loaded. After each test stage the test gears are disassembled and the surface of the tested flanks is analyzed.

The test is completed when a scuffing failure occurs or the whole range runs without any failure. The failure criterion is reached if the sum of all gear failures on the pinion flanks (width of all scuffing and scoring marks) exceeds 20 mm. The load stage in which the failure criterion is reached is called failure load stage (Fig. 12).

FZG slow-speed wear test (C/0.05:0.57/90:120/12). The results of the FZG slow-speed test according to DGMK 377-01 (Ref. 2) can be used for relative ranking of gear oils to a reference oil and, in addition, specific wear rates c_{IT} can be derived for inclusion in the wear calculation method developed by Plewe (Ref. 13).

The FZG slow-speed wear test C/0.05:0.57/90:120/12 according to DGMK 377-01 determines the wear characteristics of gear oils at two different temperatures under mixed and boundary lubrication conditions (Ref. 2). With an additional test part, the influence of circumferential speed can be investigated.

Test gears type C-PT run at a very low circumferential speed of $v_t = 0.05 m/s$. The load applied is load stage LS12,

Load stage	Pinion torque, T_I, Nm	Hertzian pressure, $p_c, N/mm^2$
LS1	3.3	146
LS2	13.7	295
LS3	35.3	474
LS4	60.8	621
LS5	94.1	773
LS6	135.5	929
LS7	183.4	1080
LS8	239.3	1223
LS9	302.0	1386
LS10	372.6	1539
LS11	450.1	1691
LS12	534.5	1841
LS13	626.9	1996
LS14	714.2	2130

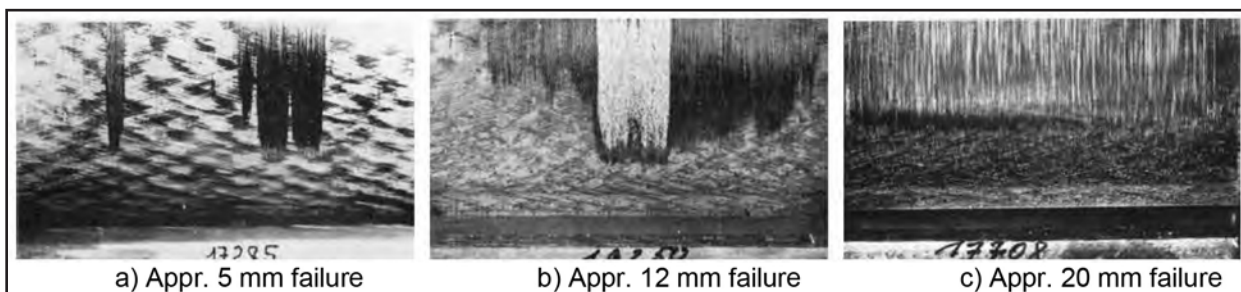


Figure 12 Scuffing failures on tooth flanks.

which is equivalent to a pinion torque of $T_1 = 378.2 \text{ N}\cdot\text{m}$. This corresponds to a Hertzian pressure of $p_c = 1,853 \text{ N}/\text{mm}^2$ in the gear contact. The oil temperature is $\vartheta_{oil} = 90^\circ\text{C}$ during test part 1 of 2×20 hours and $\vartheta_{oil} = 120^\circ\text{C}$ during test part 2 of 2×20 hours. In the optional test part 3 of 1×40 hours a higher circumferential speed of $v_t = 0.57 \text{ m}/\text{s}$ is run at an oil temperature of $\vartheta_{oil} = 90^\circ\text{C}$.

The test is run on a modified FZG back-to-back gear test rig according to ISO 14635-1 (Ref. 7) using an additional reducer gearbox after the drive motor in order to run very low speeds. After each test interval the pinion and the wheel are disassembled and weighed separately. The classification of the results of the FZG slow-speed wear test is shown (Table 4).

For high-performance gear oil, a test result of the FZG slow speed wear test is given (Fig. 13) showing a very low wear behavior. The sum wear of pinion plus wheel is below the failure criterion of 40 mg (wear category low) — not only for the individual test part of 40 h but also for the whole test procedure of 120 h.

FE8 wear test (D 7.5/80-80). The influence of gear oils on the wear behavior of rolling bearings is examined in the FE8 wear test D 7.5/80-80 according to DIN 51819-3 (Ref. 5) using the FE8 bearing test rig. In this test, axial cylinder roller bearings type D are subjected to a speed of $n = 7.5 \text{ min}^{-1}$ with an axial force of $F_a = 80 \text{ kN}$ at a steady-state temperature of 80°C over a period of 80 h. With a $C/P < 2$, a very high load is applied. Wear is then determined gravimetrically. Gear oils in the FE8 wear test according to DIN 51819-3 have to show a roller wear of $\leq 30 \text{ mg}$ according to DIN 51517-3 (Ref. 4); only the cage wear must be reported (Table 5).

Foam test. The foam behavior of gear oils is examined in the foam test according to ISO 12152 (Ref. 6). At the beginning of the test the oil temperature is at $\vartheta_{oil} = 25^\circ\text{C}$. The gears rotate with a speed of $n = 1,450 \text{ rpm}$ for 5 min. After this the observation of the foam behavior lasts 90 min. Figure 14 shows the inspection window with a scale. The mark 0 on the scale corresponds with a volume of 1.0 liter. This is also the required volume of the gear oil which has to be filled in. The total volume increase and the oil and air dispersion could be read from the scale.

The classification of the foam behavior of fresh gear oils is shown in Table 6 according to the Flender report GG-V 425 (Ref. 8). If the total percentage volume increases above 15%, the gear oil is not recommended for use in gear units, as this negatively affects the load capacity of the teeth. Additionally, the percentage volume increase of the oil and air dispersion must be lower than 10% (Ref. 9).

For used gear oils, OEMs of wind turbines typically require that a total volume increase of the foam does not exceed 20%.

Table 4 Classification of test results of the slow speed wear test

Wear category	Sum wear per test part, mg
low	< 40
medium	< 170
high	< 400
very high	> 400

Table 5 Limits for the test results of the FE8 wear test

Description	Failure limit, mg
Roller wear	≤ 30

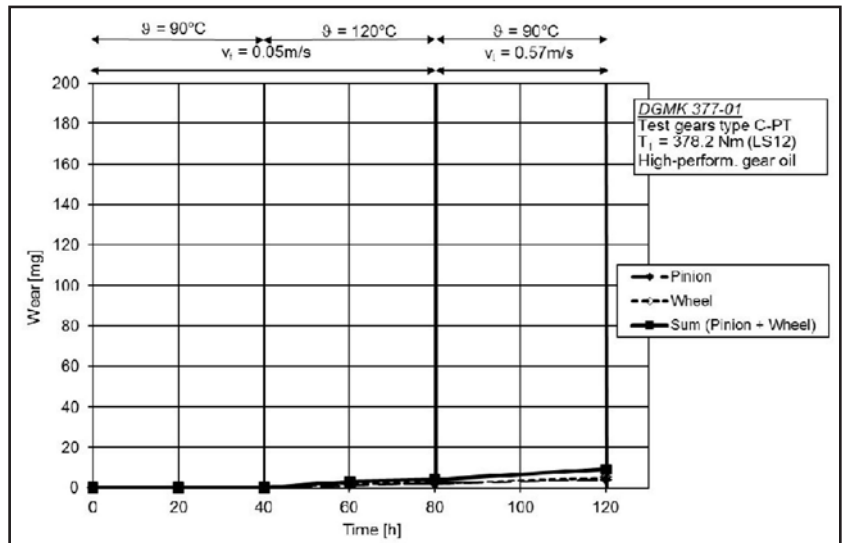


Figure 13 Slow-speed wear test of a high-performance gear oil.

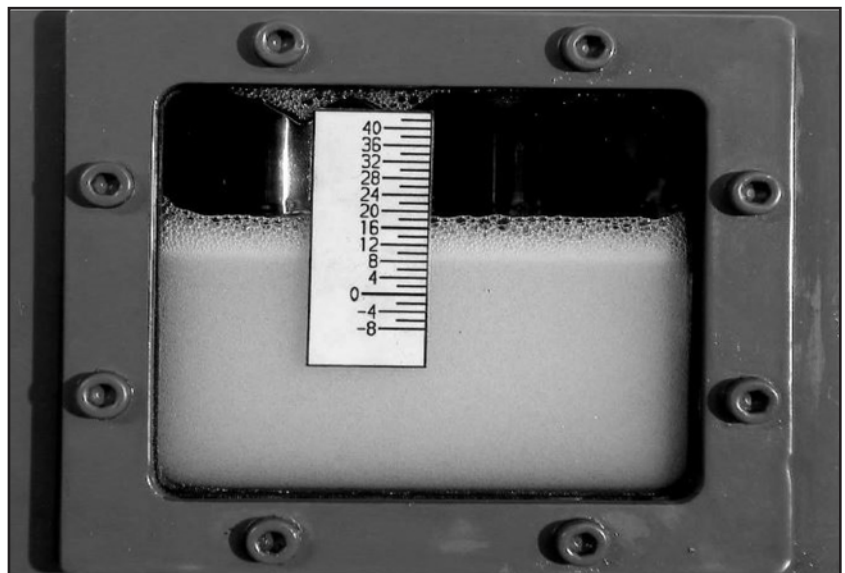


Figure 14 Foam measure scale of the foam test according to ISO 12152.

Table 6 Classification of foam behavior for fresh gear oils

Evaluation foam behavior	Total volume increase	Oil and air dispersion
good	up to 5%	up to 4%
satisfactory	up to 10%	up to 7%
still permissible	up to 15%	up to 10%
excessive	over 15%	over 10%

Tested Lubricant

The tested high-performance gear oil is on the basis of polyalphaolefin showing high wear protection, high scuffing resistance as well as a high micropitting load-carrying capacity. It shows a very low wear behavior of gears determined in the

FZG slow-speed wear test according to DGMK 377-01 (Ref. 2) at oil temperatures of 90°C and 120°C. The scuffing, load-carrying capacity tested in the FZG test rig according to ISO 14635-1 (Ref. 7) at a circumferential speed of $v_t = 16.6$ m/s is very high. The micropitting load-carrying capacity tested in the FZG micropitting test according to FVA 54/7 (Ref. 10) at an oil temperature of 60°C is high as well. The wear behavior of rolling bearings examined in the FE8 wear test according to DIN 51819-3 (Ref. 5) at an oil temperature of 80°C is also very low.

The tested gear oil is of ISO VG 320 and is a specified CLP gear oil according to DIN 51517-3 (Ref. 4), which includes the minimum requirements for industrial gear oils and is similar to ANSI/AGMA 9005-E02 (Ref. 1).

The oil data of the tested gear oil is shown in Table 7.

High-performance gear oils based on polyalphaolefin are typically used in wind turbines today. Klübersynth GEM 4-320 N is one such gear oil and in fact was used for three years in the field and in these investigations. The application was a 750kW GE wind turbine in Spain. During operation the gearbox was filtered with an in-line filtration system (50µm) and an off-line system (5µm). The performance of the oil was constantly monitored and at the time of oil change, the chemical and physical properties of the used oil were analyzed. To show that the oil maintains its ability to protect gears and rolling bearings reliably over the entire duration of use, the mechanic-dynamic tests described above were performed.

Test Program

To find out if the high-performance gear oils of today are able to reliably protect gears and rolling bearings in gearboxes against damage also

Product	Klübersynth GEM 4-320 N
Symbol	GEM 4-320 N
ISO VG	320
Base oil	Polyalphaolefin
DIN 51517, ANSI/AGMA 9005-E02 designation	CLP HC, EP oil
FZG micropitting test acc. to FVA 54/7 $\theta_{oil} = 60^\circ\text{C}$	GFT-high
FZG scuffing test acc. to ISO 14635-1 $\theta_{oil} = 90^\circ\text{C}$	\geq LS 14
FZG slow speed wear test acc. to DGMK 377-01 $\theta_{oil} = 90^\circ\text{C}$ and 120°C	\leq 20 mg
FE8 wear test acc. to DIN 51819-3 $\theta_{oil} = 80^\circ\text{C}$	\leq 10 mg
Foam test according to ISO 12152 (total volume increase)	< 10%

Test procedure	GEM 4-320 N (fresh)	GEM 4-320 N (used)
Oil condition analysis	X	X
FZG micropitting test acc. to FVA 54/7 $\theta_{oil} = 60^\circ\text{C}$	X	X
FZG scuffing test acc. to ISO 14635-1 $\theta_{oil} = 90^\circ\text{C}$	X	X
FZG slow speed wear test acc. to DGMK 377-01 $\theta_{oil} = 90^\circ\text{C}$ and 120°C	X	X
FE8 wear test acc. to DIN 51819-3 $\theta_{oil} = 80^\circ\text{C}$	X	X
Foam test acc. to ISO 12152	X	X

Criterion	Limits		Results
	GEM 4-320 N (fresh)	GEM 4-320 N (used)	GEM 4-320 N (used)
Water content in %	< 0.3	< 0.3	0.005
Viscosity at 40°C, mm ² /s	268 ... 352	256 ... 384	322
Viscosity at 100°C, mm ² /s	32 ... 40	29 ... 43	37
Cleanliness	--	--	18/16/12
Elements			
Sulfur (% deviation from fresh oil)	90 ... 110	80 ... 120	113
Phosphor (% deviation from fresh oil)	90 ... 110	80 ... 120	95
Iron, ppm	< 10	Depending on	< 10
Copper, ppm	< 10	application	< 10
Infrared spectroscopy	no deviation	no deviation	corresponds without any deviation

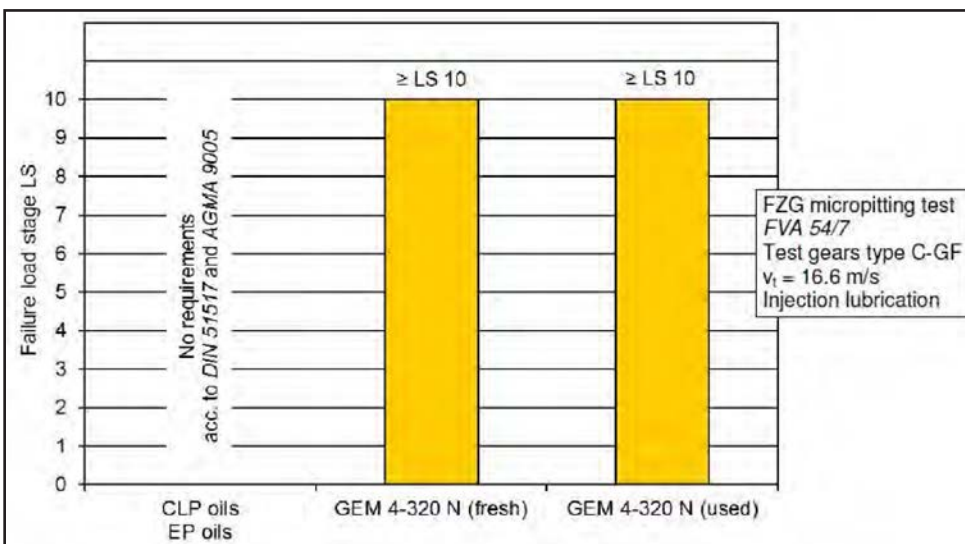


Figure 15 Micropitting of gears can be prevented by using a high-performance gear oil.

in long-term use, the standardized test methods mentioned in Clause 4 had to be considered for used oil tests. Table 8 shows the tests for fresh oil as well as for used oil.

Today's high-performance gear oils show chemical and physical changes which are under 20%—even after long-term use. Regarding the protection of the tooth flanks and bearings, the load carrying capacity should be nearly unchanged.

During use, the foam behavior could be affected negatively through contamination and filtration.

Regarding the used gear oils, OEMs of wind turbines typically require a test result of at most 20% in the foam test according to ISO 12152.

Test Results

The aim of this research is to determine whether a gear oil that was used for three years in a wind turbine can protect gears and bearings like a fresh gear oil. The test results show that the chemical and physical properties of the high-performance gear oil have changed very little compared to the fresh oil (Table 9).

For the high-performance gear oil based on polyalphaolefin, an FZG micropitting test at an oil temperature of $\vartheta_{oil}=60^{\circ}\text{C}$ was performed showing a high micropitting load-carrying capacity for the fresh oil. Additionally, the FZG micropitting test with used oil reached a high micropitting load-carrying capacity of GFT-high. This shows that the additives can prevent micropitting at the surface of the tooth flanks after three years of use. Fig.15.

For the high-performance gear oil based on polyalphaolefin, an FZG scuffing test at an oil temperature of $\vartheta_{oil}=90^{\circ}\text{C}$ and a circumferential speed of $v_t=16.6\text{m/s}$ was performed showing a high scuffing load-carrying capacity of ≥ 14 for the fresh oil. The FZG scuffing tests with the used oil reached the same scuffing load-carrying capacity and shows that even the gear oil after three years in use provides the same scuffing protection compared to fresh oil. See Figure 16.

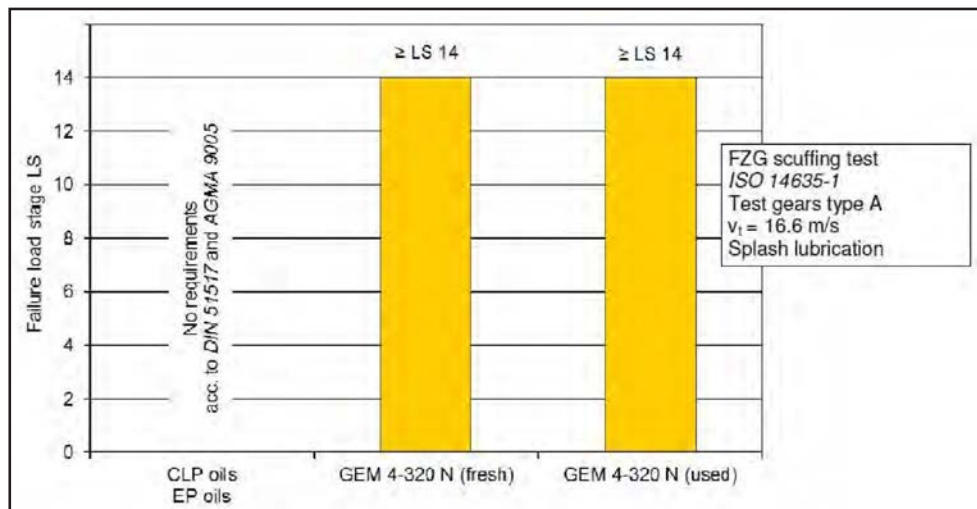


Figure 16 Scuffing load-carrying capacity for gears by using a high-performance gear oil.

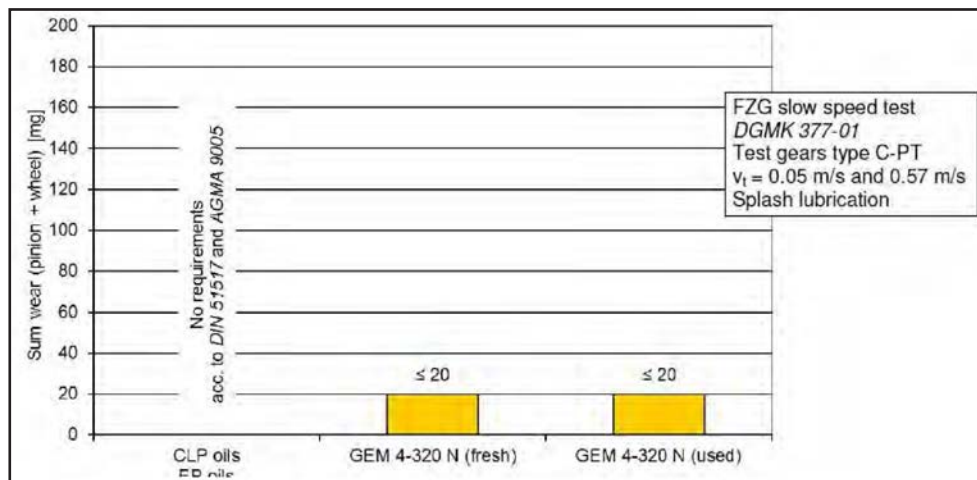


Figure 17 Gain wear protection for gears by using a high-performance gear oil.

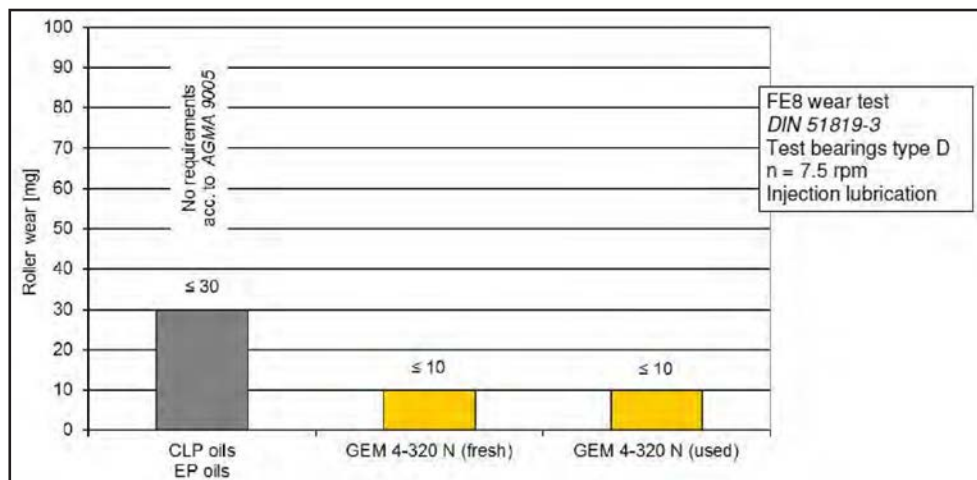


Figure 18 Gain wear protection for rolling bearings using a high-performance gear oil.

Both the fresh and the used high-performance gear oil based on polyalphaolefin show very low wear behavior with a sum wear on pinion plus wheel of less than 20 mg at the oil temperatures of $\vartheta_{oil} = 90^{\circ}\text{C}$ and 120°C of the FZG slow speed wear test. This shows that the advanced oil technologies can prevent wear after three years of use. See Figure 17.

The FE8 wear test shows that the tested high-performance gear oil based on polyalphaolefin provides an optimum wear protection at the oil temperature of $\vartheta_{oil} = 80^{\circ}\text{C}$. After three years in use the gear oil offers the same wear protection compared to the fresh oil. See Figure 18.

A foam test according to ISO 12152 was also performed for the high-performance gear oil. The results show that the total volume increase for fresh oil is $\leq 15\%$ and for used gear oil $\leq 20\%$. This shows that the gear oil perform the required foam behavior by OEMs of wind turbines after three years of use (Fig. 19).

Conclusions

The gear oils of today are expected to protect gears and rolling bearings against damage such as wear or micropitting—even under critical lubrication conditions and during the entire oil change interval. Gear oils are normally tested in standardized mechanic-dynamic tests using fresh oil. However, the chemical and physical properties of gear oil in use may change more or less depending on its formulation and the operating conditions.

The test results show that the chemical and physical properties of the investigated high-performance gear oil have changed very little compared to the fresh oil after three years of use in a wind turbine.

Also by the end of the oil change interval, the oil provides full micropitting and wear resistance as well as a good anti-foam performance.

In conclusion, it could be shown that high-performance gear oil can offer its full performance spectrum and protection of gears and rolling bearings over the entire duration of use. **PTE**

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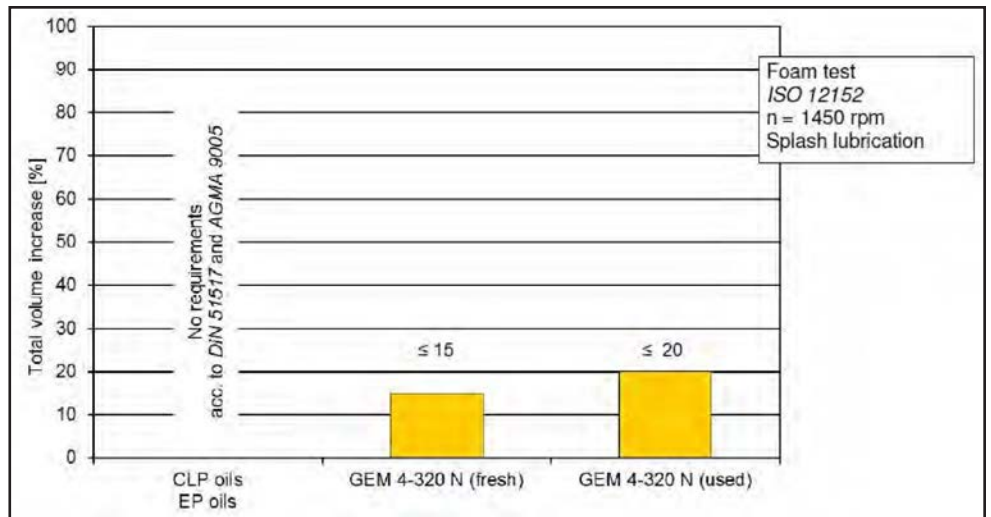


Figure 19 Much longer life with high-performance gear oil.

of Industrial Gear Oils Using a Spur Gear Test Rig/ Flender Foam Test Procedure.

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Steve Mazzola is director of engineering and technical services for Klüber Lubrication North America, in New Hampshire. He has a Bachelor's degree in mechanical engineering and has experience as a manufacturing engineer at Raytheon Corporation's equipment division in Massachusetts, as well as an applications engineer at the Gates Rubber Company in Colorado. His several years at Gates involved power transmission belt drive systems as well as hydraulic systems. Since joining Klüber 18 years ago, Mazzola has been providing technical expertise in tribology and lubrication and is currently an active member of the AGMA Gear Lubrication Committee.

Dr. Michael Hochmann studied mechanical engineering at the Technical University Munich (TUM), where he earned his doctorate. He is employed at the Research Center for Gears (FZG) in the marketing and application engineering department with a focus on gear oils.

Julian Wald completed his industrial engineering degree at Baden-Wuerttemberg Cooperative State University, and is studying for his masters at the University of Applied Sciences, Munich. His concentration of study includes marketing and application engineering, focusing on gear oils.



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The Step Motor

Dan Jones

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Step motors come in many sizes and shapes. But they all share one item in common—each step motor type moves in discrete-degree steps. They react to a series of voltage pulses supplied by their basic controller, known as an “indexer.” The step motor was the first to accept digital pulses, then move or rotate a prescribed amount without any feedback device. All step motors are position devices without the need to use any feedback devices. They operate primarily in an open-loop control scheme.

VR Step Motor

The first appearance of a step motor was in the mid-1920s. It was the variable reluctance (VR) type used in the British Navy as a direction indicator for guns and torpedoes. Figure 1 details six rotor teeth and eight stator teeth. It uses a magnetic attraction process when the windings are energized sequentially A-B-C-D in a simple counter-clockwise direction. The rotor teeth rotate in a clockwise direction by being drawn magnetically to the aligned position. Each voltage pulse move or step is 15 mechanical degrees. The VR step was the most popular step motor in the 1960s and 1970s, as many office equipment machines and numerical controls turned to computer control; it was largely replaced by other step motor types in the 1980s.

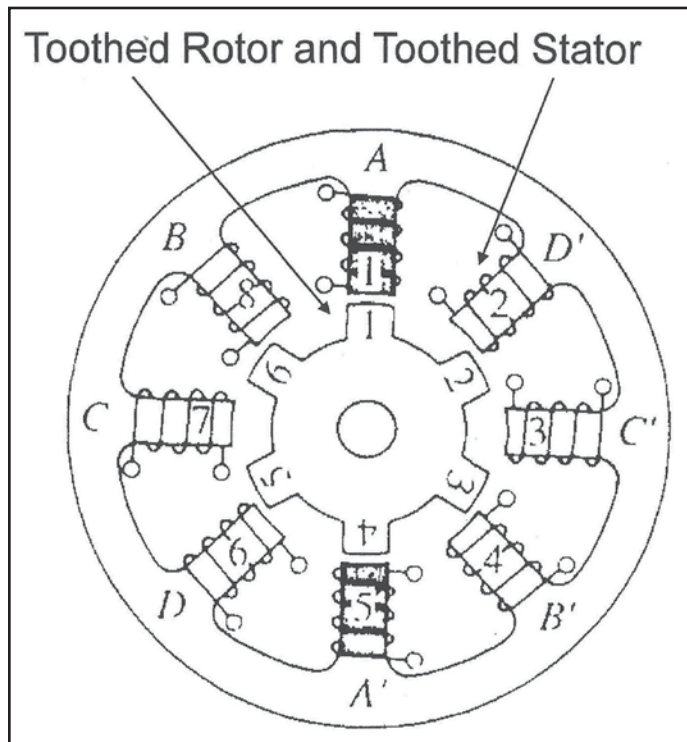


Figure 1 A detail showing six rotor teeth and eight stator teeth of a step motor, which uses a magnetic attraction process when the windings are energized sequentially — A, B, C, D—in a simple, counterclockwise direction.

PM Step Motor

The next step motor to appear was the 4-pole PM step motor that used Alnico magnets. It appeared during World War II and was used as a 4-position switch in military cockpit and other instrumentation packages. It was a 2-phase step motor with four 90° steps-per-revolution. Figure 2 shows the 2-pole rotor magnet and four stator teeth—each with a copper winding and an operating excitation sequence of A-B-A¹-B¹. Its large step angle motion limited its use to very specialized applications. There are some military and space applications that use this motor type with a rare earth rotor magnet.

Can-Stack Step Motor

The availability of the “new” ferrite magnets in the early 1960s led to the development of the can-stack step motor. It combines an inexpensive magnet with multiple poles rotating within two-stator simple toroidal coils surrounded by

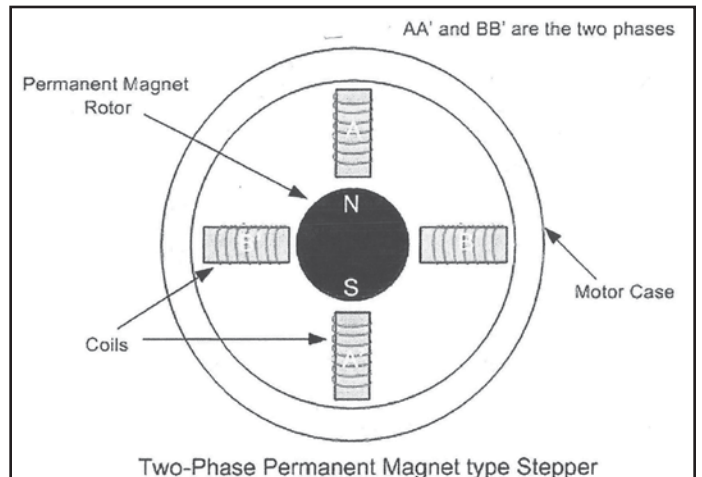


Figure 2 A two-pole rotor magnet and four stator teeth—each with a copper winding and an operating excitation sequence of A, B, A¹, B¹. There are some military and space applications that use this motor type with a rare earth rotor magnet.

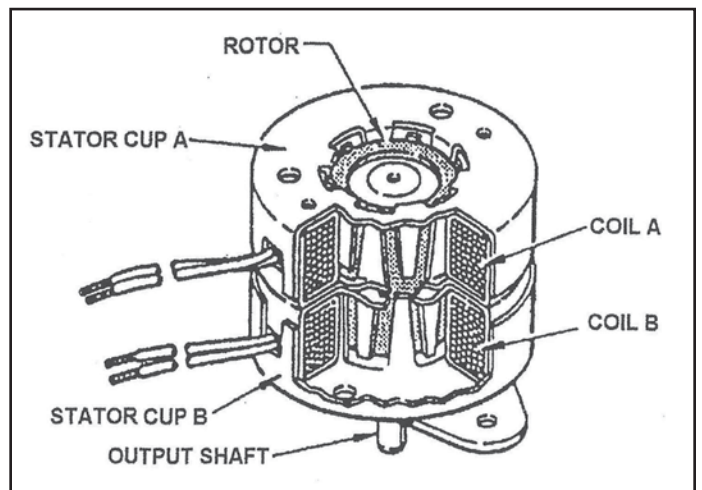


Figure 3 With ready availability of ferrite magnets in 1960s came development of the can-stack step motor. High-volume applications in automobiles and printers use these smaller-sized, cost-effective can-stack step motors.

stamped sheet metal teeth. As shown in Figure 3, the two coil assemblies are offset to achieve alternate N and S magnetic profiles from the all-north top section and the all-south bottom section. The most popular step angle in use for the can-stack step motor is 7.5°. High-volume applications in automobiles and printers use these smaller sized, cost-effective can-stack step motors.

The Hybrid Step Motor

While there are more can-stack motors used in high-volume applications, the hybrid step motor is the workhorse in a myriad of factory, industrial and medical applications. The hybrid step motor is a combination of permanent magnet and variable reluctance motor technology. It was developed in the early 1960s, along with the can-stack step motor, but it immediately differentiated itself as a higher performance step motor. It possesses the highest continuous torque and the best resolution step accuracy of any type step motor.

It is also a two-phase step motor, although there are now both 3-phase and 5-phase hybrid step motors on the market today. The most popular step angle is 1.8° but other step angle operations are available. This motor is a 2-pole permanent magnet—initially Alnico—but later switching to Neodymium-Iron-Boron for improved torque density performance.

Their construction (Fig. 4) is the most complicated of all step motors. The 2-pole, axial-oriented magnet connects to two soft-iron pole pieces with small teeth facing the motor's air gap. The two rotor cups are misaligned with respect to each other by a half-tooth pitch. There are eight major stator teeth with coils and five minor teeth per-motor-stator-tooth-tip facing the air gap. The copper windings are wound on each tooth in bifilar configuration. While the excitation scheme is A-A¹B-B¹(2-phase), the magnetic circuit is split with the upper rotor cup (north polarity) magnetically engaging two stator teeth opposite each other (positions 1 and 5) and the lower half of the rotor (south polarity) engaging two other stator teeth (positions 3 and 7). The magnetic circuit is three dimensional due to the polarity difference between the two rotor cups and their flux connections to the stator coils.

Controlling Step Motors

Driving and controlling a step motor in an open-loop configuration (Fig. 5) will provide the user with a simple pulse-and-direction command format.

A constant frequency clock will provide signals into an excitation sequence generator or indexer, and then into a 4-transistor drive block to drive the step motor and application load. A counter can count the number of pulses needed to move the load to the desired position. Substitute a microprocessor in place of the clock and sequence generator and counter with a micropro-

cessor and the user possesses the lowest cost electronic positioning system. Add a command function (a larger microprocessor or a digital signal processor (DSP) and a variable pulse rate for starting, slewing and stopping can be created. This system cost is still lower than any position control system. The microprocessor provides the basis for many types of input pulse control such as full step, half step, and micro step strategies. The application motion profile and the position accuracy will determine the desired step motor and control motion strategy. All step motors possess little internal damping capabilities and will “ring” or oscillate around the final position. Figure 5 illustrates an oscillation pattern as a typical step response during a low pulse rate (speed) motion profile.

One can also select different methods for energizing step motor winding. There are two winding hook-ups that are popular. The top approach is the 4-lead bipolar hookup that

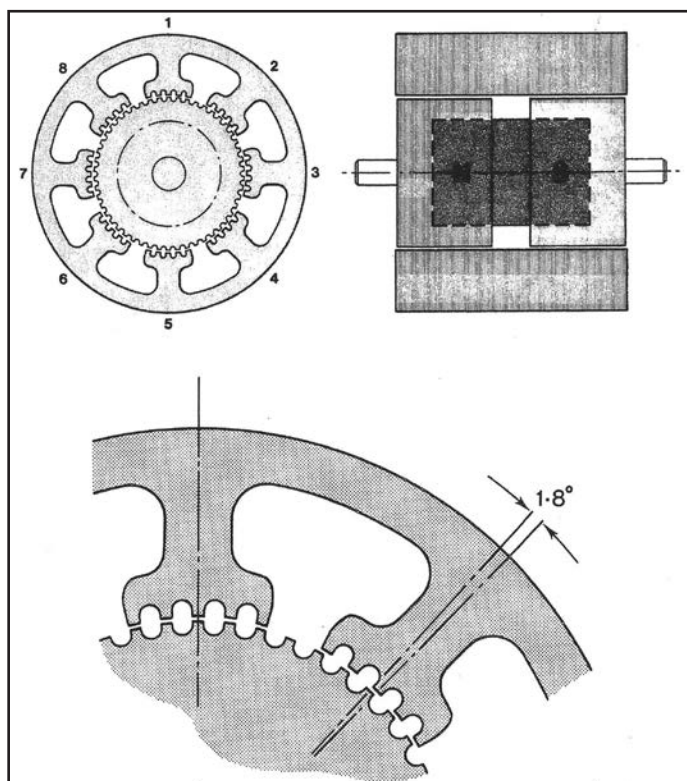


Figure 4 A hybrid (200 step/rev) stepping motor. The detail shows the rotor and stator tooth alignments, and indicates the step angle of 1.8°.

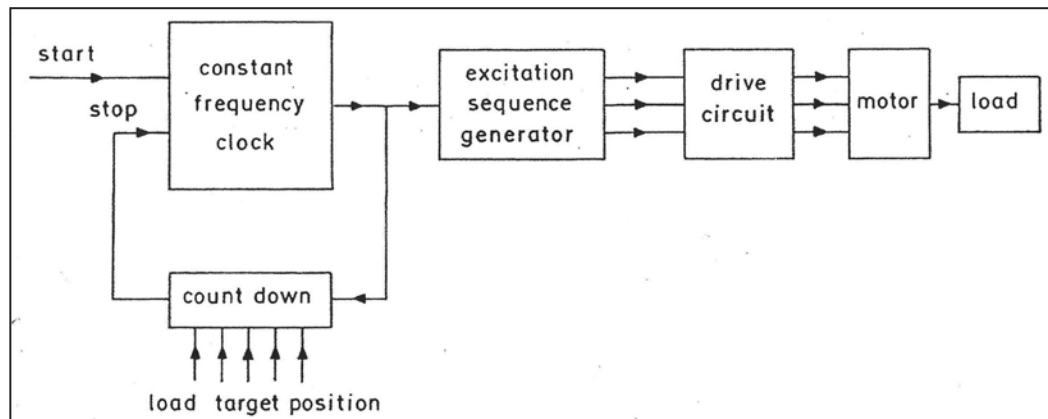


Figure 5 Driving and controlling an open-loop-configuration step motor provides the user with a simple pulse and direction command format.

provides the highest low-speed torque. The second is the 6-lead unipolar hookup for lowest cost, lower torque and higher speed. Many recent step motor controllers can electronically add damping to better control step motor resonances and oscillations. These controllers can also identify a loss of synchronism.

There are many more techniques for driving a step motor, but there is insufficient space in this article to cover them all.

Ins And Outs of Step Motor Performance

The step motor has a unique output torque vs. speed (pulse rate) performance curve. Figure 6 displays a typical curve for a hybrid step motor. There are two major elements in a step motor performance curve, the pull-in and pull-out torque regions. The pull-in torque region is that area of torque and pulse rate (speed) where the step motor can move the load at that commanded pulse rate (speed) within one step. As

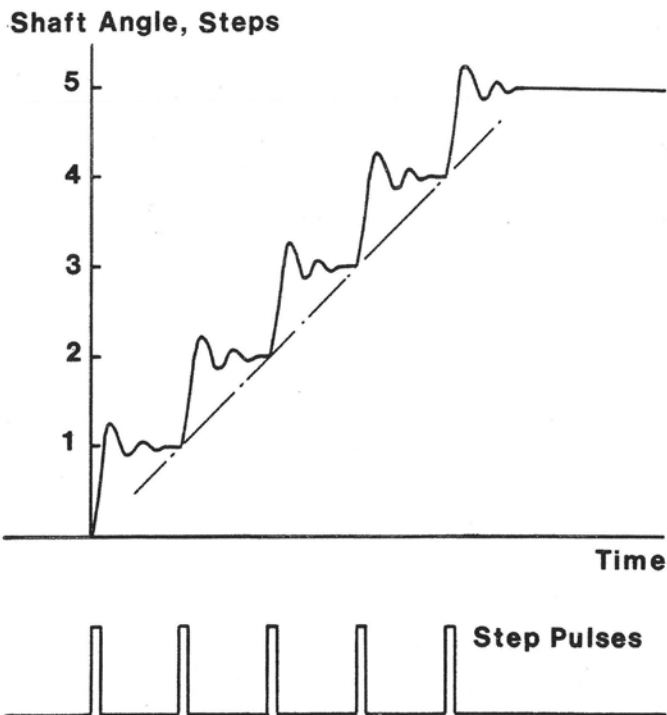


Figure 6 Normal step response to low-frequency, train-of-step command pulses.

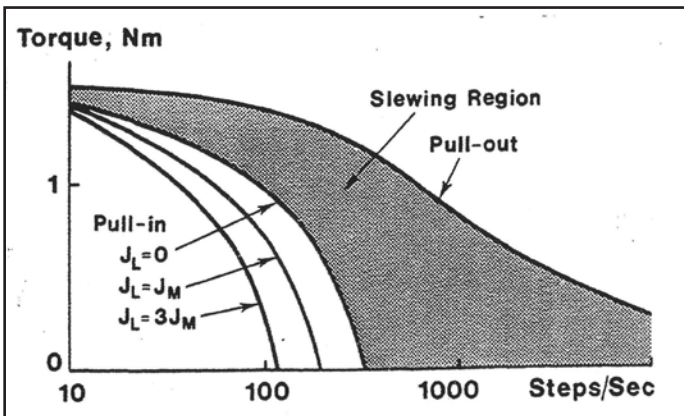


Figure 7 A typical curve for a hybrid step motor. There are two major elements in a step motor performance curve: the pull in, and pull out, torque regions.

shown in Figure 6, increasing load inertia reduces pull in the torque region.

The pull-out torque region (cross hatched) area will provide usable torque as long as the step motor is already in controlled motion. The typical motion strategy is to start the step motor in motion at the lower pulse rates and move it using a number of faster pulse rates to move into the pull-out region. This is designated as the pulse rate ramping technique.

Since most applications look at motor shaft speed in rpm, converting a full-step operation of a 1.8° hybrid step motor providing 1,000 pulses-per-second (pps) equals 300 rpm. A typical hybrid step motor will operate at speeds below 4,000 pps or 1,200 rpm. Some special drives can double the step motor speed to 2,400 rpm.

There is another parameter that must be addressed with open-loop control; it is called torque margin. While moving a step motor in the slewing region, any load perturbation could cause the step motor to lose synchronism and drop to zero speed. Step motors do not like load changes— especially increasing load inertias. As a specific pulse rate is commanded, there is a maximum pull-in and pull-out torque rating available. It is displayed as a vertical line upward from the commanded step rate. If just starting a move, one must not have the needed torque approach the pull-in torque load line. If the torque perturbation occurs in the cross hatched region, it is prudent to have a margin of torque available to protect continuous step motor motion. A typical value of torque margin is 60%. Then there would be an extra 40% available to keep the step motor from losing its synchronism. This is a simple example. For longer moves (more pulses), the motion disturbance can be very complicated. All motion is based on timing the pulses at or near peak torque developed per step.

Final Comments

As digital devices continued to improve, new developments attached low-count encoders to the step motor shaft to provide a signal that would identify the hybrid step motor's peak torque locations so that the step motor could always supply maximum torque. Further software control algorithms allowed one company to create a 50-pole, brushless PM motor with a 1,000 count optical encoder from a hybrid step motor. Other control innovations added electronic damping and stall detection. While the lower pole count, brushless PM motor continues to grow at a faster pace, the step motor continues to grow as well, driven by its lower cost motion and position solution. **PTE**

Dan Jones received his B.S. degree in electrical engineering from Hofstra University and a M.S. degree in mathematics from Adelphi University. He has since 1962 been a chief engineer and staff engineer with numerous companies. Either as a direct employee or consultant, he has applied his technical skills and experience working on DC motors, step motors, AC motors, brush and brushless motors, electronic drives, and on control systems in applications for the military, industrial, and commercial markets. Jones is a former president of the Association of International Motion Engineers (AIME) and has served on the Board of Directors of the Small Motor Manufacturers Association (SMMA). Jones is now president of Increation Associates, a firm combining the capabilities of engineers and marketing focusing on the motion control and power conversion industries.





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Longer Service Life + Less Waste = Lower Cost

The bottom line on bearing reconditioning

Brian Trolan, NSK reconditioning service specialist

Bearings that show wear may not always need to be replaced. Depending on the degree and type of wear, they may be candidates for reconditioning, a process that restores bearings to like-new specifications and performance—at an average 50 to 60 percent of the cost of replacement.

Despite the attractiveness of the potential cost savings, some facilities hesitate to recondition bearings due to concerns that a reconditioned bearing may not perform as well as a new one. In fact, reconditioned bearings are set to a like-new state, and typically carry a similar warranty. This is because while much of the reconditioning process—polishing, grinding, refinishing—is done by machine, bearings are cleaned, inspected and re-set by hand. This gives each bearing the individual

attention and precise adjustments required to ensure all specifications conform to new bearing standards, including their original load and speed ratings.

Seventy-five to 80 percent of bearing reconditioning involves full bearing rebuilds, including roller replacement, where 20-25 percent requires only cleaning, polishing and re-assembly. The process is increasingly popular, as more companies look for additional ways to reduce costs, maintain consistent production levels and reduce their environmental footprint.

The case for reconditioning. The paper industry is one that has fully embraced bearing reconditioning – and for good reason. The astronomic cost of downtime in paper mills has made reconditioning a standard practice to reduce replacement costs, and to maximize uptime.

Paper mills routinely check bearings for wear and remove them during standard maintenance intervals. New bearings are installed and the used bearings sent out for reconditioning to extend their service life. These facilities maximize productivity and improve profitability through:

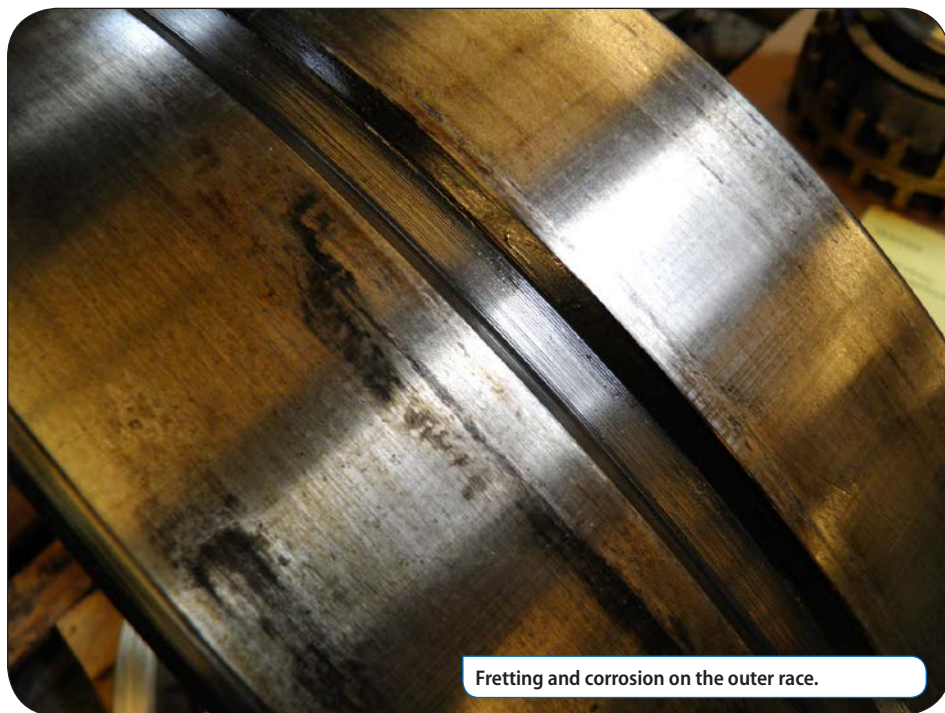
- Reduced unplanned downtime
- Reduced replacement costs due to longer bearing service life
- Reduced waste disposal costs
- Reduced lead times for large bearing replacements

NSK reconditions large bearings in ten weeks or less, and smaller bearings in three-four weeks. The steel industry, for example, is starting to utilize reconditioning more and more for just that reason.

NSK does not charge an inspection fee and guarantees reconditioning turnaround time. Costs are based on the specific work required on each bearing.

When to recondition — or not. Routine maintenance checks can indicate signs of bearing fatigue and the need for further inspection. In addition, the history, performance and operating environment will provide indications as to the condition of the bearing. Some may be too damaged to recondition and will need to be replaced, where others may be excellent candidates for the process and can be reconditioned as many as two or three times.

It's critical to have an expert inspect and evaluate the bearing to determine its potential — or lack of it — for reconditioning. They should provide the specific work requirements for the bearing, the associated costs, the turnaround time and warranty information. Added-value services may also be available. NSK, for example, offers troubleshooting services and provides



Fretting and corrosion on the outer race.



Heavy fretting and corrosion on the inner bore (photos courtesy NSK).

on-site technical support to ensure bearings are installed correctly to optimize service life. The company will recondition any brand of bearing, and backs the work with a one-year warranty.

Not surprisingly, more and more manufacturers are taking advantage of bearing reconditioning to maximize the value of their bearing investment and minimize unplanned downtime, with the added benefit of reducing replacement and disposal costs and decreasing waste. **PTE**

A Brief Q&A with Brian Trolian

PTE: For inspected bearings that might be considered a “toss-up” as to whether they can be reconditioned or not, would a reasonable guideline be “When in doubt, throw it out?”

BT: The best advice is to determine how quickly the bearing is needed; if needed urgently reconditioning may be the best approach; if there is time, a new bearing can be ordered.

PTE: While a piece of equipment’s bearings are being reconditioned, what bearings are used in the interim?

BT: A lot of customers (especially paper mills) typically have multiple bearings on hand that run on the same application (in most cases there are requirements to have a specific number of bearings on hand). They use these additional sets while the bearings are being reconditioned; it is a rotating process.

PTE: Given that many manufacturers today are increasingly relying on bearing reconditioning, is the process becoming—or destined to become—a big part of bearing manufacturers’ business?

BT: Reconditioning is becoming increasingly popular, especially in a soft economy, and yes, this could become a significant part of a bearing manufacturers’ business.

PTE: When it is said that reconditioning bearings can “extend their service life,” how does that apply to original warranty coverage?

BT: It doesn’t affect the original warranty. Generally, if a bearing is in need of reconditioning it is already out of warranty. Once a bearing is reconditioned, a one-year warranty is granted from time of reconditioning.

PTE: Which size bearings are most likely to withstand multiple reconditioning—large or small?

BT: Larger bearings have greater potential for reconditioning because it makes more sense to invest in the reconditioning of a large bearing vs small bearing due to its higher cost.



Fully reconditioned bearing.

Brian Trolian is the large-bore and reconditioning service specialist with NSK Corporation, based in Ann Arbor, MI. He has nine years of industry experience, and in his tenure at NSK has worked hand-in-hand with the engineering, field service and industry specialist departments to assure the best service for the customer.



China!

By Brian Langenberg, CFA

Our last installment called out the likely headwinds from both the C.R.A.P. currencies (Canada, Russia, Australia and Latin America) and also weather impact. As companies start reporting in the coming weeks, expect first quarter results to be mildly impacted.

China bears discussion. After the leadership transition in 2012—when Xi Jinping ascended to the presidency—most corporate executives, investors and (we believe) markets implicitly assumed they would simply “switch on” the engine and stimulate growth. This has not played out. We stated at the time that the removal of Bo Xilai from power (remember him?) was a unique indication of the rivalries beneath the surface, given his family lineage and close associations with the military hierarchy.

Recent and developing anti-corruption actions have a purpose. Actions against current and former senior military leaders and the former head of China National Petroleum Corporation are intended to strengthen the power of the central government, reduce military political power and reform/improve the energy sector. Roundhouse

punches are being thrown by and at big people. In a hierarchical society, decision-making slows when fights are still occurring at the top because the lower-level people duck.

The financial sector is also a concern. A recent *Wall Street Journal* article highlighted the fact that with lack of liquidity from banks, Chinese companies are trading bills and invoices as IOUs in lieu of cash; that isn't the way it is supposed to work. China knows the export-driven growth model is receding and must put in place the reforms to enable healthy long-term growth tied to increasing consumption—all the while tackling an awful pollution problem and shortages of energy and water.

Long-term growth will remain solid. Assuming political stability can be maintained or improved, we still see massive opportunity—even if rate of growth is slower—in supporting infrastructure build out (rail, roads, commercial aviation) as well as rising car and truck demand.

Oil & Gas. The headlines out of Big Oil, with respect to capital spending notwithstanding, we see a stable capital spending profile in 2014 and beyond. Indeed, the big boys have

stepped back a bit—when mega projects in the tens of billions experience overruns, the accountants and controllers take over. But the action isn't over. And closer to home, the U.S. is still punching holes in the ground, drilling and building out the midstream infrastructure to move the oil and gas.

Refinery capital spending out of Phillips 66, Valero and Marathon Petroleum is slated to rise 55%, collectively. With the cold U.S. winter (not yet over!) and utilities running all out, natural gas inventory going into spring is down year over year and below their five-year average.

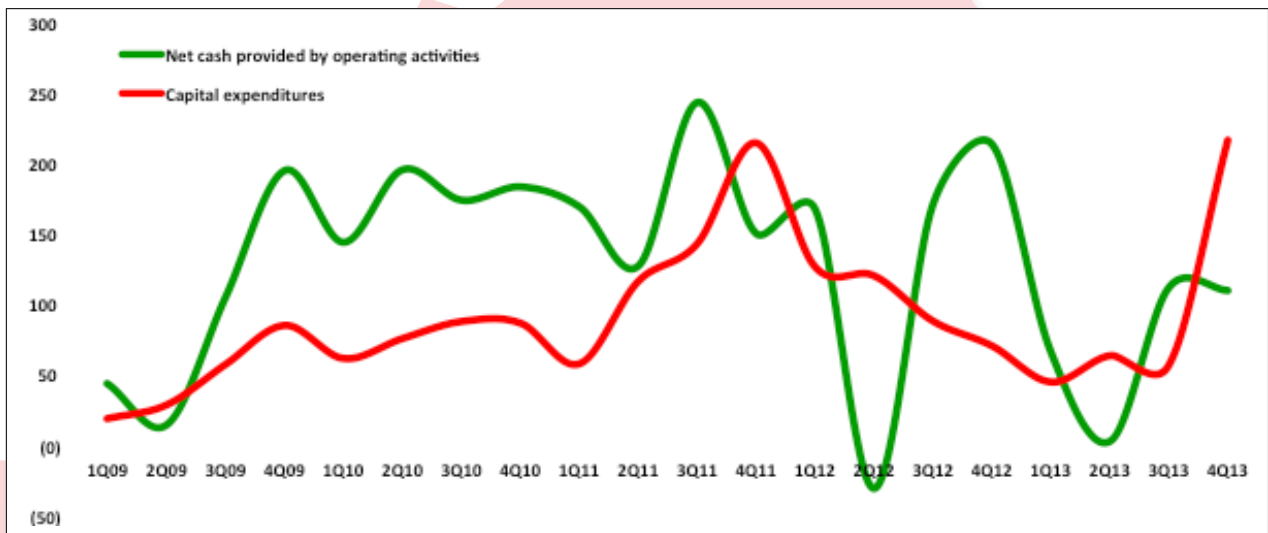
Mining. Current conditions remain awful but we see signs of a thaw and stabilization beyond 2014. But not this year. Capital spending in the mining sector will fall another 25-35% this year and can fall further in 2015. But we are starting to see private equity capital formation behind experienced management teams (Mick Davis, who sold Xtrata to Glencore, is raising a \$3.75 billion fund) while the “Big 4”—particularly Rio Tinto and BHP Billington—are seeking to rationalize and sell off non-core assets. Near-term, this causes further weakness, but once the assets change hands, new projects become likely. Near-term, high utilization will drive continued stability in consumables and service.

Power generation. Global power generation capacity continues to expand—coal, gas and some renewables—while the U.S. is experiencing a strong wind turbine recovery in lieu of additions to, or renewal of, baseline generation capacity. The U.S. remains a mess in that most wind is located away from people, coal-based generation is nearly at capacity, and natural gas is the “popular choice now,” yet the gas delivery infrastructure is strained to ensure full supplies. Without a ratio-

ENERGY SECTOR CAPITAL SPENDING TRENDS

Exxon	\$42,500	\$37,000	(13%)
Chevron	41,900	39,800	(5%)
Pemex (Mexico)	25,000	28,000	12%
Petrobras (Brazil)	48,100	Flat/off	Flat/off
NORTH AMERICA	157,500	~153,000	(3-4%)
PetroChina	51,400	47,800	(7%)
Sinopec	25,000	24,000	(4%)
CNOOC	15,000	>15,500	Up
CHINA	91,400	>87,300	(1-4%)
UPSTREAM NON-INTEGRATED – Top 6	52,500	56,100	7%
DRILLING – Top 5	7,400	8,650	16%
MIDSTREAM	7,200	8,500	18%
REFINERS	6,250	9,700	55%
TOTALS	\$322,250	\$323,250	Flattish

Aside from indisputable facts and figures, the opinions and conclusions are the author's and do not necessarily reflect the position of Randall Publications LLC.



nal tax (pro wind) and regulatory (anti-coal) environment, expect to benefit from deliveries of band aids (wind) and incremental gas units.

Transportation infrastructure. No change here. U.S. infrastructure spending will remain flat until *late* 2016 at the earliest, as it would require bi-partisan support and willingness to spend on infrastructure.

Water & environmental. Municipal demand improved with positive sales momentum the past two quarters. Improved home prices should start to reduce the strain on municipal budgets, and industrial markets continue to grow at a moderate pace.

Machinery. Expect more of the same: *strength in construction equipment* driven by replacement demand and anticipation of rising late-cycle activity; refineries, non-residential construction and LNG all look good. *Truck demand also continues to improve.* According to the USDA, U.S. farm cash receipts are slated to fall 6-7% in 2014 and we see a similar decline in North American demand.

Consumer (auto, appliances). U.S. auto demand remains strong, with March running at 16.33 units SAAR (seasonally adjusted annual rate) and consistently running over 15 million units. Pent up demand, low interest rates and gradually declining unemployment support continued stability. Appliance demand continues to benefit from an improved housing market—even if weather likely impacts starts going into spring and an uptick in rates has cooled activity a bit.

Aerospace/defense. Commercial aviation continues to look good. Boeing continues to book large orders (\$23 billion recently moved into backlog on one order alone!), which will benefit GE’s aircraft engines business in particular. Aftermarket activity, including spares uptake and shop visits, remains strong and airlines are making money. Longer-term we think the downtrend in defense spending is near. Russia’s invasion of Crimea will prove to be a wake-up call—we think—for Europe and the United States. For example, the Chief of Naval Operations finally stood up last month and told Congress we need a 450-ship navy, *not* the 283 we have (which includes reserve cruisers, littoral combat ships, even hospital ships). My sense is that U.S. defense spending starts to rise again after the 2016 presidential election. Stay tuned.

Focus Company: Alpha Natural Resources (ANR)

“People are entitled to their own opinion, but not to their own facts” (*Senator Daniel Moynihan*). Contrary to popular belief, coal consumption for electricity generation is going to rise globally over the next few years—even if U.S. domestic consumption declines moderately. In addition, metallurgical or coking coal is absolutely necessary to support steel production.

Currently the price of both thermal and metallurgical coal can only be described as awful and, as a result, capital spending in this subsector of mining remains particularly weak.

As mentioned, mining sector capital spending will decline this year and probably into at least the first half of 2015, but we also think you may have opportunities to cultivate and support your customers beforehand in anticipation of the next upswing—particularly given the increasing level of Chinese competition and customer willingness (at least offshore) to buy their equipment.

Our Integrated Company Dashboards (ICD) will give a better sense of these trends. These analyses are available on our website for \$199 but readers of *Power Transmission Engineering* magazine can email me directly at Brian@Langenberg-llc.com and ask for a copy by putting “PTE Offer” in the subject line and the ticker for which company they want – choose 1 from: ALFA.IX, AME, ATCOB.IX, CAT, CMI, DOV, EMR, HON, MMM, MTW, ROK, SDVKF, SKFB, UTX, or XYL. We also offer subscriptions at special rates for PTE subscribers. **PTE**

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.



C&U Americas

RECEIVES QUALITY AWARD

C&U Americas, LLC has received the “2013 Quality Award for Excellence” from Remy International, Inc. The award was given to C&U Americas in appreciation and recognition for consistently providing superior quality parts to Remy Mexico during the 2013 business year.

Remy International, Inc. presented the award to Matt Unsworth, C&U Americas director of sales, and Victor Lopez Navarrete, C&U Americas regional sales manager, during their 2014 Annual Supplier Conference, which was held in San Luis Potosi, SLP, Mexico on February 20, 2014. “We are very excited about this prestigious award, and grateful for the opportunity to partner with Remy International, Inc.,” states Unsworth. “It takes a great effort and commitment to become a valued supplier, so when you are recognized for excellence by a world leading manufacturer such as Remy, it says a lot about you and the way you do business. We are very proud of our people and their dedication in serving Remy International, Inc.” For more information, visit www.cubearing.com.



Kollmorgen

EXPANDS DEALER NETWORK IN INDIA

Kollmorgen is expanding its presence in India. The motion control specialists completed a distributor agreement with the Ruju Corporation at the recent SPS/IPC/Drives Expo in Nuremberg. Ruju, based in Ahmedabad in the western Indian state of Gujarat, is part of Hiecon Technologies. Founded in 1996, the industrial automation solution provider is espe-



Kollmorgen Managing Director Udo Panenka Ruju, Ruju owner Hiren Joshi and Market Development Manager Alexander Hack (from left) look forward to the distributor agreement.

cially active in the textile, packaging and plastics industries as a drive and control technology provider.

During the contract signing, Udo Panenka, managing director of Kollmorgen Europe, commented, “For us the partnership with Ruju is an important building block to enable our continued growth in a strong market.” Hiren Joshi, owner and CEO of Ruju was very pleased with the prospects offered by the agreement, “Kollmorgen’s high level of expertise in servo drive technology and motion control solutions immediately provides us with real benefits as a premier supplier of automation equipment in our country.”

The two executives are also satisfied because the first joint packaging technology projects are already in completion. Alexander Hack, market development manager for Kollmorgen, concludes further benefits of the deal, “Based on our open and standardized product platform, and together with Ruju, we can develop well scaled motion and machine control applications for machine builders in India that are accurately tailored and implement faster.” These also include increased opportunities to effectively address the rising energy costs in India with efficient solutions. For more information, visit www.kollmorgen.com.

Timken

WINS ETHICAL AWARD

The Timken Company has been named one of Ethisphere Institute’s World’s Most Ethical Companies for the fourth time. The award recognizes organizations that continue to raise the bar on ethical leadership and corporate behavior. World’s Most Ethical Company honorees understand the correlation between ethics, reputation and daily interactions with their brand and that the award belongs as much to their associates as it does to them.

“Ethical business practices are a core value at Timken, and it’s something our associates worldwide embrace and demonstrate every day,” said chairman of the board Ward J. “Tim” Timken, Jr. “To be honored in this way again is a tribute to our 19,000 employees, who are committed to making our brand one that can be trusted.”

To determine the winners, Ethisphere uses in-depth research and a multi-step analysis of companies’ business practices that includes reviewing codes of ethics, litigation and regulatory infraction histories; evaluating investment in innovation and sustainable business practices; examining activities designed to improve corporate citizenship; and studying nominations from senior executives, industry peers, suppliers and customers.

“The entire community of World’s Most Ethical Companies believe that customers, employees, investors and regulators place a high premium on trust and that ethics and good governance are key in earning it,” said Ethisphere’s chief executive officer, Timothy Erblich. “Timken is a member of an exclusive community committed to driving performance through leading business practices. We congratulate everyone at Timken for this extraordinary achievement.” For more information, visit www.timken.com.



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NovaTorque

WELCOMES VICE PRESIDENT OF ENGINEERING

NovaTorque, Inc. (www.novatorque.com), a Fremont, California-based supplier of ultra-efficient, cost-effective, electronically commutated permanent magnet motors, recently announced that **Ramon Guitart** has joined the company as vice president of engineering.

Guitart has almost 30 years' experience in motors and motor applications. Most recently he led a large global R&D team at TECO-Westinghouse Motor Company. Prior to that, Guitart worked in various engineering management and design engineering roles at GE Electric Machinery (now WEG), Pentair Corporation, and Rockwell Corporation. "I am excited to welcome Ramon to NovaTorque. His deep expertise with motors and motor-based applications will enhance our ability to develop new products and continue delivering affordable, high efficiency motors to our customers," said Emily Liggett, NovaTorque CEO. "NovaTorque is privileged to have motor technology experts like Ramon Guitart, Alan Crapo, CTO, and John Petro, NovaTorque founder and board member, as part of our incredibly strong and innovative team."



IG Watteeuw

CHANGES NAME TO IGW

Global industrial gear manufacturer IG Watteeuw is changing its name to IGW. The rebranding follows some recent changes to the company's operating structure introduced to support the company's plan for sustainable growth triggered by a growing interest from new and emerging markets and opportunities to build on its international reach.

Changes include the introduction of a centralized sales and marketing team, which will bring together its gear and gearbox services for the first time. Its locations will also be brought under centralized control, led by Holger Stehling. IGW operates in three key markets: transport, energy and manufacturing industries with sites in Belgium, Czech Republic, Romania, China and the USA as well as headquarters in Belgium. The company has been manufacturing premium customized gears and gearboxes for over 60 years and also provides a range of specialist support services to its customers across the globe. The rebranding will make it possible for even more clients to benefit from our premium products and services.

During this time the company has built a reputation for its commitment to excellence and innovation, providing high quality, specialist transmission solutions in a wide variety of sectors; these include the company's core applications of rail, transport and marine, as well as a number of new markets including oil and gas, power generation and waste water treatment plants. Holger Stehling, chief executive, said:

"This is an exciting time for IGW, with our manufacturing competences and capacities exceeding market expectations. We now have the opportunity to offer our extensive range of products and services to an even wider audience, entering new markets and achieving a greater geographical reach than ever before. As such we took the decision to take a fresh look at how we present ourselves to the outside world.

"We're part of a family owned group of companies, and we are proud of the fact that we balance a global manufacturing capability with the ability to provide a local and personal service. These allow us to maintain our agility and respond quickly to the needs of our customers. The business has been established on a tradition of power and precision, providing engineering excellence at low risk and best value to our customers. Now, as we extend our reach in the international marketplace we want to create a brand, and an identity, that not only reflects our heritage but will support the organization as we accelerate into new market sectors around the world. This isn't just about a new name and a new look, it's about a new approach to the way we operate within the global marketplace and our aspirations for the future." For more information, visit www.igwpower.com.

Kaydon Bearings

EARNs GOLD BOEING AWARD

Kaydon Bearings, an SKF Group company, recently announced that it has received a 2013 Boeing Performance Excellence Award, given annually by Boeing to suppliers who achieve superior performance. Kaydon is one of only 124 suppliers to receive the Gold Level award, having maintained a gold composite performance rating for 12 consecutive months, from Oct. 1, 2012 to Sept. 30, 2013. "Kaydon is delighted to be honored again this year by Boeing, and especially proud to achieve the gold level," said John Saber, director, aerospace and defense, for Kaydon Bearings. "This award is a tribute to the hard work and dedication of the entire Kaydon team." Kaydon has supplied bearings to Boeing for the Apache helicopter program since it went into production in 1983. Two Kaydon plants — in Muskegon, Mich. and Sumter, S.C. — are certified to AS9100C, the international standard for the aerospace industry. For more information, visit www.kaydonbearings.com.

Motion Industries

ANNOUNCES LATEST PROMOTIONS

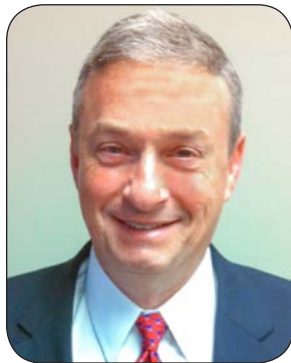
Motion Industries is pleased to announce two promotions to group executive as part of the company's field organization changes, according to Motion Industries' President and COO, Tim Breen.

Richard Burmester has been named senior vice president and group executive for the re-



aligned Southwest sales group. He began his career with Motion Industries in 1976 at the Baton Rouge, Louisiana branch, and since then has held positions as operations manager, outside sales, branch manager, sales manager and division manager. Burmester most recently served the company as division manager for the Nashville Division.

Austin Amos has been named senior vice president and group executive of the newly formed Midwest sales group. He started his career at the Little Rock, Arkansas location in 1989 and has held the positions of outside sales and then branch manager, with responsibilities of a second branch subsequently added. He has most recently served the St. Louis Division as division manager, since 2011.



“These changes in our field organization will further position us for growth in 2014,” said Breen. “Richard and Austin are both experienced leaders, and have done a great job for the company over the years.”

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.

Bodine Electric Company

WINS WORKPLACE SUCCESS AWARD

Bodine Electric was recently awarded the Workplace Success Award from Iowa’s Department of Education for their efforts in supporting numerous training and workforce preparation programs at Northeast Iowa Community College (NICC). Bodine Electric Company collaborated with NICC to develop training and education programs aimed specifically at technical jobs that require more education than a high-school diploma, but less than full college degree. According to the company’s Executive Vice President, Jeff Bodine, there is a significant gap in the educational makeup of the Iowa workforce. “Middle-skill jobs such as CNC machinist and industrial maintenance technician represent 56 percent of Iowa’s employment needs, yet only 33 percent of Iowa’s workers have the skills to fill these critical occupations,” he said during the award ceremony.

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Rick Brindle, plant manager and Jeff Bodine, executive vice president of Bodine Electric Company.

Bodine worked closely with NICC to bring this idea to life. The company donated equipment, developed and reviewed curriculum, and along with other local employers worked with the program advisory board to ensure graduates would be well positioned for success after graduation. Currently, the company is working with NICC to expand the curriculum to include a non-credit mechatronics specialist certificate.

Not only are more positions available to these students, but they have the opportunity to choose where they would like to start. Bodine's program allowed NICC students to shadow current employees, tour the plant itself, and apply for internships immediately after graduation. Bodine also sponsored recent graduates from the NICC program with a hands-on 2-week training program. According to Dubuque's Telegraph Herald, ninety-three percent of recent program participants found employment since graduation.

Iowa Department of Education Director Brad Buck stated that this training effort represents a long-term commitment to the Peosta/Dubuque area. Instead of 'switching gears' and moving their plant elsewhere, "Bodine tackled its worker shortage by partnering with local educational institutions to elevate the entire community."

Crouzet Motors

CELEBRATES NEW GLOBAL CENTER OF MOTOR TECHNOLOGY

Crouzet Motors celebrates the inauguration of its new 49,514 square foot facility, appropriately named, Global Center of Motor Technology in Ales, France with a brief video on the company's core strengths and capabilities. The new video offers a fast-paced look at where Crouzet Motors' high performance, motorized solutions are meeting the demands of severe environments in many mission critical applications. The unique glimpse into the company's people and processes for design, prototyping and production, gives the viewer a real sense of the company's competencies.

Viewers are treated to a close up tour showing the company's mastery of technologies in electromagnetism, thermodynamics, electromechanical systems and electronic control. This expertise allows Crouzet Motors' teams to design and adapt DC Motors to meet customers' most demanding specifications for safety, reliability and precision. From co-engineering to prototyping, production, and product delivery, Crouzet Motors can handle all the processes involved

to provide finished products that comply with stringent international quality and safety standards. Viewers will also learn how the company's priority for customer satisfaction is achieved from close collaboration, reliable products delivered on time, and locally based technical sales and application support teams throughout the world.

A video seemed the appropriate way to commemorate the opening of the Crouzet Motors' plant. As mentioned by John Morehead, national sales manager for Crouzet Motors, "Its inauguration marked a milestone with the production of our revolutionary DCmind Motor Series - an amazingly quiet, higher efficiency brush DC motor of which we are extremely proud."



Crouzet Motors' vast range of brush and brushless DC motors are designed to operate in the extremely demanding environments where security and reliability are crucial. Applications include machinery, medical equipment, railway, aerospace, pumps, access control (barrier, turnstile, lift doors etc) as well as water treatment, advertising billboards, solar tracking, valves and others.

Curtiss-Wright

OPENS INDUSTRIAL DIVISION IN MUNICH

Curtiss-Wright Corporation recently announced that its Industrial division has opened a new office near Munich to provide sales and technical support and customer service to its OEM customers and distributors in Europe. The move follows Curtiss-Wright's recent acquisitions of Arens Controls, PG Drives Technology and Williams Controls; and the merging of its existing Penny + Giles business into a newly formed Industrial group. Together, these four businesses represent four powerful brands in the Industrial marketplace.

As a result of the mergers, Curtiss-Wright has consolidated its existing offices in Germany and moved to larger premises in Garching near Munich. The move will provide a more efficient administration process and service, with new orders being placed directly with Curtiss-Wright's Industrial division in the U.K. Orders will also be dispatched directly to customers from the company's manufacturing facilities in the U.K. and the United States.

In addition, Curtiss-Wright can also increase its offering to incorporate products from all four brands, including by-wire shift controls, electronic throttle pedals, joystick controllers, motor control systems, power electronics and sensors for industrial, commercial and mobility vehicles. Commenting for Curtiss-Wright's Industrial division, Senior Vice President & General Manager Kevin Rayment says: "Europe continues to be a key and developing market for the company and we believe there is a real opportunity for products from all four brands to enter new markets. We are also sure that these operational changes will benefit customers and distributors alike."

Rotek

OPENS SALES OFFICE IN TEXAS

Rotek Incorporated has announced the opening of a Houston, Texas sales office. Based in Aurora, Ohio, Rotek Incorporated is an ISO 9001, ISO 14001, ISO 18001 and ABS certified manufacturer of as-rolled ring forgings, machined rings and slewing bearings for a variety of applications and industrial markets. "We are very pleased to announce the opening of a Houston sales office and look forward to being closer to one of the key markets we serve," stated Rotek President Dr. Tim Gudzend. "The oil and gas market is very important to us and opening a Sales office will allow us provide a better overall experience for our customers and meet their product needs for as-rolled and machined ring forgings."

Rotek Incorporated, which is part of the ThyssenKrupp organization, will be located at 12321 Cutten Road, Houston, TX 77066 and will be shared with the ThyssenKrupp Materials division. The office will be led by Pete Elizondo. "Pete is a great addition to our sales team and we are excited to have him representing Rotek rolled rings. With 20 years of experience, Pete's background of rolled ring sales, with both domestic and international service and leadership skills make him a great asset to our team," stated Corporate Manager Sales & Marketing, Dr. Frank Kuepper. "Pete will be leading Rotek's team of authorized sales agents for rolled and machined rings in the Gulf Coast Region, via Texstar Sales Inc."

Opening a sales office in the Gulf Coast Region puts Rotek in close proximity to the Petroleum Industry, where rolled ring forgings are an integral part of the drilling and extraction process for the oil and gas markets. Dr. Kuepper offered the following comments, "Rotek has made significant investments to become a premier manufacturing facility to our customers in this region. We are one of a few manufacturing locations in North America offering large diameter rings in a variety of materials, while combining forging and machining capabilities under one roof. Our two forging lines allow us to roll rings up to 240" OD and with a single piece weight of up to 18 tons. High precision 5 axis machining centers provide state-of-the art milling, turning, gear cutting and drilling operations. We also have the capability to custom-tailor the tribological properties of machined parts as required using localized heat treatment operations and other surface modification techniques."

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May 3–6—BSA Annual Convention 2014.

Scottsdale, Arizona. The BSA Annual Convention theme is “Legacy of Excellence...Shaping the Future.” The business program will examine the convergence of industry trends and sustainable growth. How do we continue to achieve more in a mature marketplace? Presentations will include Dr. Barry Lawrence of Texas A&M University on “Industry Trends and Sustainable Growth,” Courtney Killion, Cleveland Research, on “An Evolving Industry: Analysis and Insight” and Dr. Jeff Dyer, Brigham Young University and the Wharton School, on “Disruptive Innovation: Empowering Growth.” In addition to these individual presentations, all three thought leaders will participate in an industry panel to continue the discussion. This learning-based programming is just the beginning. Important updates from BSA and ABMA on the state of the industry and BSA’s Conference Table Session, which encourages distributors and manufacturers to build problem-solving relationships, are also scheduled. For more information, visit www.bsaconventions.org.

May 5–8—Windpower 2014. Mandalay Bay Convention Center, Las Vegas. Windpower is the annual conference and exhibition for the U.S. wind industry. It’s the nexus of wind energy professionals who converge to generate actionable ideas for expanding the wind energy economy through technology and collaboration. In 2014, Windpower comes to Las Vegas as a place for business. American wind power topped 4 percent of the U.S. power grid for the first time last year and has delivered 30 percent of all new generating capacity for the last five years. In Iowa and South Dakota, wind power now exceeds 25 percent of total electricity production. In nine states it provided more than 12 percent and in 17 states, more than five percent. “Wind energy continues to make inroads as a major contributor to the U.S. power mix,” said Elizabeth Salerno, vice president of industry data and analysis for the American Wind Energy Association. “The electricity generated by American wind power has more than tripled since 2008 not only due to significant growth in new wind projects but also technology innovation leading to more productive wind turbines.” All renewable energy sources now deliver nearly 13 percent of the nation’s electricity.” For more information, visit www.awea.org.

May 6–8—MFG 2014. Connecticut Convention Center, Hartford. Manufacturing is growing and changing... moving from low value repetitive assembly to high value, technology-rich products and services. To serve the evolving needs of East Coast industry, SME produces this exclusive event for aerospace, defense (including arms), medical, and micromanufacturing. These three major industries plus one strategic technology are driving change through their supply chains and leading the way in innovation and collaboration. Mfg4 surpasses the traditional manufacturing technology event by delivering content and suppliers mandated by industry. Mfg4 is an event for industry developed by industry, with an emphasis on industry-specific solutions with attention to cross-collaboration. Technology Zones include additive manufacturing, automation,

contract manufacturing, finishing & coatings, joining and fabrication, materials, micromanufacturing, machining and tooling and inspection, software and design. For more information, visit www.mfg4event.com.

May 12–14—MMTS 2014. Place Bonaventure, Montreal, Canada. The Montreal Manufacturing Technology Show (MMTS) is Quebec’s leading manufacturing event, attracting more than 4,500 buyers and influencers. MMTS specializes in Machine Tools, Tooling, Metalworking, Automation, Design and Physical Asset Management solutions for manufacturing professionals looking to upgrade their operations, source new solutions and keep up-to-date with current industry news and products. The three-day event features credible and relevant education, technical sessions and working demonstrations of the latest cutting edge technologies. More than 150 leading suppliers exhibit at MMTS to showcase new and proven metalworking solutions, meet face-to-face with decision makers and expand their business network. Featured technologies include automation, cutting tools, lubricants, energy, machining, lean manufacturing, material handling, robotics, workholding and more. The show is produced by SME. For more information, visit www.mmts.ca.

May 18–22—PM2014 World Congress.

Orlando. PM2014 World Congress boasts more than 450 experts presenting the latest in PM, particulate materials, tungsten, refractory and hard materials. An inaugural conference on additive manufacturing will feature worldwide industry experts presenting the latest developments in this fast-growing field. It is an essential meeting for anyone interested in metal components produced via additive manufacturing. The trade exhibition will include 175+ booths from suppliers in the PM industry. Special conference events include global trends sessions, three luncheons, a welcome dinner and a closing dinner. Conference session topics include composites, mechanical properties, sintering, magnetics, heat treatment and more. For more information, visit www.mpif.com.

June 9–12—Rapid 2014. Cobo Center, Detroit, Michigan. Interest in Additive Manufacturing, 3-D printing and 3-D scanning is skyrocketing. It suddenly seems like everyone wants to take advantage of these technologies. Even more so, they want to know what’s next. How will these technologies revolutionize manufacturing in the future? Rapid brings these answers to life. For nearly 25 years, Rapid has been the authority on 3-D. The event was developed by SME members who wanted an annual forum to learn and share additive manufacturing knowledge and best practices, and buy and sell related equipment and services. These members built a community of like-minded professional with whom they have grown their skills, developed their network, and advanced their businesses. Rapid continues this tradition in 2014, leading the way for innovation in all areas of manufacturing. Highlights include: slot car races, innovation exchange, personal 3-D Playground, additive manufacturing resource center and the literature lounge. For more information, visit www.sme.org.



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Gonzo Gear Design

Longtin Adds Completely Non-Circular Planetary Gears to his Unique Portfolio

Tom Longtin's work has been featured in past issues of *Gear Technology*.

The digital sculptor/graphic designer has created gear mechanisms for books, music videos, puzzles and for his own personal amusement. He once created a full-screen field of 50-odd synchronized, rotating gears for a television commercial using the book *Spur Gears* by Earle Buckingham.

Longtin's interest in rotating mechanical objects typically leads him to various websites to build on existing designs. When he originally came across a pair of elliptical gears at <http://www.thingiverse.com/thing:205>, it prompted Longtin to develop a pair of crosslink ellipse gears linked together at both foci, as well as quad-ellipse gears linking four identical elliptical gears.

Longtin explains, "I wanted to rotate a pair of matching elliptical-shaped gears linked at their centers. This is not practicable with strictly elliptical gears and requires a modified shape.

I then moved on to creating code for pairs of arbitrarily shaped gears using an iterative loop which converges on a solution to match the output pitch curve length to the input.

My original planetary gears appeared on the cover of the March 1996 *Power Transmission Design*, and I had seen hypotrochoid planetary gear animations online. I noted in the animation that the planets were all circular, but did follow a non-circular orbit."

Longtin wanted to make all non-circular planetary gears using the same iterative coding ideas. The planet gears follow a circular orbit so that when the orbit radius solution for the planet/sun matches (within some epsilon) the orbit radius solution for the planet/ring, he's got the pitch curves.

This is just one of many side projects that interest Longtin, along with creating laser-cut jigsaw puzzles, 3-D manipulative puzzles and a motorized assembly of various-sized elliptical gears with prime numbers of teeth in which a single gear repeatedly jumps between two columns of gears, seemingly at random by virtue of the columns alternately lengthening and shortening. (Got all that?)

He's inspired by building on existing designs and seeing what the reactions are. For example, imagine what it would be like if looney gears (an asymmetric, planetary gearing system) were all non-circular. "I'd say nearly impossible without a quantum computer," Longtin says. And he likes to ask lots of questions of his colleagues who have created various gear demonstrations online. When he's not searching online, Longtin enjoys attending mathematics/puzzles/sculpture conferences.

Longtin would like the assistance of both *Power Transmission Engineering* and *Gear Technology* readers by weighing in on his non-circular planetary gears. "I hope to have my non-circular planetary gears entered into the Guinness Book of World Records as I believe they are the world's first. Of course, the readers could certainly help educate me on that notion," Longtin says. Record-breaking or not, the variety and depth of Longtin's gear work is definitely inspired. For more information, visit http://homepages.sover.net/~tlongtin/index_old.html. **PTE**





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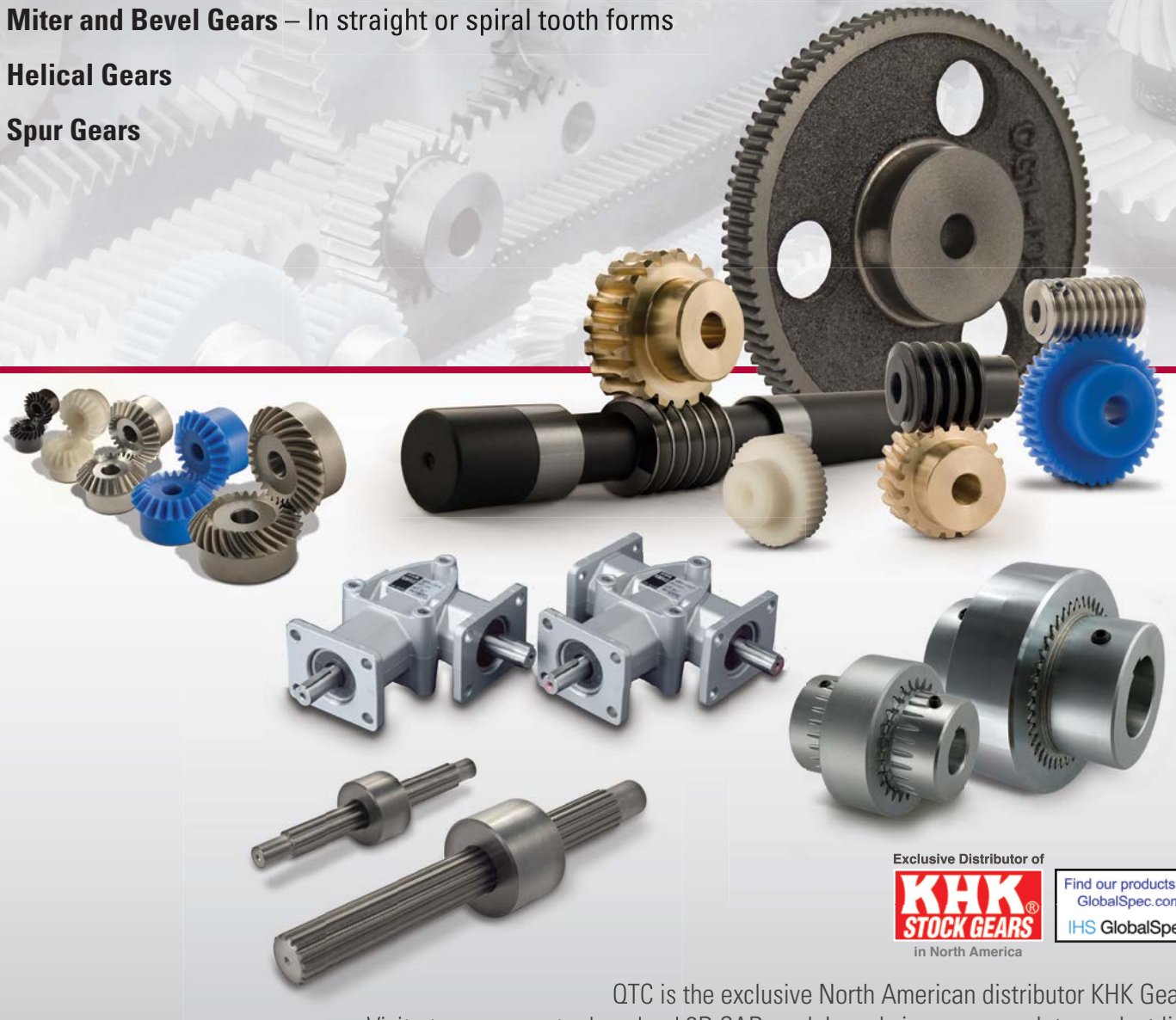
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