Power Transmission Engineering®

MARCH 2014

# NEW HYDRAULICS SPUR

## the Heave-Ho Factor

## IFPE 2014 Review

## PURCHASING: The Art (and Science) of the Buy

### Technical

[Downsizing Gears for Hydraulic Pumps]

[Best Practices for Gearbox Assembly and Disassembly]

[Bearing Failure Linked to White Etching Areas in Wind Turbine Gearboxes]

### Power Play

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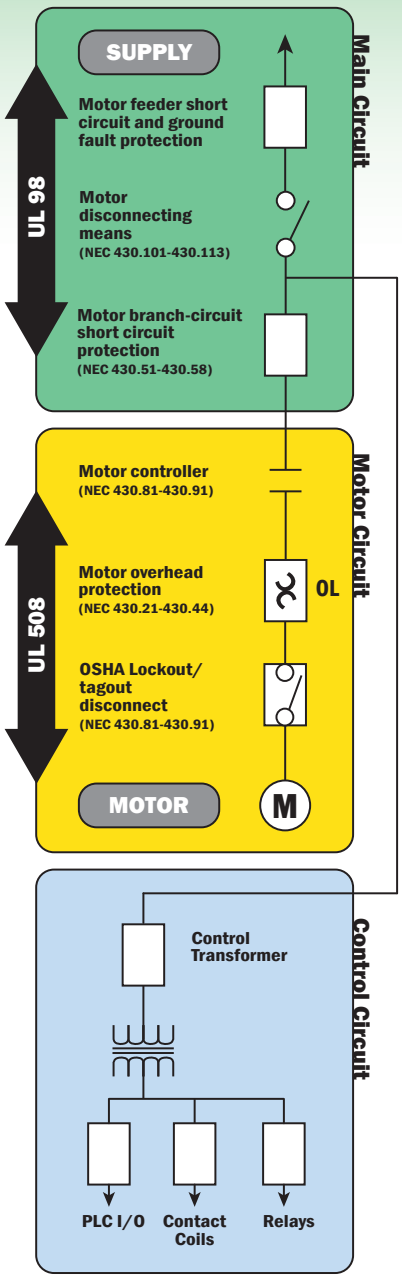


### UL 489 MCCBs

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- Standard and high-interrupting capacity types

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*starting at $37.50 (10-pack)*

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### UL 98 Disconnect Switches

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- Make/break loads up to 800 amps

### Bryant Manual Motor Controllers

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- Lockout / Tagout capability
- 30, 40 and 60A up to 600 VAC
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- UL Listed as "Suitable as Motor Disconnect" under UL 508

### UL 508 Load Switches

*starting at $26*

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- Loads from 16 to 125 amps
- IP20 degree of protection

### UL 98 and UL 508 Compact Fusible Disconnect Switches

*starting at $19*

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- 1, 2 and 3-pole models
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- Lockout/Tagout capability

### UL 1077 Supplementary Protectors

*starting at $9.00*

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- Class CC, general purpose class M (Midget) and small dimension glass and ceramic fuses
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MARCH 2014

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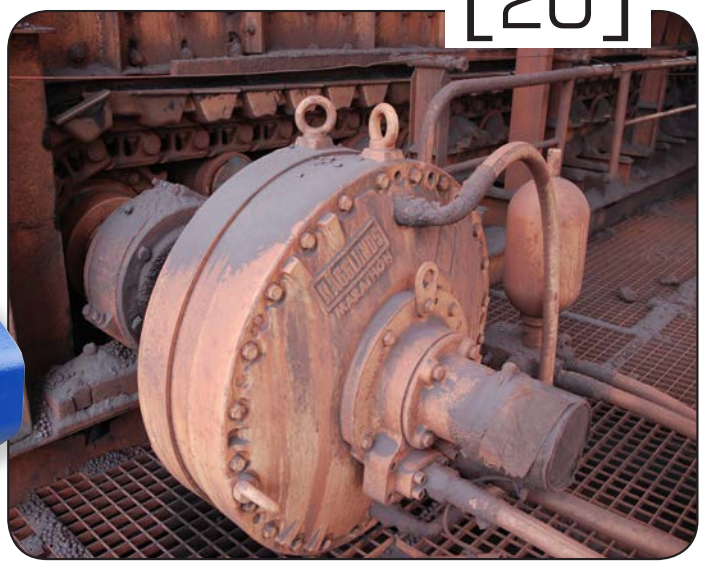

## Engineering Showcase

[Pages 46–52]

## FEATURE ARTICLES



## TECHNICAL ARTICLES



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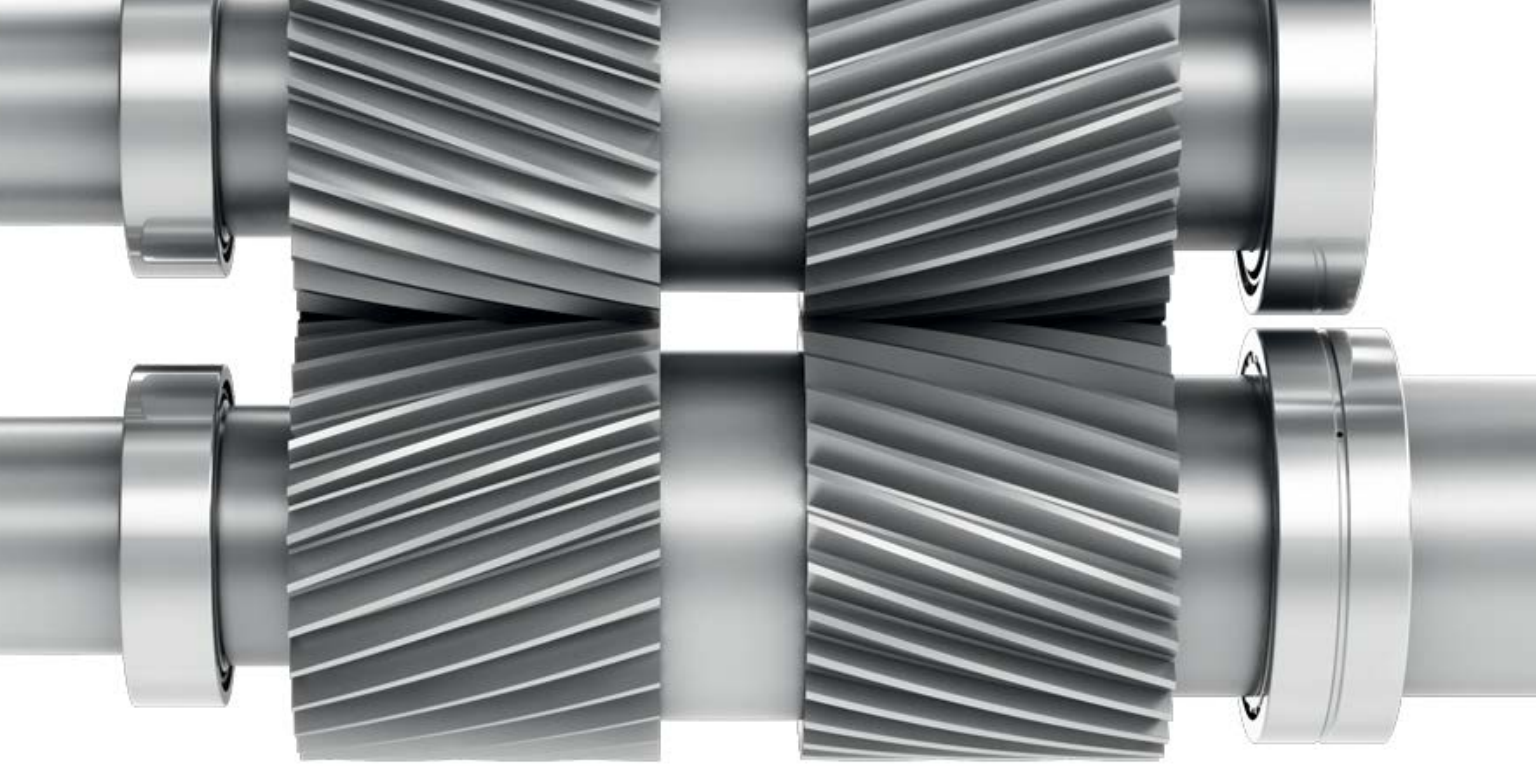

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## PTE Videos

The widest range of gearbox sizes and torques designed with the customer in mind. Watch this video developed for the IFPE-CONEXPO 2014 by Bonfiglioli USA at *www.powertransmission.com*.

**LinkedIn:** Napoleon Engineering Services has expanded its inspection capabilities to include enhanced source qualification inspection with bearing contact stress analysis. Learn more about this on the PT LinkedIn page (*www.linkedin.com/groups?home=&gid=2950055&trk=anet_ug_hm*).

**Twitter:** The *PTE Twitter* feed keeps readers up-to-date on the latest products and services available to the PT community. Recent IFPE updates from Trelleborg, Oerlikon, Emerson and SKF are available at: *https://twitter.com/PowerTransMag*.

## Gear Technology Blog

Charles D. Schultz is offering his insights into the gear manufacturing industry and asking readers to share their knowledge as well. Read his most recent post at *www.geartechnology.com/blog*.

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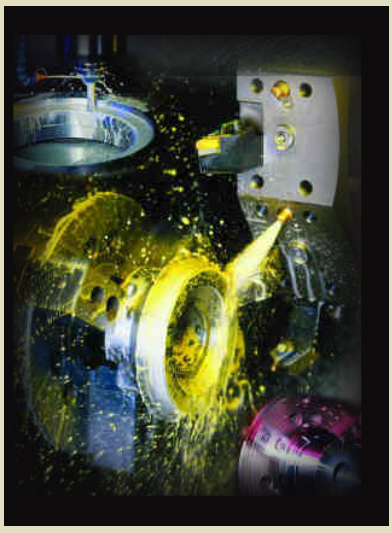
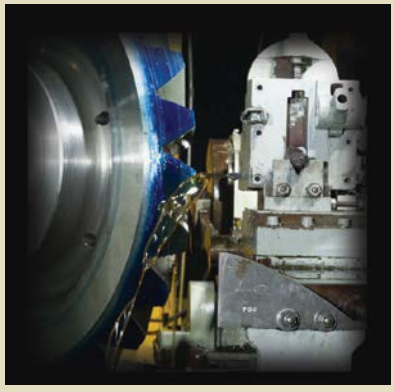
## BEVEL GEAR MANUFACTURING





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Randy Stott, Managing Editor

# Forward March!

## We're pleased to present the first-ever *March* issue of *Power Transmission Engineering.*

For the past six years, we've published this magazine on a bi-monthly schedule, but in 2014 we've increased our schedule to eight times per year. In your hands is one of the bonus issues. The other will come in September.

The additional issues allow us the opportunity to cover our subjects in greater depth and to address industries, applications and topics that in the past we just didn't have room to include.

For example, in this issue, we bring you extensive coverage of fluid power components and contruction and mining equipment applications. There was a lot to see and learn about at the recently concluded IFPE and CONEXPO-CON/AGG 2014 show. Hopefully those of you who went to the show had the opportunity to stop by our booth and meet Associate Publisher Dave Friedman. But for those who didn't make it, we put together some of the show highlights beginning on page 16.

In addition, Senior Editor Jack McGuinn put together an in-depth look at the critically important role of purchasing personnel in the design and manufacturing of machinery and equipment with highly engineered components. His article begins on page 24.

As usual, we've tried to put together a roster of technical articles that will appeal to a wide variety of interests. We have an examination of gear pumps that use differently sized gears and a primer on the best practices in gearbox assembly—an article that should be of especial interest to those who are designing gearboxes or those who are involved with maintenance and repair. Also, we have an analysis of one of the common failure modes in wind turbine bearings that sheds light on which materials and processes are most suitable for that highly demanding application.


Finally, this issue included our first annual *Engineering Showcase*, a special advertising section featuring some of the leaders in the design and manufacture of mechanical components. Thanks to all of the companies who participated this year.

As we continue to grow, we look forward to your feedback and comments. Your input helps us bring you the articles that are of most use to you. So please drop me a line at *wrs@powertransmission.com* if you'd like to respond to any article in this issue, if you have ideas of your own you'd like to contribute, or just to say hello. We always look forward to hearing from you.


# High Quality Spiral Bevel Gears from Stock!

Every day, thousands of power transmission manufacturers around the world rely on precision stock gears produced by Arrow Gear Company.

Arrow Gear offers a full range of precision spiral bevels from stock - up to 16 inches in diameter - including ground tooth gears. Featuring carburized and hardened teeth, and gears that are produced in matched sets, Arrow's stock gears are available for immediate delivery. Arrow's stock gears can also be modified to meet individual customer needs.

With over 65 years experience, Arrow's stock gears are manufactured with the same processes used for our custom aerospace products. With a state-of-the-art production facility and dedicated personnel who are among the best in the business, Arrow Gear offers the expertise and precision for the most demanding quality requirements.

**When you need quality, expertise, and precision,**
**you can rely on Arrow Gear!**

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630.969.7640

# Napoleon Engineering

## EXPANDS BEARING AND INSPECTION CAPABILITIES

Napoleon Engineering Services have announced the recent expansion of their bearing manufacturing capabilities to now include back-up bearings for use with active magnetic bearings (AMBs), where they serve as highly reliable secondary fail-safe systems.

AMBs are increasingly used within electrical power generation, petroleum refining, machine tools, and natural gas pipelines. Their design incorporates the use of electromagnets, which magnetically levitate rotating shafts or other moving parts. The lack of contact between the bearings and the loads they support removes the need for lubricating systems and increases the speed at which the moving parts can operate. To ensure the success of AMB systems, a reliable backup or auxiliary bearing must be in place to enable controlled shutdown, in case of a power or control systems failure.

When using AMB to support a rotating shaft, any reduction or loss of power could cause the shaft to drop. With NES Bearings AMB back-up bearings in place, the shaft will drop 2 to 3 thousandths of an inch onto the back-up bearing system, allowing it to coast to a stop without damage to the shaft or surrounding machinery. The robust design of NES Bearings AMB back-up bearings incorporates specialty heat treatments, wear resistant material combinations, conventional or dry film lubricants and a variety of cage and internal design characteristics, all of which help to effectively manage the safe coast down of the rotating shaft.

Notes Chris Napoleon, NES Bearings president and chief engineer, "Understanding the magnitude and distribution of radial and axial loads, rotational speeds and lubrication constraints allows us to determine whether a full ball complement or caged bearing design is warranted. In some cases, standard bearings can be highly modified to meet specific application needs, resulting in manufactured AMB back-up bearings with very short lead times."

**For more information:**
Napoleon Engineering
Phone: (877) 870-3200
*sales@nesbearings.com*
*www.nesbearings.com*

# Voith Turbo

## FLUID COUPLINGS PREVENT DOWNTIME

The Indonesian mining company Bukit Asam expands its operations at Tanjung Enim Coal Mine in Sumatra, Indonesia. For ten new belt conveyors at Tanjung Enim, Bukit Asam deploys 14 TVVS fluid couplings from 55–315 kW. In the past, the mine operator has always been pleased with the reliability of its already installed Voith fluid couplings. They ensure smooth start-ups day after day and a long service life for all components — especially the belts.

"We're all very impressed with the performance of the TVVS constant-fill fluid couplings. They're very easy to maintain — only oil changes are needed — and the reliability is just great," says Kris Tjahajaning Tyas, manager of maintenance planning at Bukit Asam. The mine operates 24/7, and any equipment downtime means loss of production. In older sections of the mine they've been using TVVS on belt conveyors since 1997 — without any unplanned downtime. "Proven reliability is why we absolutely wanted to have Voith fluid couplings in the new conveyor drives as well," adds Tatra Muis, senior manager of maintenance at Bukit Asam.

The Voith fluid couplings are well suited for use in extreme environments and are completely insensitive to harsh conditions like dust, dirt and humidity. The fine coal dust in Tanjung Enim Coal Mine has no effect on performance. The couplings dampen torsional vibrations in the driveline and

protect it against overload, extending the lifetime of the entire system. Because torque is transmitted by a fluid, the power transmission of the fluid couplings is wear-free, reducing maintenance to a minimum. Bukit Asam's Muis and Tyas are happy with the many benefits that the fluid couplings provide. They also appreciate the useful advice and after-sales support from the local Voith team, along with unmatched know-how on the entire drive system.

The 13 existing belt conveyors in the Tanjung Enim Coal Mine still rely on TVVS fluid couplings (rated from 55 to 500 kW) that were installed more than 17 years ago. The mine has two coal handling facilities, with the longest belt conveyor having a length of 4,284 meters and a capacity of 1,700 tons per hour. The drive of this conveyor is equipped with three 315 kW motors and three fluid couplings, type 750 TVVS. In addition to the conveyor drives, the bucket wheel excavator drives in the Tanjung Enim Coal Mine are equipped with five 750 kW fluid couplings, Type T, that dampen vibrations and protect the driveline from damage also in case of frequently occurring overload.

**For more information:**
Voith Turbo
Phone: +(49) 7951 32-429
*www.voith.com*

# JVL

## MAC402 SERVOMOTOR MAXIMIZES PRODUCTION TIME

Designed for battery powered and low-voltage applications, the MAC402 is now available from JVL. The MAC402 is the VDC version of the popular MAC400 400 W integrated servomotor. The supply range for the MAC402 is from 12 VDC up to 48 VDC, and full power of 400 W (RMS) up to 1200 W (peak) can be reached with 24 to 48 VDC. This powerful, compact motor measures 191 mm (7.52 in.) × 60 mm (2.36 in) × 114 mm (4.49 in.). Applications include remotely operated robots, robotic vehicles, portable equipment, tracking devices, antenna mounts and positioning devices.

JVL offers a 400 W continuous (1,200 W peak) integrated servomotor in the supply range of 24–48 VDC operating at 0 to 3,000 rpm. In many applications it is not necessary to choose a 750 W or larger motor as the 400 W (1,200 W peak) motor will be sufficient, thereby reducing cost and saving space. MAC402 options include brake, absolute multi-turn encoder, and planetary & cycloidal gearheads.

A wide selection of communication modules is available for MAC402 motors: basic modules for pulse-direction (or analog input) or fieldbus modules including Profibus, Devicenet and CANopen, or programmable modules with easy connections to local sensors make integration into new and existing applications easy. Moreover, a wide variety of industrial Ethernet options are available: EtherCAT, EtherNet/IP, Profinet, Powerlink, Modbus TCP and Sercos III. With the VDC supply option the advantages of the MAC400 VAC servos have been expanded to include applications for battery and low voltage operation, from 12 to 48 VDC. With wireless options like WLAN/Wifi, Zigbee or Bluetooth, the MAC402 MAC motor can run completely wireless.

A big advantage of using an integrated MAC motor is that there is no need for a separate servo driver/controller. The advantages are: Space savings in the control cabinet, eliminating expensive motor and encoder cables, RFI/EFI noise is minimized due to internal cabling, and connection errors between driver and motor are eliminated. Additionally, service is much easier as the motor and controller are replaced as a single integrated unit minimizing downtime and maximizing production.

**For more information:**
JVL
Phone: +(45) 4582 4440
*www.jvl.dk*

# Bodine

## EXPANDS DC MOTORS WITH DYNAMIC BRAKING

Bodine Electric Company expanded its family of DC motor speed controls to include a new enclosed model with forward-brake-reverse switch and dynamic braking. The new control is suitable for use in bi-directional applications such as conveyors, packaging machines, screen-printing equipment, food processing applications, medical devices, lab instrumentation and labeling equipment.

Housed in a NEMA 1/IP-20 enclosure, the new model 0794 provides smooth speed control for PMDC gear motors and motors. Its pulse width modulated (PWM) design provides higher torque and lower motor operating temperatures than typical SCR controls. Filtered DC output to the motor allows cooler operation, longer brush life, lower audible noise, and wider speed range. The type "WPM" control accepts 115 VAC, 50/60 Hz, 1-phase input. Motor power ratings are 7/16 hp (326 Watts) at 90 VDC, or 5/8 hp (466 Watts) at 130 VDC.

This new stock model features a forward-brake-reverse switch, allowing dynamic braking for applications where the motor needs to be manually and infrequently reversed, or when required as a setup function in an application. Five trim pot adjustments (torque limit, minimum and maximum speed, acceleration/deceleration, and IR compensation) eliminate the computer-like programming required in other drives. DIP switches allow the control to be easily calibrated for different motor sizes. Two Diagnostic LEDs on the PC board indicate when power

# AutomationDirect

## OFFERS STEPPER GEARBOXES

AutomationDirect's new SureGear PGCN series of stepper gearboxes is a suitable choice for stepper and other motion control applications requiring a NEMA-size input/output interface. Available in NEMA 17, 23, and 34 sizes and gear ratios of 5, 10, 25, 50, and 100:1, SureGear stepper gearboxes are designed with a nominal speed of 3,500 rpm and maximum input speed of 6,000 rpm. Additional features include a low backlash of 30 arc-min or less, and a 20,000 hour service life. The SureGear PGCN series is an accurate, high-performance, and cost-effective solution for applications include material handling, pick and place, automation, packaging, and other motion control applications requiring a NEMA input/output. While SureGear planetary gearboxes can be mounted in any orientation, they are not designed for back driving. These maintenance-free gearboxes require no additional lubrication for the life of the unit and hardware is included for mounting to SureStep stepper motors; optional shaft bushings are available for mounting to other motors. SureGear PGCN series prices start at $209 and are backed by a one-year warranty.

**For more information:**
AutomationDirect
Phone: (800) 633-0405
*www.automationdirect.com*

is on and when current output is at limit set by the torque pot.

This new model 0794 is available through Bodine's extensive distributor network, via direct sales to OEMs, or from the Bodine web site. Stock orders typically ship within 2–3 business days.

**For more information:**
Bodine Electric Company
Phone: (773) 478-3515
*www.bodine-electric.com*

# NovaTorque

## EXPANDS PREMIUMPLUS MOTOR LINE

NovaTorque, Inc., a Fremont CA based producer of ultra-efficient, cost-effective, electronically commutated permanent magnet motors, introduces 7.5 hp and 10 hp models of its PremiumPlus+ motors. NovaTorque motors use low-cost ferrite magnets in an innovative flux-focusing design to deliver the superior efficiency of rare-earth permanent magnet motors at a price that is competitive with induction motors. "NovaTorque's new 7.5 hp and 10 hp versions, driven by variable frequency drives, boast motor-only rated point efficiency of over 94 percent, a full 3 point advantage over NEMA Premium induction motors. That advantage grows under partial load, as is the case in variable speed fan applications, with typical efficiency improvements ranging from 5 to 15 percent. In a high duty cycle 10 hp fan application in an average cost of power area, annual energy cost savings can exceed $300," says Scott Johnson, NovaTorque's vice president of sales. "The advantage is even more dramatic when compared to the current installed base of induction motors, where efficiency improvements of 20 percent or more are achievable," continues Johnson.

Importantly, due to its unique patented flux-focusing stator and rotor hub geometry, the NovaTorque motor produces this performance with an all-ferrite (versus rare earth) magnet design. "The cost of rare earth (neodymium) magnet material, the basis of most conventional permanent magnet motors, has risen erratically over the last several years. Further, supply of rare earth magnets is increasingly uncertain. The ability to use ferrite magnets allows NovaTorque to price its motors comparable to induction motors. This means OEMs and HVAC systems builders can now economically deliver superior permanent magnet motor efficiency with modest first cost impact and a rapid payback," explains Jaffer Hussain, NovaTorque's vice president of marketing and product management.

NovaTorque PremiumPlus+ motors are packaged in standard NEMA frame sizes and mounting dimensions for easy substitution of AC induction motors. NovaTorque PremiumPlus+ motors are compatible with readily available variable frequency drives (VFDs) from most leading manufacturers, including ABB, Yaskawa, Mitsubishi, Siemens, Fuji, Hitachi, Toshiba, Delta, Danfoss, Schneider, Vacon and others.

**For more information:**
NovaTorque
Phone: (510) 933-2700
*info@novatorque.com*
*www.novatorque.com*


# Klüber Lubrication

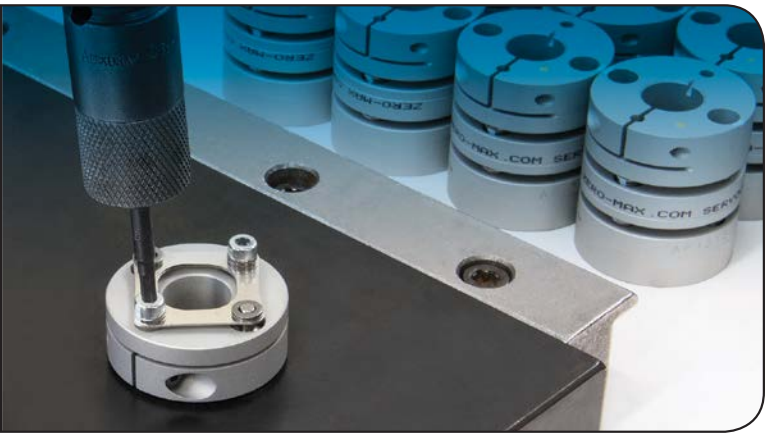
## INTRODUCES BEARING GREASES

Klüber Lubrication, a worldwide manufacturer of specialty lubricants, has introduced Isoflex Topas NB 52 and Isoflex Topas NB 152, two rolling and plain bearing greases based on a synthetic hydrocarbon oil and a barium complex soap. The products are suited for amusement industry applications, such as roller coaster wheel bearings, in order to optimize operational reliability, cut servicing costs, conserve energy and extend maintenance intervals. The special barium-soap thickener used in the Isoflex Topas NB 52 and 152 greases offers good load-carrying capacity, as well as resistance to water

# Zero-Max

## OFFERS COUPLINGS FOR PRECISE POSITIONING AT ANY SPEED

ServoClass Couplings are often described as very smooth and quiet during operation. That smooth operating characteristic is a result of several factors, including how consistent the various parts of the coupling are assembled and held together. Maintaining precise and repeatable assemblies is more than having a good torque wrench. For example, it is possible to have several bolts that are all torqued to the same value and still have inconsistent clamping forces. This situation would be caused by an inconsistent coefficient of friction in the threaded surfaces.



To ensure that each and every ServoClass coupling is assembled correctly and will grip the shaft precisely, Zero-Max uses a special solid film lubricant treatment on the threads of all the socket head cap screws used in the ServoClass line of couplings. It is this attention to even the smallest details that makes the ServoClass couplings run smooth and perform at the highest level in applications of any speed.

Additional design features of this product line include all high quality materials including precise 304 stainless steel disc members. These are aligned and locked precisely into position onto the high strength aluminum alloy hubs with ISO 4762 XL 12.9 corrosion resistant socket head cap screws. The coupling assembly process itself is also controlled with a computerized system for the most precise fit of all components.

Zero-Max ServoClass couplings are suitable for precise positioning requirements and high speed reversing loads common of many AC and DC servo motor systems. These applications include automation of all types, packaging, semi-conductor assembly, laboratory automation and medical equipment, to name just a few. They are designed to provide superior shaft engagement and reliable use with system speeds up to 10,000 rpm. Further, the coupling's increased clamping strength eliminates the need for keyways while providing a clean, balanced design.

Available in 12 sizes with both single and double disc models, ServoClass couplings handle torque ratings ranging from 0.5 to 250 N-m. The ServoClass couplings can also accommodate parallel (radial), axial, and angular misalignments. All ServoClass coupling models are manufactured of RoHS compliant materials.

**For more information:**
Zero-Max
Phone: (800) 533-1731
*www.zero-max.com*

and ambient media. Both products protect against corrosion, as well as oxidation and ageing.

Isoflex Topas NB 52 is suitable for temperatures ranging from -60°F to 250°F and short peak temperatures up to 300°F depending on the application. Isoflex Topas NB 152 can be used in a wide service temperature range of -40°F to 300°F.

Isoflex Topas NB 52 is versatile for many applications, including:

- rolling and plain bearings subject to high speeds and loads, as well as low temperatures – ideal for road, side-guide, and up-stop wheels
- tooth flanks in precision gears, such as bevel gears in milling machines and electromechanical actuators for valves
- electric contacts and components to reduce insertion forces

Isoflex Topas NB 152 is compatible with many plastics and is used primarily for medium speed rolling and plain bearings, such as coaster wheels, wheel bearings in racing cars, fan bearings and pump bearings. The grease is also suitable for plastic/plastic or steel/plastic friction points.

"Using Isoflex Topas NB 52 and Isoflex Topas NB 152 greases leads to more consistent torque over a wide temperature range as well as longer component life when exposed to water or aqueous media," said Stephen Mazzola, director of engineering and technical services for Klüber Lubrication North America L.P.

Mazzola recently conducted two training seminars on lubrication fundamentals and advanced lubrication of gears, bearings, chains at the Amusement Industry Manufacturers and Suppliers (AIMS) International Safety Seminar, Jan. 12–17 in Orlando. The AIMS International Safety Seminar is a comprehensive safety-training experience for individuals responsible for the care and safety of the amusement industry's guests.

**For more information:**
Klüber Lubrication
Phone: (800) 447-2238
*www.klueber.com*

# Maxon

## DEVELOPS SPECIALIZED MOTORS FOR DRILLING OPERATIONS

Deep drilling technology (called "downhole drilling" in the field of oil and gas exploration) makes it possible to recover oil and gas from depths of more than 2,500 m. By combining deep drilling with directional drilling (dynamic position alignment of a bore in the earth), previously unreachable oil reserves are being opened up, with drilling depths of approx. 5,000 m and drill lengths of up to 11,000 m. The development of specialized electronics and drives has made it possible to better monitor and control many functions across the entire drilling process. For instance, it is now possible to dynamically measure and adjust the position of the drill head during the drilling process. Diverse deep drilling tools also use hydraulic valves or flaps that are operated by electromechanical drives. The temperatures and pressures at these depths, combined with the strong vibrations that occur during the drilling work, present unique challenges for the use of electronic drives.

The different versions of the EC-4pole 32 HD are designed for operation in air or in oil (flooded in hydraulic oil). The power rating depends on the surrounding medium and amounts to 220 W in air and, due to the much higher heat flow, 480 W in oil. They are designed for ambient temperatures of more than 200 °C and atmospheric pressures of up to 1700 bar. The Ø 32 mm motors must also be able to withstand vibrations of up to 25 grams as well as impacts of up to 1,000 G (1,000 times the acceleration due to gravity at the earth's surface). As an example, a Formula 1 vehicle is exposed to approximately 2 G and fighter jets are exposed to approximately 13 G. The motors feature high efficiency (up to 89% in air, more than 80 percent in oil), making them ideal for use in battery-operated applications. With their detent-free running properties, they have excellent control characteristics and are suitable for high-precision positioning tasks in outer space, even at low speeds.

The EC-4pole 32 HD is suitable 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.

### For more information:

Maxon Motors
Phone: (508) 677-0520
*www.maxonmotorusa.com*

# Bell-Everman

## SEALED LINEAR STAGES KEEP OUT DEBRIS AND CONTAMINANTS

A new line of ball screw- and linear-motor-driven sealed motion stages has been developed by Bell-Everman, Inc. SLS Sealed Linear Stages feature a novel lip seal design that keeps debris, particulate and liquid contaminants from gumming up the internal drive and bearing components. Made from a ruggedized polyurethane elastomer, the seal integrates seamlessly with the stage's anodized aluminum housing. Polyurethane is resistant to chemical exposures, temperature extremes and mechanical wear. The seal's design allows it to be field replaceable in minutes without disassembling the stage—or even removing the payload in most cases.

Available with both linear motor and ballscrew drives, SLS is intended for precision positioning jobs:

- Linear motor configurations can achieve accuracies of ± 4 µm per meter of travel and bi-directional repeatability of ± 2 µm.
- Ballscrew configurations can achieve accuracies of ± 10 µm per meter of travel and bi-directional repeatability of ± 5 µm.

Other technical specifications include:

- Standard travel lengths from 100 to 1,000 mm and custom lengths to 2,000 mm.
- Speeds to 4 m/sec for linear motor drives and 0.4 m/sec for ballscrew drives.
- Continuous linear force to 300 N for linear motor drives and 1,540 N for ballscrew drives.

Applications for the SLS Sealed Stages include laser machining, welding, semiconductor, machining and many other contamination-sensitive precision motion jobs.

### For more information:

Bell-Everman
Phone: (805) 685-1029
*www.bell-everman.com*

# Igus

PRESENTED WITH THREE DESIGN AWARDS

With multiple awards collected in recent years, Igus has shown the results of using a combination of user-oriented function and advanced design simultaneously in its products. Last month, three Igus products, the chip-proof R4.1 Energy Tube, compact DryLin SLT linear guide, and mounting and transport frame ReadyChain rack were selected after 49 jury members reviewed 4,615 products, communication designs and packaging entered by participants from 55 countries. Since 1987, 31 Igus products have been chosen for the award, which distinguishes products with a high degree of invention, design quality, material, ergonomics, functionality, and environmental compatibility.

### R4.1 Light Energy Tube

The R4.1 light provides cable protection in extreme environments, while still making movement and maintenance easy. The lid of the enclosed tube can be flipped open on either side, allowing for easy access to cables and hoses. At the same time, they are designed in a way that virtually no chips can pass to the interior. In a leakage test, only 2.7 grams of chips were found inside the tube after 250,000 motion cycles. The tube is lightweight, about 25 percent lower than comparable systems, but remains highly stable, allowing cable fill of up to 17 pounds per foot thanks to a double-stop system with large contact surfaces, keeping the load optimally distributed.

### DryLin SLT Linear Guide

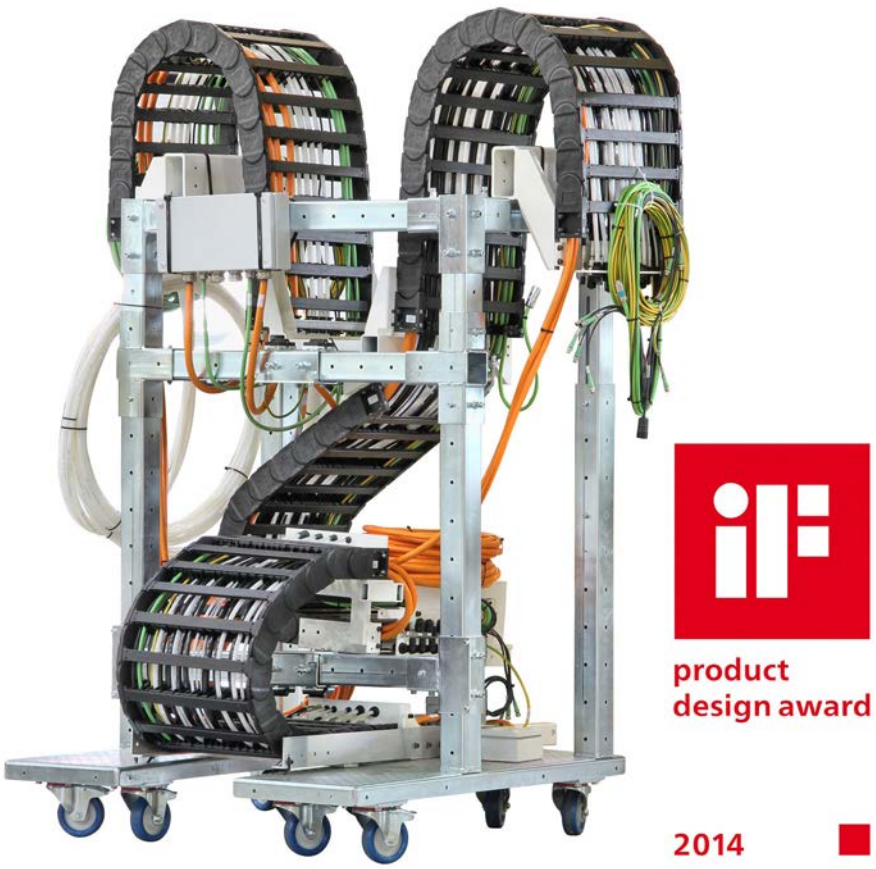
By utilizing a lateral arrangement, with the lead screw next to the linear guide system, the DryLin SLT offers a minimum installation height of just 20 mm, and structural widths of only 45 mm are possible. The compact design is extremely light, weighing in at just over five ounces. The flexible system can be driven manually or with optional motor, and the smooth operation can move at a maximum speed of 5 ft/minute. The lead screw, mounted on ball bearings, is available with trapezoidal or high-helix threads, and a variety of thread pitches are available from stock. Due to its high efficiency, small size and lubrication-free operation, the DryLin SLT is ideal for automation tasks in food and beverage processing equipment, vending machines, and a variety of other applications.

### ReadyChain Rack:

For nearly 20 years, Igus has been providing preassembled ReadyChain Energy Chain Systems, reducing purchasing and process costs in a variety of industries. In order to install the harnessed system even more quickly and more easily for the customer, the ReadyChain rack was developed. The transport and mounting frame is comprised of a modular system of supports and braces, which are able to telescope to adjust for length or height at any given time. Various latching mechanisms are available to ensure the proper mounting of any component. The modular nature of the rack allows for easy adjustments by the customer of alterations become necessary. If the machine happens to be discontinued by the customer, the frame can be broken down into component parts to be reused; a sustainable use of resources and environmentally friendly alternative to waste and disposal of the frame if it were not recycled.

### For more information:

Igus Inc.
Phone: (800) 521-2747
*www.igus.com*



# The Sights and Sounds of IFPE

## Navigating PT Components and Fluid Power in Las Vegas

Matthew Jaster, Senior Editor

**If you attended IFPE 2014 in Las Vegas (co-located with ConExpo and Con/AGG), chances are you saw plenty of products and technologies set to redefine the construction and off-highway markets.** It's a safe bet, however, that you didn't see everything. Between the outdoor maze of cranes and construction equipment and the eye-opening, innovative booths at IFPE, it's okay to admit that you may have suffered from a case of information overload. Here are a few points of interest for those that didn't attend IFPE this year or didn't see everything they wanted to see.

## NFPA

BOOTH 81730

Prior to the show, *Power Transmission Engineering* caught up with Eric Lanke, CEO of the NFPA, to discuss the current state of the fluid power industry. Some of the planned topics at IFPE included the trends and challenges of the global construction equipment industry, a report from the International Fluid Power Statistics Committee, a worldwide fluid power market trend by country including Britain, Canada, China, Germany, India, Italy, Japan, Mexico, Taiwan, Turkey and the United States and a report on ISO/TC 131 Work and Priorities.

"In a survey this past year, NFPA members told us the most challenging issues they will face in the next five years include the recruitment of a skilled workforce, differentiating themselves against competing technologies and dealing with the demands of a globally competitive business," Lanke said.

With this information, the NFPA board of directors set their strategic priorities for the next several years. "These priorities include building and connecting our members to an educated fluid power workforce, promoting the technical advancement of fluid power and serving as a forum where all fluid channel partners work together," Lanke said.

On the education front, Lanke reports that a $100,000 grant to develop a new fluid power lab was recently awarded to the Milwaukee School of Engineering (MSOE). The envisioned mechatronics/fluid power lab will support a transformative curriculum that will develop students' technical skills through the four years of undergraduate study. "In 2012, the first grant in our program was awarded to Western Michigan University for a lab that is already impacting 40 students in the IME3840 Fluid Mechanics and Hydraulics class. It is anticipated that 130 students in five different undergraduate and graduate level classes will get hands-on experience with the lab each year," Lanke said.

The NFPA is looking forward to a successful 2014 and keeping a close eye on the future of the evolving fluid power industry.

"The fluid power industry continues to be shaped by changes in both technology and geography. On the technology front, electronic controls and hybrid-electric systems are changing fluid power's capabilities and application within a suite of motion control technologies. On the geographic front, U.S.-based fluid power companies are increasingly global in their footprints and their market strategies," Lanke said.

**For more information:**
NFPA
Phone: (414) 778-3344
*www.nfpa.com*

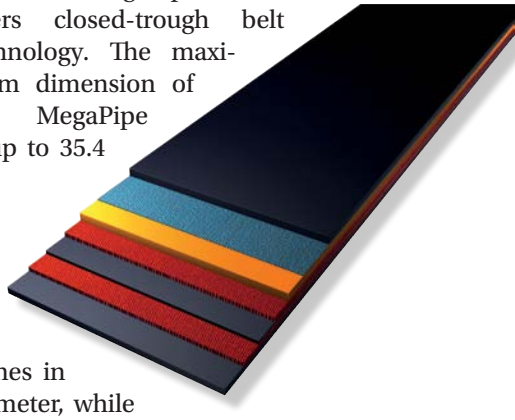
## ContiTech

BOOTH 9479

ContiTech offered innovative products for various applications — from heat-resistant conveyor belts and high-performance hose lines to air spring systems for construction and agricultural vehicles.

The ContiTech Conveyor Belt Group offers unique conveyor belts for the transportation of hot bulk materials being utilized by industrial companies worldwide. These belts can be used to transport extremely hot materials (up to 1,000 degrees Fahrenheit). The conveyor belt can be manufactured using different components and compounds depending on the type of application, thus ensuring tailor-made solutions.

With the MegaPipe, ContiTech offers closed-trough belt technology. The maximum dimension of the MegaPipe is up to 35.4 inches in diameter, while standard brands do not exceed an external diameter of 27.6 inches. Thus, the capacity of the conveyor system is increased by more than 100 percent compared to conventional closed-trough belts. With this new development, the ContiTech Conveyor Belt Group now provides an enclosed conveyor belt solution which can transport large lump sizes. MegaPipe can be utilized immediately after a primary crusher application.



ContiTech Fluid Technology has developed hot-end fuel lines specifically for modern high-performance engines. They can withstand pressures of up to 35 bar and operating temperatures of up to 180°C. "Thanks to our comprehensive material and process expertise, we are also a development partner and original equipment manufacturer of tailor-made complete solutions for fuel applications including hoses, pipes, tubes, fittings, and quick couplings designed to transport media such as gasoline, diesel, hydrogen, and LPG in engine fuel supply systems," says Achim Liecker, sales manager for industrial vehicles. Elastomers and plastics are used here, combined with materials such as textiles, steel, and aluminum.

Additionally, the company offered its ECO AC refrigerant circulation system from ContiTech Fluid Technology, large hoses for water, oil, cement, and bulk material applications and air springs for off-highway vehicles. These springs can also be used in agriculture implements like boom sprayers, seeders and trailers to stabilize the boom, provide suspension or serve as a low cost actuator with high reliability.

**For more information:**
ContiTech
Phone: (800) 654-0974
*www.contitech-usa.com*

# Bosch Rexroth

BOOTH 80216

Dana Rexroth Transmission Systems announced during the show that its R2 hydromechanical variable transmission (HVT) is undergoing bench testing in the final validation stage of development. Engineers expect the R2 HVT to enter field testing across a wide spectrum of market vehicles by the end of the year, with production slated to begin within the next 12 months, depending on OEM adoption.

The R2 HVT is a modular platform that delivers a full suite of configuration options and software controls, such as direct or remote mounting, flexibility in shift control and drive strategy parameters, and the deployment of up to three PTOs. It is the latest powersplit system resulting from the 50-50 joint venture between Dana Holding Corporation and Bosch Rexroth AG.

Designed to maximize efficiency and reduce overall vehicle ownership and operating costs, the R2 HVT is suitable for front-end loaders, motor graders, industrial lift trucks, reach stackers, forestry skidders, and other select off-highway applications requiring 180 to 260 hp (135 to 195 kW) of engine output power.

Initial tests on front end loaders with Dana Rexroth's HVT powersplit systems demonstrate fuel savings in the drivetrain of up to 25 percent when compared with the same vehicle outfitted with a conventional torque converter transmission.

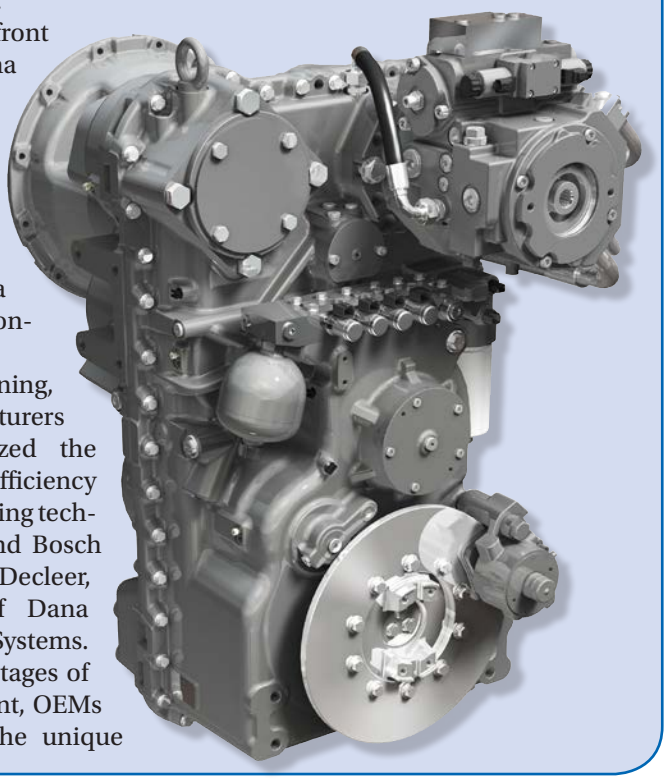
"From the beginning, equipment manufacturers have readily recognized the dramatic increases in efficiency that result from combining technologies from Dana and Bosch Rexroth," said Jeroen Decleer, managing director of Dana Rexroth Transmission Systems. "As we enter the final stages of testing and development, OEMs are seeing firsthand the unique benefits that can result from integrating hydrostatic, mechanical, and control systems through a modular approach."

HVTs from Dana Rexroth improve productivity by enabling sensitive, precise vehicle positioning with a stepless drive that offers improved acceleration while maintaining tractive effort. They occupy the same space within the design envelope as conventional torque converter transmissions while allowing for engine downsizing.

The HVT optimizes the operating point of the diesel engine by decoupling engine speed from drive speed, and maintenance costs are reduced by utilizing hydrostatic braking and wear-free directional reversing.

This HVT system helps reduce complexity for equipment manufacturers, since the entire system of gears, clutches, and hydrostatic units is managed by an advanced electronic control unit (ECU) and optimized for efficiency by a single supplier.

**For more information:**
Bosch Rexroth
Phone: (800) 739-7684
*www.boschrexroth.com*

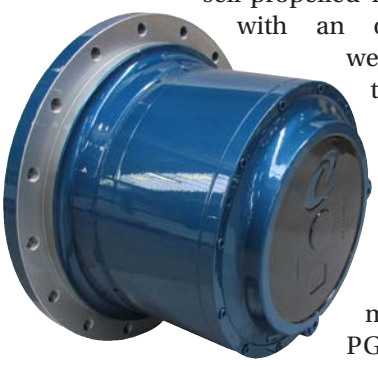


# Comer Industries

BOOTH 82130

Comer Industries featured a variety of axles, wheel drives and heavy-duty track drives during the show. Some highlights at the show included a series of new-generation axles starting from S-228, which delivers the highest braking and efficiency performance for the category, and the heavy duty track drives PGRF-7003/11003 for track mobile equipment (crawling forestry machines, drill rigs and excavators, compactors, cranes) and for winches or milling applications, which represent compact, flexible and robust solutions. Comer Industries also showcased planetary drive PG-3503PR for crawler cranes and drilling machines, featuring a compact output that provides high performance for maximum torque and loads, axle S-128 for application on compact telehandlers and wheeled excavators, planetary drive PG- 954PR for use on concrete pumps.

Other products on display included the planetary drive PGRF-25004 for very large winches and fully tested at Comer Industries' Mechatronics Research Center; the slewing drive PG-5003PR for tower crane applications; the wheel drive PGR-402 with automatic shift, designed to equip tracked self-propelled machines with an operating weight up to 7t; the track drive PGRF-802 for crawler equipment; the PGRF-2403 single speed planetary drive for road rollers and the PGRF-1702 drum drive for compactors.



**For more information:**
Comer Industries
Phone: (704) 588-8400
*www.comerindustries.com*

# B&R Automation

BOOTH 83550

B&R offered modular systems for off-highway vehicle architectures and displayed its new MA170 control and I/O system. This device series has been specially developed for use in harsh conditions. An IP65 housing and coated circuit board allows these modules to withstand extreme temperatures from -40°C to +85°C without difficulties. These new B&R modules are also shock and vibration resistant. The MA330 mobile automation keypad system with intuitive handling, robust design and flexible functionality was also featured. In addition, the company recently equipped mobile devices with CAN bus, and the option to use Powerlink, the deterministic real-time protocol for standard Ethernet. This open source Ethernet protocol can address both data and control needs on a single wire, while reducing design costs, minimizing system jitter, and achieving maximum system performance.

The new Panel PC 900 with multi-touch functionality from B&R offers high levels of total computing power. Combining brand new display sizes with multi-touch operation, B&R's new flagship system is more versatile, offering full compatibility with the previous device generation.

Recently, the company also offered Hart Modules to the X20 I/O series. B&R now includes an analog Hart input module and a Hart output module in their successful series of X20 communication modules. These new modules are equipped with two inputs and outputs and use real-time Ethernet Powerlink to transfer Hart data supplied by sensors and actuators directly to the controller. To evaluate the data, the controller forwards information via the process bus to maintenance stations with FDT containers, for example B&R Automation Studio, PACTware or FieldCare.

**For more information:**
B&R Automation
Phone: (770) 772-0400
*www.br-automation.com*

# Bonfiglioli

BOOTH 80642

The 700CT series from Bonfiglioli offers an extremely compact, lightweight and reliable solution for compact construction equipment for machine weights from 2.5 up to 9 tons. Key features include: integrated axial piston hydraulic motors, high torque capacity: 3,500 – 12,500 N-m (31,000 – 110,000 in-lb), gear ratios form 15 to 33, high load capacity, mechanical lifetime seals, rotating output flange with large PCD suitable for sprocket, speed sensor mounting, hydraulically released spring applied parking brake, with external independent port.

With Bonfiglioli Trasmital hydraulic motors with fixed OR dual displacement, flushing valve circuit (suitable for closed-loop applications), the 700CT series is an efficient solution that will provide smooth and reliable operation for many years.

With one of the widest ranges of torque available on the market today and countless configurations, the 700C series from Bonfiglioli is suitable for any size crawler machine in any off-highway application. The 726C (on display at IFPE), is a travel drive that transmits up to 625,000 N-m (5.5 million in-lb) of torque in heavy-duty excavators up to 350 tons and cranes and drilling rigs up to 400 tons. With advanced engineering and technical

# Danfoss

BOOTH 80529

Danfoss has introduced the 210/250 $cm^3$ pump frame sizes that complete its H1 family of piston pumps and bent axis motors for high-power mobile machines. With these additions, the now comprehensive range comprises 14 pumps with displacements covering 45–250 $cm^3$, five bent axis motors spanning 60–250 $cm^3$ and five control options – a scope that leads the market for advanced transmission solutions. "The largest frame sizes in our range bring new-generation hydrostatics to agricultural harvesters, combines, forestry machines and shredders, meeting OEM demands for top design flexibility and operational precision, efficiency and safety," says Markus Plassmann, product marketing manager for high power closed circuit products. Featuring a compact, lightweight design, the H1 pumps and motors afford maximum flexibility when designing systems for today's emission and functional safety legislation. High operating efficiency compensates in full for the lower rpm of emissions-compliant engines – the motors outperforming the competition by up to six percent. "As we approach full implementation of the US Tier 4 emission legislation in 2014, OEMs need effective transmissions that maximize the use of available engine power," says Plassmann. "H1 provides the necessary flexibility and functionality, improving fuel economy and saving power for other vehicle functions."

A patented integrated speed limitation (ISL) circuit adds to the high-level pump functionality, enabling improved vehicle braking with no risk of engine over-speed.

In designing the optimized electric controls, Danfoss has paid attention to the SIL 2 functional safety requirements that, along with Tier 4, are driving the trend towards intelligent machine management. Enabling automatic adjustment of vehicle driving characteristics to on or off-highway conditions, H1 Automotive Control (AC) is pre-SIL 2 certified.

"H1 AC brings intelligent electronics to machines such as telehandlers, wheel loaders, dumpers and sweepers, which need to maintain a constant speed when moving up and downhill," Plassmann explains. "In transport mode, H1 AC switches to automotive driving characteristics for the best operator comfort."

Most recently, Danfoss has supplemented H1 AC with Eco Mode and Cruise Control options. Configured to lower engine rpm during on-highway transport, Eco Mode cuts fuel consumption by up to 20 percent. The entire H1 family is compatible with the Danfoss Plus+1 control platform, including pre-tested software blocks that save on system development time, bringing new applications faster to market.

**For more information:**
Danfoss
Phone: (515) 239-6000
*www.powersolutions.danfoss.com*

specifications, it is suitable for heavy duty applications like mining. Key features of the 700C series include a torque range 1,000 – 625,000 N-m (8,850 – 5.5 million in-lb), gear ratios from 5.3 to 492, rotating housing, high load capacity, mechanical lifetime seals, compact design, cartridge axial piston motors, flange axial piston motors, orbit motors, failsafe parking brake (hydraulically-released parking brake on request). The 724C and 722C for mining crawler cranes, 710CK for excavators and 720C for lift cranes were also on display during the show.

For Class 1 material handling vehicles, Bonfiglioli supplies high efficiency, low noise planetary axles and drives with integrated, high performance electric motors and low maintenance braking systems. Typical applications include 3- and 4-wheel counterbalance lift trucks and ground support equipment. With a guaranteed reduction in energy consumption, the electric powertrains enable longer battery times, extended service intervals and a lower total cost of ownership. Complemented by a range of idle steering systems based on number of axles or steering units, the 600F series is suitable for material handling vehicles (CB forklifts, airport equipment), indoor and outdoor use, CB trucks with lift capacity from 1.6 to 5.0 tons, GSE vehicles with draw bar pull from 6,000 to 25,000 kgf (13,227 to 55,115 pound-force).

**For more information:**
Bonfiglioli USA
Phone: (859) 334-3333
*www.bonfiglioliUSA.com*

# Bosch Rexroth

## Powers Coal-Handling Equipment with Hydraulic Direct Drive


150 Hägglunds drives are in operation at the EECV port. Rexroth cylinders and power units can also be found on stacker/reclaimers and ship-unloaders, ranging from relatively small units for hinged lids to massive units holding the arms or jibs (all photos courtesy of Bosch Rexroth).

**EECV in Rotterdam, the Netherlands, keeps on expanding and improving.** In 2013 their transhipment of coal increased and they installed a new bucket wheel reclaimer with a capacity of 3,500 tons per hour. They chose a direct-drive system from Bosch Rexroth for this big bucket wheel. The drive system consists of a Hägglunds MB 1600 motor and a DUe drive unit. It is the seventh bucket wheel reclaimer at EECV with Hägglunds direct-drive systems installed and has been in successful operation since February.

### Versatility

Direct drives are suitable not only for the bucket wheel itself, but also for many of the main functions on a stacker/reclaimer. Their specific advantages and high torque capacity make them well suited for heavy-duty applications. At EECV, Hägglunds direct drives are also installed for slewing and long traveling on some of the stacker/reclaimers; on three of the four older stacker/reclaimers the slewing drives have been changed to direct drives, replacing the electric motor with brake, gearbox and open gear stage. Today, Hägglunds CB 840 motors with Bica brake successfully drive the pinions for slewing. The long travel drives on two of the bucket wheel reclaimers have been fitted with Hägglunds CA 50 motors.

Govert de Bruin, mechanical manager at EECV, said "These drive systems offer reliability and torque. They are low maintenance, have a long life span and we always receive excellent support."

### Long-term performance

In 1987 EECV installed the first Hägglunds direct drive on two of their apron feeders in Rotterdam. Since then they have installed direct drives on the remaining apron feeders, their bucket wheels, slewing drives, long travel drives and conveyor head wagons. Today some 150 Hägglunds direct drives can be found at EECV. In addition to the Hägglunds drive systems, the stacker/reclaimers and unloaders are also equipped with Rexroth cylinders and power units. The cylinders range from relatively small, suitable for hinged lids, to massive units that hold the arms or jibs.

## The first direct drive – More than 140,000 trouble-free working hours

EECV was first introduced to the hydraulic direct drive concept in 1984. They had previously experienced problems with variable speed electromechanical drives, leading to high repair costs and unacceptable production losses. At that time, EECV was handling iron ore and considering other options; after considerable research, discussion and investigation, they decided to try an alternative technology. In 1987 EECV installed the first two Hägglunds MA 200 motors on the two apron feeders on one of the ship unloaders.

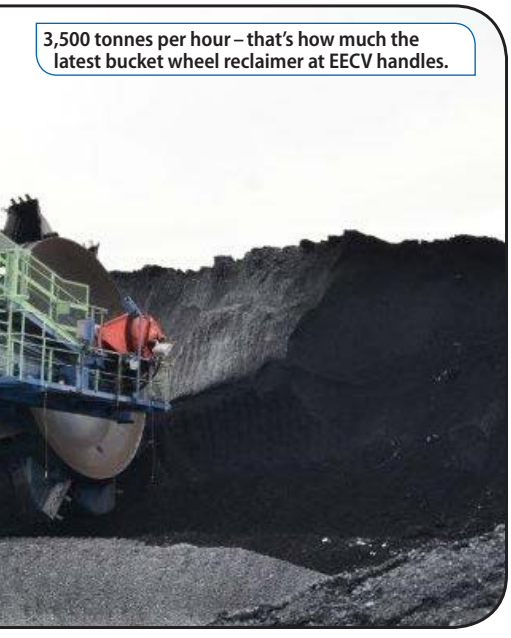
After one year of trouble-free operation, EECV was sufficiently pleased to order an additional four motors for the remaining apron feeders. Today, 26 years later, the first two motors have been running for more than 140,000 hours and are still working perfectly. Only the shaft seals and wear rings have needed to be replaced, but only twice. The apron feeders that were the source of so many headaches in the past now run so well that many people at EECV say they even forget the drives are there.

"Before using the hydraulic drives we had constant headaches. We tried several variable-speed solutions, but we were constantly plagued by unforeseen downtime and high maintenance costs. Ever since we introduced the Hägglunds motors, things have been working perfectly," de Bruin said.

## The first bucket wheel drive– production increased by 15–20%

Performance of bucket wheel stacker/reclaimers is essential to EECV operations. When problems were encountered here, they chose to install the first hydraulic bucket wheel drive based on their positive experience with direct drives on apron feeders. The solution was the prototype of the Hägglunds MB 1600 motor. The advantages of direct drive on bucket wheels

soon became apparent, with features such as variable speed that optimized material throughput, while overload protection and high starting torque reduced stall delays from the prior 90 seconds down to about 10 seconds. In addition, the highly reliable system features low weight that reduces the load on the slewing bearing, while its



3,500 tonnes per hour – that's how much the latest bucket wheel reclaimer at EECV handles.

excellent overload protection has significantly reduced both downtime and maintenance costs, which are even further reduced by soft, smooth starts.

The first hydraulic bucket wheel direct drive was commissioned in April 1991 and has now logged about 50,000 trouble-free hours. After 7,500 hours the motor was opened and inspected in the presence of EECV engineers. The results were impressive: everything was in perfect condition. In 1992 EECV ordered an additional three direct-drive systems for their remaining three stacker/reclaimers. The hydraulic bucket wheel drive has boosted production by a total of about 15-20 percent, depending on materials and circumstances, while simultaneously slashing maintenance costs. Over time, the slewing drive on the first three stacker/reclaimers was also replaced by direct drives.

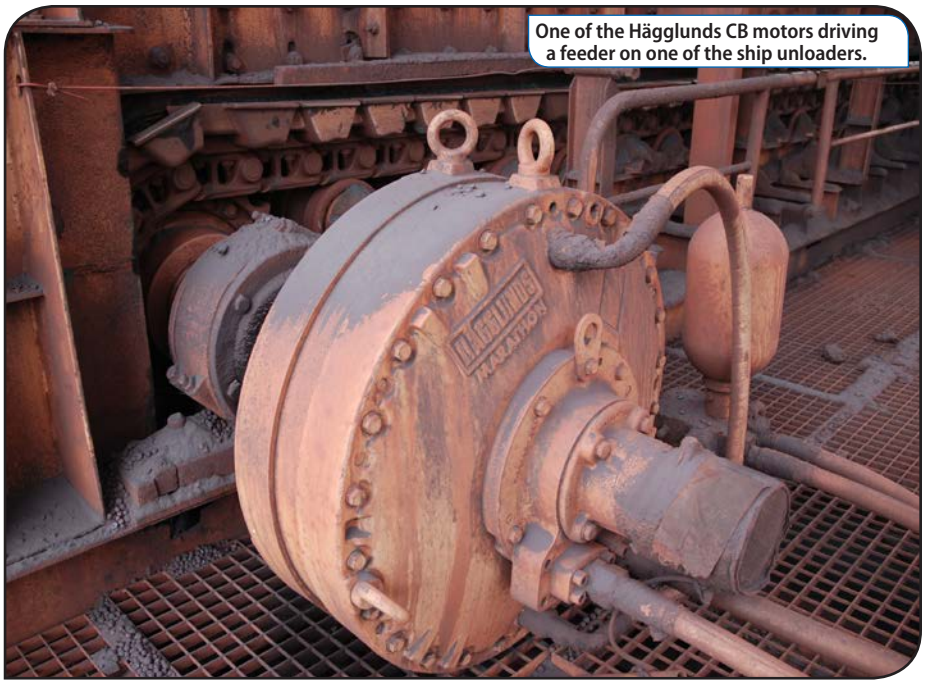
## Small but powerful

The small, compact Hägglunds CA motors with MDA brakes were soon also found to be suitable for the long travel drives that move the large ship unloaders along the rails. Between 2001 and 2010, direct drives were installed on the long travel drives of the ship unloaders, providing benefits such as simplicity, automatic load-sharing and reduced system complexity. In all, 54 direct drives, 18 on each unloader, were installed on the long travel drives, providing a compact and clean solution around the wheels, fewer components in the contaminated area, and convenient cleaning using water jets. Maintenance also improved and could be concentrated to a single sheltered convenient location.

## Going into coal

In 2005 EECV expanded operations to encompass coal transshipment. Two new stacker/reclaimers and a barge loader were ordered for this purpose. Hägglunds direct drive systems were fitted on the bucket wheel of the stacker/reclaimers, as well as on the long travel drives. The barge loader was fitted with twelve Hägglunds CA motors and Bica brakes. In 2008 coal operations were further expanded with a new ship unloader, a grab-type portal crane with a 65-ton hoisting capacity. This time around, Hägglunds direct drives were specified for the long traveling wheels, the feeders below the bunker and their head wagons. The long travel drives were equipped with 18 CA 100 motors with MDA 14 brakes, one on each side of a double wheel set. This clean, compact solution results in excellent load-sharing, as well as smooth starting and stopping. Two Hägglunds CB 280s with built-in crossover valve

EECV's Mechanical Manager Govert de Bruin and Bosch Rexroth's Hans Langerak have met with each other many times since long-term cooperation between Hägglunds Drives, now Bosch Rexroth, and EECV began in 1983. In the background is one of the first bucket wheels at EECV with Hägglunds direct drives installed.


One of the Hägglunds CB motors driving a feeder on one of the ship unloaders.

and speed encoder are installed on the feeders, providing advantages such as excellent starting torque and performance, overload protection, and convenient maintenance. Two CA 70s were also installed on the head wagons. Drive units and the rest of the system were engineered, produced and delivered by Bosch Rexroth in a collaborative effort involving their German and Chinese facilities.

## Experienced service

The drive systems and motors at EECV are handled and maintained by an enthusiastic small team of hydraulic engineers. The teams were previously managed by de Bruin, who is currently mechanical manager at the site. When asked to give his opinion about Bosch Rexroth's direct drives he does not hesitate: "I've known Hägglunds for a long time. Hägglunds

stands for torque, longevity, reliability, low maintenance costs and excellent service and support."

## New direct drive brings new possibilities

The latest addition to Rexroth's wide range of products is the Hägglunds CBM motor, released in late 2012, yet another direct drive that is advantageous for many heavy-duty applications. The new motor opens up new possibilities. The CBM not only handles heavier workloads, but also occupies less space and places less weight on the driveshaft. This allows customer machines, and in some cases the facilities that house them, to be smaller, lighter and simpler.

The motor's reduced installation requirements, combined with improved productivity, can translate into lower overall investment and higher long-term revenue; added to this are the unique operating advantages of a hydraulic direct drive: full torque from zero speed, protection from shock loads, overload protection and four-quadrant operation. **PTE**

### For more information:

Bosch Rexroth AG
Phone: (800) 739-7684
*www.boschrexroth.com*

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hydraulics
at www.powertransmission.com

# Good Purchasing Personnel Are a Priceless Investment

Jack McGuinn, Senior Editor

"A purchasing manager is an employee within a company, business or other organization who is responsible at some level for buying or approving the acquisition of goods and services needed by the company."

**— U.S. Dept. of Labor**

Seems simple enough doesn't it? It is most decidedly not. Indeed, one can make the case that—aside from uppermost management (or ownership)—no one else in a heavy/high-tech manufacturing concern has more ownership of the company's everyday needs and necessities than the purchasing department.

Yes, unsung heroes have it tough—they are rarely seen *or* heard. And yet they are all around us in everyday life—e.g., fire department, social services, law enforcement—you name it.

So why not add purchasing personnel to the list? Whether it is manager, buyer or agent—purchasing people play an integral role in manufacturing settings like those that receive this magazine. And of course we're talking about those agents involved in the sexy stuff—not pens and paper and sticky notes—but gears, motors, bearings, etc. To do that job well, the purchasing buyer must be adept at—among other things—evaluating suppliers based on price, quality and delivery speed; and interviewing vendors and visiting suppliers' plants and distribution centers to examine and learn about products, services and prices.

Of equal importance, purchasing buyers must: know their way around price proposals, financial reports, and other information to determine reasonable pricing; be able to negotiate contracts; work out binding delivery agreements with suppliers; determine root cause and corrective action of defective or unacceptable vendor goods or services; evaluate and monitor contracts to be sure that vendors and suppliers comply with the terms and conditions of the contract and to determine any need for changes; maintain and review records of items bought, costs, deliveries, product performance, and inventories.

As mentioned, it must be tough. OK—not so much the hero part. But having to deal on a 24/7 basis with deadlines and contracts and prices and delivery dates constantly swirling through one's head.

To find out how tough, we went and asked some purchasing folks. The following comments are from: Bill Cidlik, VP operations and Roxane Durst, master scheduler, Arrow Gear; Douglas Felsenthal, vice president, Kleiss Gears Inc.; Schafer Driveline (SD; did not wish to name a spokesperson); Pat Greathouse, materials manager/tooling, Sunnen; and Barb Watkis, purchasing manager, Zaber Technologies.

Given the skillsets required today to cut it as a competent purchasing buyer, it figures that filling that position — and keeping it filled — is just as difficult as finding a good machinist. Let's see.

"To perform this job successfully, an individual must be able to perform each essential duty satisfactorily," says Bill Cidlik. "The requirements listed below are representative of the knowledge, skill, and/or ability required. Reasonable accommodations may be made to enable individuals with disabilities to perform the essential functions. Education/Experience: Master's degree (M.A.) or equivalent, or four to ten years related experience and/or training, or equivalent combination of education and experience.

"Arrow Gear has a long history of promoting from within. Many people have used Arrow's tuition assistance programs."

"The individual should possess expertise and knowledge of the supply chain from order placement to shipment," says Sunnen's Pat Greathouse. "A well rounded understanding of manufacturing processes and ERP systems and be able to execute and implement in alignment with corporate goals. We try to emulate the Institute of Supply Management's (ISM) standard practices in conducting business. An individual needs to be knowledgeable regarding this."

As for finding good candidates**, "**It is definitely a challenge," she concedes. "We have a stringent interview process. We try very diligently to make sure the candidate possesses the skill sets that are required, but would also fit with the team dynamics. When we find a candidate that we feel has the foundational skill sets and would be a valuable asset to the team, we take the time to develop and train, if required."

"(Purchasing personnel) should possess expertise and knowledge of the supply chain from order placement to shipment,"

**Pat Greathouse, Sunnen**

And at Zaber Technologies, Barb Watkis says they look for "A background in numbers (accounting), sales and logistics (as) a good place to start. Knowing the product components is essential in understanding lead times and negotiating on price. Purchasing for Zaber is based on short lead times for our customers while maintaining optimum stock levels in our inventory.

It is a balance of knowing supplier lead times and not keeping too much stock on the shelves.

"Developing good relationships with suppliers and taking advantage of volume pricing is an important part of purchasing at Zaber. Good relationships with suppliers help to ensure that we are notified of delays and allow us to receive emergency goods when needed."

And given the job skills shortage?

"Zaber tries to promote from within," Watkis says. "I started in administration, sales and shipping at Zaber. I already had a background in accounting and purchasing from previous jobs. Having this type of experience and education within a company helps with knowing the company core values. Once you have the core values, you can put the knowledge and learning to use around it. I think for Zaber it would be tough for a purchaser to not have this previous knowledge."

Given their job description, it is not surprising that purchasing buyers are involved at most every level of product development—new and existing.

"We are basically involved once the concept is developed," says Greathouse. "We are involved before the prototypes are developed. We will also bring in our suppliers, as required, to give input on areas that are the suppliers' core strengths and asking what are their 'lessons learned' with the product. We will then take these into consideration in the design.

"The value of doing this has been proven over many projects. We incorporate these cross-disciplines to converge and contribute valuable information as it relates to their area, which ultimately leads to a smooth project launch."

"Purchasing is involved in monthly APQP meetings with engineering to receive updates on new projects that are being developed," says SDL. "There is also involvement in obtaining quotations for sample parts and ordering the same. Once parts are released, purchasing is responsible for issuing tooling, PPAPs (production part approval process), and production part orders."

While at Arrow Gear, "Purchasing personnel are involved from the initial quoting process through the assembly, testing and shipment of the gearboxes," says Cidlik. Durst adds that "As soon as we receive the customer's drawings I start reviewing with our technical quality department-approved sources and specifications. Through the entire process purchasing is involved to ensure that proper certification and quality details are followed to avoid delay upon completion of the unit."

We've all read many articles on lead-time nightmares and the customers who cause them. Just think of the dreams purchasing people must have. After all — *nothing* happens until the needed material comes through the door. And if, like Arrow Gear, your niche is aerospace, we're talking of a need for nerves of steel.

"The constant delivery pressure is a way of life in the aerospace gearbox world," Cidlik allows. "Aerospace PAs must have the drive and desire to achieve the impossible on a regular basis. It's the same for both internal manufacturing and outside purchases. Daily follow up is the only way to keep these projects involving up to 300 part numbers on schedule."

Adds Durst, "Arrow Gear is all about satisfying our customers. We do everything possible to meet our promised delivery schedules. Daily production meetings— with communication between manufacturing and purchasing—help to keep us on schedule. The aerospace processes are long and can have several outside services."

"No doubt there are pressures to deliver product 'yesterday,'" Greathouse agrees. "We rely on relationship building with our suppliers and we continue to have good working relationships. We also share information of forecasting key component parts so we can be flexible in reacting to fluctuations in sales. We also focus on what we determined to be 'key items' so we can react to customer needs quickly and have seen the positive results from this strategy."

Schafer Gear sees the dilemma as a "balancing act between satisfying the customer and respecting the lead times and capacity of our supply chain. The key is to communicate effectively with the customer, supplier, and production team to deliver what you promise on time and at an effective cost. Limit surprises."

"The lowest-price supplier may not be capable to supply the required certifications and documents for aerospace parts."
**Roxane Durst, Arrow Gear**

"We are very transparent at Zaber with communication," says Watkis. "Customers and production are always up-to-date on the status of a product with the constant follow-up on suppliers by a purchaser. By being so upfront about our product status, it helps for customers to trust us."

And then there are bearings—those crazy spheroids that can drive engineers and maintenance crews crazy. But how do they affect purchasing buyers?

At Arrow, "Since we build our gearboxes to customer drawing and specifications, the bearing details, including the manufacture, are provided. We insist on the bearing manufacturer to certify all material and processes used to manufacture the bearings," says Cidlik. Durst adds that "A specific brand with manufacturing date is required on the customer drawings."

"We rely on our engineering group to determine the bearing suitability when sourcing," says Greathouse. "If an alternate is required, we initially determine that form, fit, and function are exact. The load ratings and how the load ratings were determined are reviewed by our engineering group be-

fore any alternate bearing is approved. We spend countless hours testing the bearings to ensure their performance when a bearing is installed in the assembly. We are confident the bearing is going to perform as expected."

We then put to the group what they considered to be the most complex issue facing buyers today. To a degree it depends upon what is being manufactured.

For instance, at aerospace-intensive Arrow Gear, "Adhering to all customer, military, and in-house specifications, and coordinating the shop production schedules and the outside purchased items to arrive when needed to assemble the gearbox," says Cidlik. For colleague Durst, "A big challenge is keeping on top of all the different customer quality specifications and paperwork requirements to avoid delays at the end. I work closely with our quality department, making sure every "i" is dotted and "t" is crossed at each operation."

Greathouse believes it is "Determining the scope of what is required (for) compliance with various regulations initiated by the government/European Communities."

Zaber's Watkis says it is "Communication with overseas suppliers. It can be hard to get a confirmation from some suppliers based on time zone, different culture practices, and payment options."

And for an example of an everyday purchasing problem that *never* goes away: "Pricing is the most challenging part of the job" says Arrow's Cidlik. "These gearboxes are very competitive, so being the lowest cost producer is what it takes to get business." And beyond price, Durst explains, "The lowest-price supplier may not be capable to supply the required certifications and documents for aerospace parts."

Conversely, perhaps the most satisfying part of the job is working with the various departments throughout the company in bringing product—especially new —to manufacture and seeing it roll out the door—on time and within budget.

But how does that work? Here again, it depends.

As Sunnen's Greathouse points out, "As mentioned, we involve our suppliers early on so they are very much part of the process. When a component fails, the supplier is made aware immediately so their engineering team can work with our engineering team to determine the root cause of the failure and ultimately the corrective action is determined. It is definitely a team effort—both internally and externally."

For Schafer Driveline, "New products typically begin development in our engineering department. Purchasing receives various requests from engineering during development to obtain quotes and purchase samples for sample drawings that are produced. There can be some work with engineers as quotes are returned to modify design to reduce cost or improve the ability to manufacture.

"If a chosen material fails sample testing, typically the engineering department works with our on-site metallurgist to determine root cause and corrective action to adjust the design. Once production drawings are released, we would finish sourcing by obtaining updated quotes and issuing purchase orders for PPAP and production parts."

"Aerospace purchasing works directly with the sales department and also the engineering department from the quotation, order entry and manufacturing process," says Cidlik. "Once the complete bill of materials (BOM) is created, the purchasing job is critical to the success of the gearbox project. Some long lead time items must be ordered immediately—even before the BOM is completed." As for Durst, and considering we're talking aerospace parts, this is pretty impressive—"I work closely with our gear design engineers, ensuring the approved sources understand the required drawing specifications."

And what of supply chain issues? The best capitalized, equipped and staffed company in the world goes nowhere without the *uninterrupted* flow of raw materials needed to manufacture product. Yes, uninterrupted is the key—or perhaps better said, steady supply with *no surprises*. It is the surprise factor that will incur unplanned downtime and cash losses; schedulers can plan for scheduled interruptions. But a crackerjack purchasing buyer somehow manages to stay on top of the supply chain dynamic and avoid unexpected catastrophes.

"Purchasing personnel are involved from the initial quoting process through the assembly, testing and shipment of the gearboxes."
**Bill Cidlik, Arrow Gear**

For instance, at Sunnen, "The buyers monitor the indices that are most affecting the commodities they are responsible for," says Greathouse. "The purchasing area is active in the local ISM affiliate for continuing education. The *Purchasing Managers' Index and Report on Business* are valuable tools we monitor monthly.

"ISM is a great resource to educate and keep the pulse of what your peers are seeing in the everyday business life unfiltered. We also are in contact with our suppliers to verify if what we are seeing in the indices and PMI (Project Management Institute) are translating to what we see in our spend analysis. Planning and purchasing areas actively coordinate very closely our requirements. "The planning area is active in the local APICS (American Production & Inventory Control Society) affiliate. Sunnen sponsors educational and certification classes from both organizations to ensure our folks are trained and able to execute the latest processes and trends to optimize spend and minimize inventory. And ensuring the inventory we are carrying is the correct inventory for what we are building and servicing customers." **PTE**

# The Purchasing Buyer: An Agent for Relationship-Building

*Here's a Q&A take on what's expected of a purchasing buyer from a customer perspective. The "customer" in this case is Kleiss Gears, represented by Douglas Felsenthal, company vice president.*

***Jack McGuinn, Senior Editor***

**Q: With the ongoing advancement of high-tech manufacturing, what background does a manufacturing company such as Kleiss Gears demand in a top-level purchasing agent today?**

A: *Ours is much a systems level world. For top-notch product results, it is not about individual components. It is about interaction of each component to the whole device or product. Therefore, we need a PA with technical engineering skills to understand how and why this is so and then be able to communicate that to his own organization. We need a partner in the customer company. I would look to interface with an industrial or manufacturing engineer background to do a proper job in this area. Along with this, someone who is grounded in finance and how the whole customer company works.*

**Q: Perhaps the culture differs from company to company, but to what extent are purchasing personnel involved in new projects at Kleiss Gears? Just on a "need-to-know" basis or are they in for the whole ride—from print to production?**

A: *In our customer companies I see the PA as the bridge between the dream of design and the realities of what can be produced. They are integral to the whole team in bringing back the technical aspects of component manufacturer to the OEM operation. Without this function, the engineering organization will produce devices that are overly expensive or cannot be produced at all. There are three areas of procurement—off-the-shelf, custom, and new R & D required. The PA needs to know which and has a very key role.*

**Q: With, in recent years, the constant pressure from customers — We need it yesterday! — how does that affect how PAs do their jobs? Even for internal customers, when you have to tell the salesman, the sales manager and the production manager that you will not be able to bring in the needed say, material, as soon as they would like?**

A: *This is probably the biggest money waster in the business. I could tell you stories. But at the beginning of a new program, money is of no importance to meet a timeline. But in reality, at the end, time wins as no value and we look back and see money just wasted on things that just don't have to be done. In a generic sense, I have several examples of customers who threw 2X at projects to get done in unrealistic speeds, just to have those projects languish at the end over all kinds of internal development issues. One example—a customer who had to have his gear tooling done in five weeks and production lines up in 16. Production hasn't been realized in 6 years. There were tremendous amounts of waste here. It's happened more than once; so much in fact that when projects come along with these unrealistic requests, I just have to laugh.*
*The PAs have to stop being demanding. Think relationships; this is the long-term goal. Too many PAs just become "bad" people. The PA has to go back to his organization and thoroughly understand what is driving the push, how has it gotten out of control, and guide everyone into knowledgeable decision-making. I would suspect that the misconnection started at some senior management level that did not have the proper scope or understanding. The PA could be the conduit here. This is where PAs can form a vital relationship and technical link between organizations by communicating real needs to both parties. Then evaluating the reality and plans for these needs match up.*

**Q: What is the single-most complex challenge facing PAs today?**

A: *What I see is becoming recognized in their organizations for the importance of their contribution to a new program. They are playing a true engineering role in every sense of the word. Being high enough and recognized as such in the organization as a key part of the engineering team. They are not number and chart pushers anymore; they are so much more.*

**Q: Please describe the role of the PA in a new-product development scenario. Describe in terms of degree of role in process (at what point involved, for how long, etc.); any work with engineers; does PA have final say on supplier; if chosen material fails, how, typically, is root cause and corrective action investigated, etc.**

A: *I've mentioned before that the PA needs an engineering background, (because) he has to be involved in the product from the inception. The PA is the link between development and what can be really produced in a reasonable way. The PA needs to be involved throughout the development till it's in automatic manufacturing mode. Then the role focus can change. The PA needs to be the interface between what the engineers develop/need, and what can be produced on the outside. He is the rudder of the development, recognizing when requirements are outstripping manufacturing's capability and/or communicating to the team that new processes and technologies need to be brought online for the individual product. The PA also has to know materials and methods thoroughly so as to head off potential failures and/or communicate the risks to the team.*

**Q: How do purchasing agents ensure that even commodity, off-the-shelf hardware is within Kleiss Gears specification?**

A: *PAs should be involving the quality departments of both their companies and Kleiss Gears. We find that when there is a close relationship for how materials are to meet specification, the process runs very smoothly. The PA needs to bring together members of both teams, discuss the requirements, and the over watch as the teams decide how incoming inspection will work. This is in both equipment and technique. The equipment and technique on both sides needs to be identical and also correlated for smooth success. This is a function which is easily overlooked until there is a relationship breakdown and progress is at a dead stall. The PA is the coordinator to make sure that this (does not) happen.*

# Gears for Hydraulic Pumps: Development and Results

## A procedure to reduce dimensions and mass of gear pumps

G. Di Francesco and S. Marini

After a brief introduction to the importance of gear pumps in internal combustion engines, as well as in the most diverse hydraulic applications, a calculation method was applied that allows for sizing with considerably higher delivery rates. Upon identifying and analyzing a traditional pump, along with two construction solutions of asymmetric gear pumps ($\tau \neq 1$), we then compared their related performances.

### Introduction

External gear pumps are the most common primary hydrostatic units in the field of hydraulics and in the automotive sector (internal combustion engines and other services); approximately 90 million units are built annually. For that reason they are the object of continuous studies on the part of numerous researchers and company study centers. Said studies focus on involute profile and on the details (bearings of the wheel axis and shaft, axial covers, etc.) making up the pump itself, with the aim to improve performance and, in particular — increasing the delivery rate. These studies were conducted on external gear pumps featuring a driving wheel and a driven wheel with the same characteristics and, therefore, with the same number of teeth. The number of teeth of the two wheels is approximately: 13 – 13 teeth; 12 – 12 teeth; or 11 – 11 teeth. As known, on equal factors the pump's delivery rate increases as the number of teeth decreases; for that reason we find pumps also with 10 teeth per wheel or even 9 teeth per wheel. In the latter case, however, the wheels have a large undercut, or heart-shaped teeth. One aspect that should be explored further is to examine what happens if we study a gear pump composed of two gear wheels — each with a varying number of teeth — i.e., with a gear ratio other than one (asymmetric pumps).

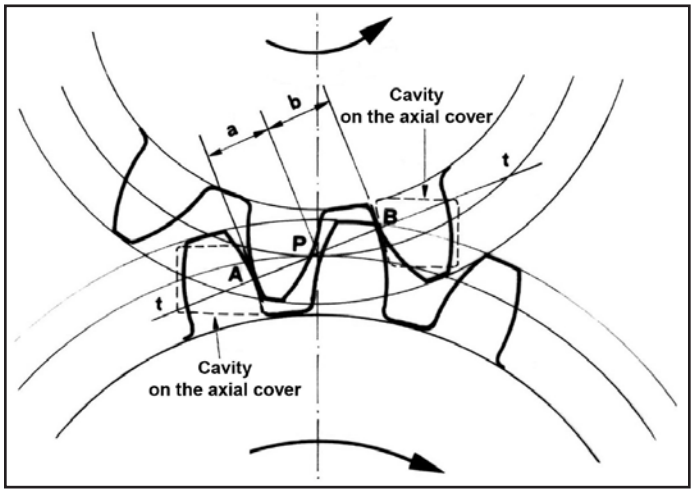


**Figure 1** A study of function D (average delivery rate) based on the characteristics of the gear wheels, will produce a functional relation that shows the parameters determining the delivery rate.

### Gear Wheels with Gear Ratio ≠ 1

In order to study the impact of gear ratio on pump delivery rates, we must establish a relationship between delivery rate and gear wheel characteristics. If we study function D (average delivery rate) based on the characteristics of the gear wheels, we obtain a functional relation that shows the parameters determining the delivery rate.

This study relies on two basic assumptions (Fig. 1): a) the length of the arc in which a pair of teeth guarantees that the sealing of oil under pressure is equal to the pitch ($a+b=p$); and b) the cavities on the axial covers are positioned in such a way that the distance from the tangent point between the pitch circles of the contact point between the teeth of the pair of teeth coming out of the sealing arc is equal to the contact point between the teeth of the pair is entering the sealing arc ($a=b$). Based on the foregoing, we obtain (Ref. 2) a complex relationship expressing the average delivery rate $D$, based on the parameters of the gear wheels; said relationship is, for brevity reasons, set out as a function:

$$D = b\,\omega_1\,a'^2\,\{\psi_1, \psi_2, \psi_3, \psi_4\} \quad (1)$$

where:

$$\psi_1 = \frac{\gamma}{2}\left(\frac{\cos^2\alpha'}{\cos^2\alpha_0} - 1\right)$$

$$\psi_2 = \frac{2\gamma^2\cos^2\alpha'}{z_1^2\cos^2\alpha_0}\left[(1+x_1-k_1)^2 + \frac{\gamma}{1-\gamma}(1+x_2-k_2)^2\right]$$

$$\psi_3 = \frac{2\gamma^2\cos^2\alpha'}{z^1\cos^2\alpha_0}(2+x_1+x_2-k_1-k_2)$$

$$\psi_4 = \frac{\pi^2\gamma^2\cos^2\alpha'}{6(1-\gamma)z_1^2}$$

$$\gamma = \frac{z_1}{z_1+z_2}$$

With (symbols are in accordance with international standardization):

$D$ = average delivery

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$a'$ = center distance
$\alpha_0$ = reference pressure angle
$\alpha'$ = operating pressure angle
$z_1$, $z_2$ = number of teeth of gear wheel 1 and of gear wheel 2
$\omega_1$ = angular speed of driving wheel
$b$ = axial face width
$x_1$, $x_2$ = addendum modification coefficient of wheel 1 and wheel 2
$k_1$, $k_2$ = addendum reduction of wheel 1 and wheel 2

The referenced relationship (Ref. 1) indicates that there are numerous parameters determining the average delivery rate and an even greater number of combinations that can be obtained by varying each of the various parameters. Note, however, that only a finite number of values can be obtained for the delivery rate $D$, as these correspond strictly to practicable solutions, taking into account the construction restraints (undercut, minimum circular tip thickness, contact ratio, etc.). The relationship thus obtained makes it possible to identify the delivery rate $D$ both in the case where the number of teeth of the wheels vary and also in the particular case where the wheels have the same number of teeth ($z_1 = z_2$), an equal addendum modification ($x_1 = x_2$), and an equal addendum reduction ($k_1 = k_2$); in other words, the mathematical expression (Ref. 1) makes it possible to calculate the value of $D$ also in the particular case of pumps currently in use (identical gear wheel pumps). The relationship thus obtained is therefore of an entirely general nature and allows to calculate the delivery rate $D$ for the widest range of possible cases. (*Note*: *Volumetric and hydro-mechanical efficiency are not considered, because they do not depend on asymmetry.*)

## Symmetric and Asymmetric Pumps

The foregoing is relevant, when conducting a study, in making comparisons between gear pumps currently in use (symmetric pumps) and pumps with gear wheels varying between them (asymmetric pumps). First, however, a number of parameters need to be set, which, for the sake of fair comparison, must be the same for symmetric pumps as for asymmetric pumps: same center distance, same axial face width, same number of revs of the driving wheel. The first and the second parameter imply that the comparison between symmetric pumps and asymmetric pumps is made on equal overall dimensions.

## Study of an Asymmetric Pump

First, we identified a symmetric pump available on the market. The main features of the gear are set out in Table 1,

where:
$j_p$ = backlash at the pitch diameter
$j_r$ = top clearance
$s_a$ = circular tip thickness
$\varepsilon$ = contact ratio
$C$ = capacity/rev (proportional to the average delivery rate)

Based on the data contained in Table 1, we have then determined the size of the asymmetric pump having the same number of revolutions as the driving wheel; the same axial face width; the same center distance (practically the same radial dimensions); the same pressure angle $\alpha_0$; and the same backlash $j_p$ at the pitch diameter. Implementing an optimiza-

**Table 1 The main features of a symmetric pump gear**

| Symmetric Pump | | |
|---|---|---|
| $a'$ | 65.31 mm | |
| $b$ | 10.00 mm | |
| $\alpha_0$ | 20° | |
| $J_p$ | 0.25 mm | |
| | **Driving wheel 1** | **Driven wheel 2** |
| $z$ | 9 | 9 |
| $m$ | 6.5 mm | 6.5 mm |
| $r_a$ | 39.64 mm | 39.64 mm |
| $x$ | +0.67 | +0.67 |
| $k$ | +0.07 | +0.07 |
| $J_r$ | 0.176 mm | 0.176 mm |
| $s_a$ | 0.72 mm | 0.72 mm |
| $\varepsilon$ | 1.14 | |
| $C = 29.82\ cm^3/rev$ | | |

**Table 2 Analysis of study results**

| Asymmetric Pump 1 | | |
|---|---|---|
| $a'$ | 65.31 mm | |
| $b$ | 10.00 mm | |
| $\alpha_0$ | 20° | |
| $J_p$ | 0.25 mm | |
| | **Driving wheel 1** | **Driven wheel 2** |
| $z$ | 11 | 8 |
| $m$ | 6.5 mm | 6.5 mm |
| $r_a$ | 44.58 mm | 35.16 mm |
| $x$ | +0.18 | +0.36 |
| $k$ | -0.18 | -0.05 |
| $J_r$ | 0.150 mm | 1.339 mm |
| $s_a$ | 1.32 mm | 0.81 mm |
| $\varepsilon$ | 1.28 | |
| $C = 36.82\ cm^3/rev$ | | |

**Table 3 Analysis of study results**

| Asymmetric Pump 2 | | |
|---|---|---|
| $a'$ | 65.31 mm | |
| $b$ | 10.00 mm | |
| $\alpha_0$ | 20° | |
| $J_p$ | 0.25 mm | |
| | **Driving wheel 1** | **Driven wheel 2** |
| $z$ | 10 | 9 |
| $m$ | 6.5 mm | 6.5 mm |
| $r_a$ | 41.71 mm | 38.47 mm |
| $x$ | +0.24 | +0.30 |
| $k$ | -0.18 | -0.12 |
| $J_r$ | 0.150 mm | 0.899 mm |
| $s_a$ | 0.72 mm | 0.72 mm |
| $\varepsilon$ | 1.32 | |
| $C = 34.52\ cm^3/rev$ | | |

tion procedure that we have previously fine-tuned (Ref. 2), we have identified each of the numerous solutions that can actually be implemented. Among these, the most convenient from a performance and technological viewpoint can be selected. For this particular case we have provided two possible project solutions (Tables 2 and 3).

## Analysis of Study Results

Both of the solutions set out in Tables 2 and 3 are practical from a constructive viewpoint, and both are more convenient in terms of performance than a symmetric pump of equal dimensions. The most convenient solution from a technological and operational viewpoint is solution No.1 (Table 2). In fact, this solution allows for a considerable increase in delivery rate compared to the related symmetric pump. The delivery rate of the asymmetric pump No. 1 is increased by 23.47%, compared to that of the symmetric pump.

## Size Reduction on Equal Delivery

Moreover, based on these results, it can be stated that on equal delivery rate of the symmetric pump, it is possible to construct an asymmetric pump with the same delivery rate as the symmetric one — but with smaller radial dimensions or with smaller axial dimensions or with smaller radial *and* axial dimensions. It is possible, in other words, to construct an asymmetric pump with the same delivery rate but with a much smaller axial face width than that of the symmetric pump (pump with smaller axial dimensions) on equal radial dimensions. As an alternative, it is possible to construct an asymmetric pump with the same delivery rate but with much smaller radial dimensions than those of the symmetric pump on equal axial face width. Or, finally, it is possible to construct an asymmetric pump distributing the size reduction in part on the radial dimensions and in part on the axial dimensions. The foregoing considerations may be of particular relevance in the field of hydraulics and, to an even greater extent, in the field of internal combustion engines used in motor vehicles, where problems of weight and dimensions have great impact.

## Conclusions

Based on the analysis set for the study of the increase of delivery rate of a gear pump, we may conclude that significant results can be obtained by using gear ratios other than one. In fact, on equal dimensions of a traditional gear pump (gear ratio equal to one) it is possible to dramatically increase the delivery rate by adopting a gear ratio determined by the procedure illustrated in the study. Conversely, it is possible to construct an asymmetric pump with the same delivery rate, but with reduced (radial and/or axial) dimensions, and with a corresponding reduction of mass.

From a technological viewpoint, we are dealing with holes in the pump body (which are to house the two different gears) with a varying, rather than equal, diameter. This was seen in the case of symmetric gears, as the machining allowance of the two different holes on the pump body was brought to size on the two holes through the use of tools having a distance from the center-of-rotation equal to that of symmetric gears and, hence, without need to modify either the machinery or the manufacturing process. Another considerable advantage is the possibility, with a single asymmetric pump, of having two deliveries, thus making the driving wheel the larger wheel or the smaller wheel. In such a circumstance two deliveries are obtained (only one of which is optimized) in which the values have the same ratio as those between the number of teeth of the two wheels. As a result, it is possible to have an entire set of delivery rates through a number of asymmetric pumps equal to half the symmetric pumps. This implies lower production costs due to a simpler and smaller structural make-up of the pump — when compared to the traditional assembly — as well as lower warehousing and distribution costs. **PTE**

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# Best Practices for Gearbox Assembly and Disassembly

Jodi Bello

In most applications, gearbox reliability is critical to the productivity of the overall plant operation. So it follows that when industry is looking at the best ways to increase efficiency, reduce downtime, and increase profitability, gearbox performance and reliability are key factors.

Designing for repair, and writing effective repair procedures, can speed the service time, and provide a quality refurbishment. The best practices listed below are proven, effective methods used to install and remove bearings, seals, gears, couplings and shafts within a gearbox.

## Introduction

When industry is looking at the best ways to increase efficiency, reduce downtime and increase profitability, gearbox performance and reliability are key factors. In most applications gearbox reliability is critical to the productivity of the overall plant operation. Repair is often required with a swift turnaround, as down time is very expensive. Designing for repair, and writing effective repair procedures, can speed the service time, and provide a quality refurbishment. Minimizing down time and extending service life will contribute significantly to achieving the lowest overall operation costs.

The best practices listed below are proven, effective methods used to install and remove bearings, seals, gears, couplings and shafts within a gearbox. These techniques are not new, and are usually obtained by hard-won experience. Collecting them in one location is an attempt to document the best practices and provide a reference for design engineers. Engineers write the procedures for assembly and disassembly, they also dictate to the rest of the design team the design intent. Including features to facilitate disassembly, minimizes repair cycle time and helps to prevent damage to components that could radically compromise their design life or performance.

## Basic Types of Component and Assembly Interfaces

First we should examine the basic methods of attachments. Figures 1–4 illustrate some basic diagrams for the different types of common connections.

Components that have sustained damage in operation may not retain their original dimensions. The design intent of the fit will have to be determined to appropriately determine the values for the repaired component. There are technical documents for designing each of these types of fits. Please see the references for some of the relevant technical specifications for more detailed information.

Each of these interfaces can be made with different types of fits, clearance or interference. To determine which fit type you have, calculate the fit using Equation 1:

$$F = d - D \quad (1)$$

where:

$F$ = maximum fit
$d$ = smallest diameter of bore
$D$ = the largest shaft diameter

Measure the bore and shaft at several locations, and use the smallest diameter bore and largest diameter shaft. If the shaft and bore tolerances are available, the entire expected fit range can be calculated. (To calculate the minimum fit, you would use the largest bore diameter minus the smallest shaft diameter.)

If this value is positive, the fit is clearance, if it is negative, the fit is interference. If the value is zero, the parts could theoretically slide together, but in practice a small amount of force or thermal difference is needed for assembly. The clearance value needed to slide parts together easily is generally assumed to be at least 0.001 inches. For long fits and large diameters, more clearance may be required; evaluating the tolerance and run-out of the parts will help determine an appropriate value.

***Clearance fits***. Clearance fits are used for easy assembly, in typically low speed applications. Set screws can be used to connect the shaft to the hub and transmit torque.

- Straight bore clearance fits slide together easily. There is no axial location control with this fit alone, and limited radial location. Shoulders, set screws and pins can be used to control axial locations.
- Splined connections fit multiple-tooth internal teeth against external teeth. There is clearance on both the sides and diameters of the teeth.
- Keyways transmit the torque between the shaft and hub. Parts assemble easily. Set screws can be used to fix the key and shaft in the bore.
- ***Interference fits***. When assembled, the bore expands and/or the shaft contracts so that the interface is in compression. Interference fits can transmit more torque than clearance fits. There are several different methods for assembly, which will be discussed later. These fits are typically used to control location of the components, axial and radial, as well as transmit torque. Interference fits are also used to maintain balance of components in high speed applications.
- ***Straight.*** A straight interface transmits torque while maintaining both axial and radial location control of the components.

- ***Tapered.*** A tapered shaft and bore under compression can be used to transmit the friction torque. The compression can be obtained by drawing the shafts together using a shaft nut or by thermal differential assembly.
- ***Keyways.*** Keys with interference fits do not shift and alter the balance of the components. They also can transmit more torque than a straight or tapered interface with the same interference, because the key helps ensure the joint will not slip.
- ***Splines.*** Usually these are interference fit on the outside diameter of the splines. These are typically used when radial position needs to be controlled.
- ***Bushings.*** There are various mechanical devices that can be used to create an interference fit. They slip on to the shaft with clearance, but when engaged create an interference fit between the shaft and hub. Tightening these devises is best done in a star pattern for proper centering of the parts. Centering is especially important if balance is critical. The best practice here is to follow the individual manufacturer's assembly instruction.
- ***Transition fits.*** Transition fits can be either clearance or interference. The tolerance range on the parts can result in a small interference or clearance based on the individual components. These fits are commonly used to ease assembly in applications that still require close fits. They can be assembled using the interference fit techniques but with much less force or temperature difference.
- ***Bearing fits.*** Bearing assembly is a special case. Bearings may be interference fit on one race of the bearing and clearance on the other. The mounting of the bearing on the shaft and in the housing will determine the operating clearance of the bearing. Having the correct bearing fit for the application is critical to achieving the design life and reliability of a bearing. Bearing catalogs have more information, or consult the manufacturers directly for each application.

## Assembly Techniques

***Thermal differential***. Heating or cooling components can cause them to expand or contract to overcome interference and allow for easy assembly. The amount of temperature difference required can be calculated by using Equation 2 (use consistent units).

Thermal differential (simplified equation):

$$\Delta T = \frac{\delta}{\alpha\,(dia.)} \qquad (2)$$

where:

$\delta$ = diametral interference
$\alpha$ = material coefficient of thermal expansion
*dia* = diameter in question

Most coefficients are given at a specific temperature, and will give a close enough approximation to the change in temperature for assembly purposes. Add a few thousands of an inch to the diametral interference to give a resulting clearance for assembly after the heat has expanded the parts.

It is common to add a few degrees to the delta to compensate for handling time and the assumptions of the equation. Rounding the value up by 20 degrees, or to an easy to measure value, is acceptable, as long as this does not put the value beyond the material limits. These material limits are based on composition and heat treatments. It is important not to exceed these limits as this could impact the ability of the component to function properly.

Because the temperature will change with time, it is important to have all the fixtures and tools for assembly prepared before removing the component from the oven or freezer. As for any job, proper personal protective equipment should be worn, as the parts will not be able to be touched by bare skin.

If there is a question about the temperature of the components or the measurement system, parts can be measured before assembly, at temperature, to determine they have reached the proper size. This must be done quickly because the delicate measurement instruments will be affected by the temperature too. It is easier to measure the temperature, but when developing a new process this technique can give valuable information.

Use Equation 2 to determine the amount of temperature difference required. The temperature differential can be obtained by heating, cooling or a combination of both.

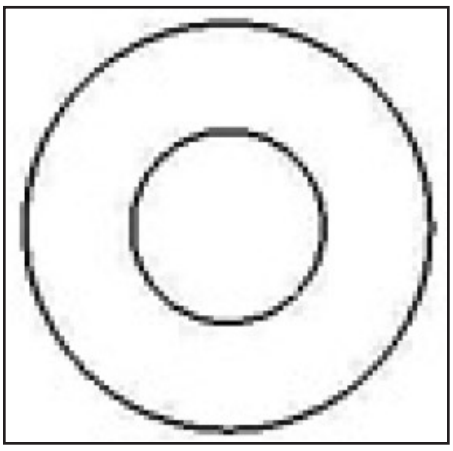

**Figure 1** Straight bore.

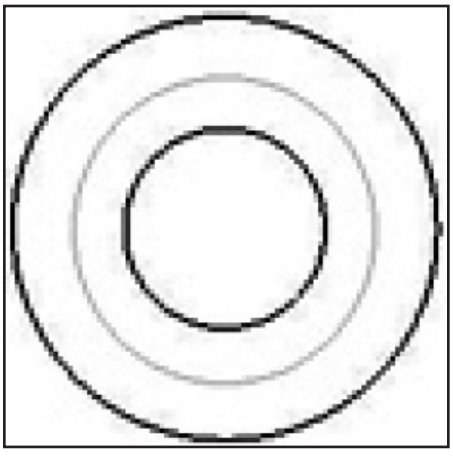

**Figure 2** Tapered bore.

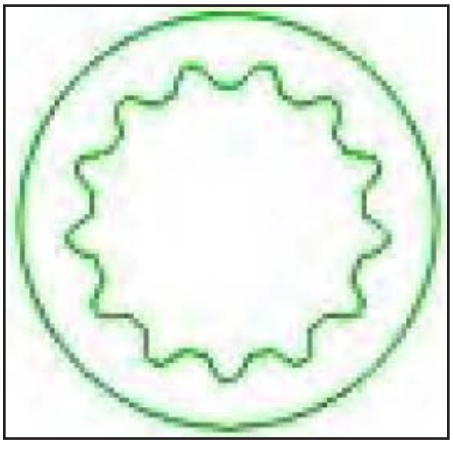

**Figure 3** Splined bore.

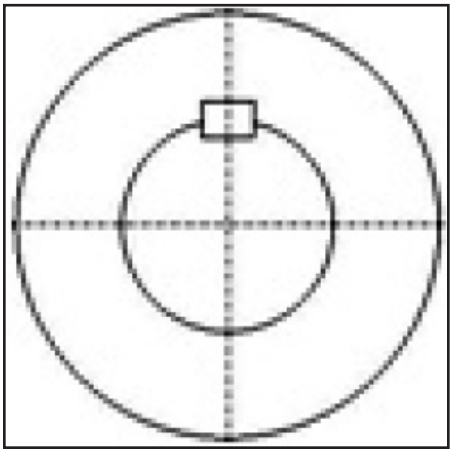

**Figure 4** Keyed bore.

Lifting holes or fixtures for holding the components are especially important in thermal differential assembly. The fixtures need to be able to withstand the temperature, and also be out of the way for assembly. Planning the methods for lifting must be done before the components have changed temperature.

Having components level during assembly seems like a simple thing, but is often overlooked. It is easy to get components jammed if they are not aligned. Occasionally this can be overcome with gentle taps, but careful alignment can eliminate this need.

Components that have been assembled using heat or cold can creep apart as they cool. A bearing that is seated against a shoulder can move apart ever so slightly, and this can impact operation later. Clamping the parts or gently tapping a spacer down repeatedly as things normalize can prevent this. Never tap a bearing across the rollers. It is OK to gently tap an inner race seating on a shaft, or an outer race without rollers into the housing.

***Heating***. There are several methods of heating components: induction heaters, ovens, or hot oil baths. Thorough heating and consistent temperature is required. The best method is dependent mainly on economics and available resources.

Ovens make sense for large parts, high volume production, or for time savings. Many ovens can run unattended, so parts can be loaded at the end of a shift and heated overnight for assembly the next morning. This allows thorough heating and efficient use of time.

Induction heaters are fast and efficient. Load the part, press the button — and the heater runs. It monitors the temperature and shuts off when temperature is achieved. Most machines will monitor the temperature and reheat the part if the temperature drops more than five degrees.

Hot oil baths are a time-proven solution for heating parts. However, careful monitoring is required to prevent the oil from catching fire, and additional safety procedures must be observed to protect the operator from the hot oil.

No matter what the method, care must be taken to prevent overheating of the parts. There are various methods available such as, infrared thermometers, contact thermometers, or even temple sticks, (wax crayons that melt at a specific temperature).

***Cooling***. Cooling can be done with freezers, dry ice or liquid nitrogen. When using liquid nitrogen, use caution that freezing the components will not damage them. There are some heat treated components that should not be cryogenically treated.

There is always a chance of condensation forming on frozen parts. Wiping them down with isopropyl alcohol before assembly will help to dissipate the moisture. This should also be done as the parts return to ambient temperature if condensation appears.

Freezers are very convenient because parts can be placed in the freezer overnight and assembled in the morning.

Dry Ice can be packed around parts that need to be cooled. It is more difficult to get a consistent cooling of the parts due to it being solid. Use a thermometer to get an accurate temperature, realizing that it is a surface temperature. Parts may need to soak for a considerable time to be cooled through.

It is not often that both cooling and heating are required. This high amount of interference may better be obtained by pressing the parts together. There is a high risk of the parts cracking from thermal shock when heat and cold are both required.

***Press***. Parts can be pressed together using a mechanical or hydraulic press.

Caution must be taken when using a press, as the forces are very large and the process can be

dangerous. As with all work, proper personal protective equipment and protective guarding around the equipment is recommended.

Basic equation. See Figure 5 for visual depiction of press fit.

$$F = A\,\mu\,P \tag{3}$$

$$A = \pi\,d\,L \tag{4}$$

$$P = \frac{\delta}{\left(\frac{d}{E_o}\right)\left(\frac{d_o^2+d^2}{d_o^2-d^2}+\mathrm{N}_o\right)+\left(\frac{d}{E_i}\right)\left(\frac{d^2+d_i^2}{d^2-d_i^2}-\mathrm{N}_i\right)} \tag{5}$$

where:

$F$ = force to press

$A$ = area of interface

$\mu$ = co-efficient of friction

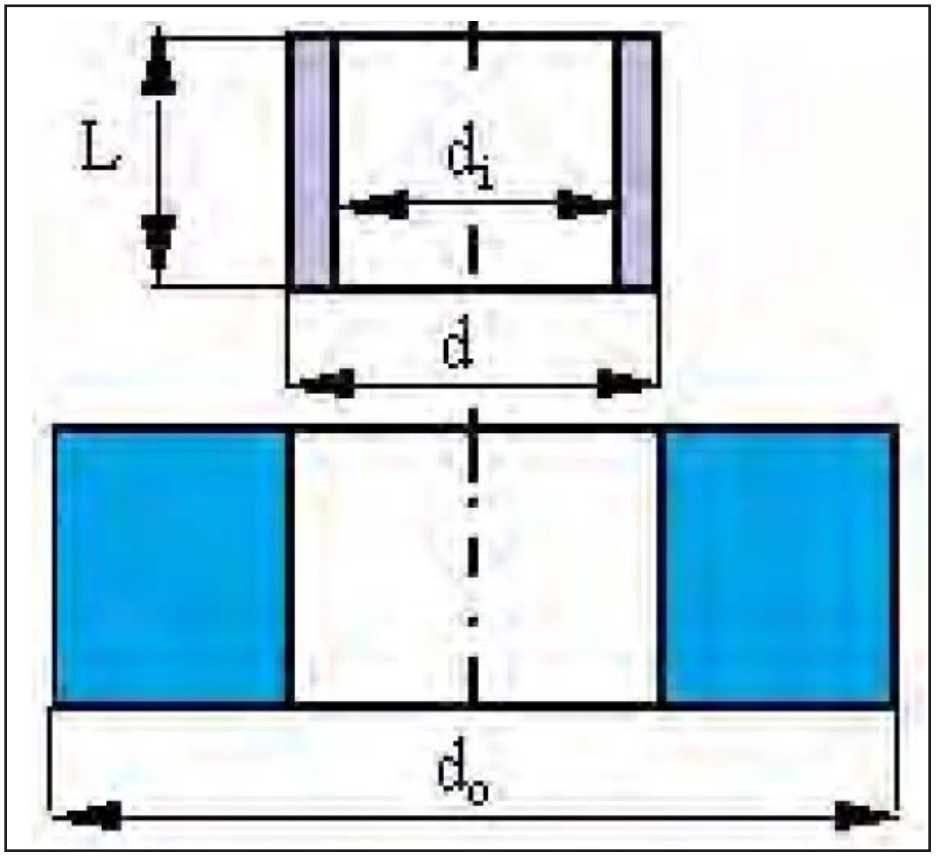


**Figure 5 Press fit illustration.**

$P$ = interface pressure
$D$ = shaft diameter/bore diameter (nominal)
$L$ = length of fit
$\delta$ = diametral interference
$d_o$ = hub outside diameter
$d_i$ = bore in shaft or zero if solid shaft
$E_o$ = Young's modulus of hub
$E_i$ = Young's modulus of shaft
$N_o$ = Poisson's ratio for the hub
$N_i$ = Poisson's ratio for the shaft

The force calculated here is approximate and should be considered a minimum. It can be used to size the equipment needed. More force than calculated may be required if there is damage to the mating surfaces, or the parts are misaligned. Surface finish effects have not been considered in this calculation.

The first operation before pressing should be leveling the parts to avoid misalignment. This will help prevent galling the shaft, but not eliminate it.

There is always a significant risk of galling parts using a press. Using a lubricant like grease or anti seize will decrease the chances of galling but will also decrease the coefficient of friction and torque transmission capability of the joint. If the components are spacers and will not transmit torque, light lubricant is recommended. If the components are bearings or gears, lubricant is not recommended. A long lead-in chamfer should be added if possible. Consideration should be given to whether the joint will ever need to come apart again or not.

***Shaft locknuts***. Shaft nuts can be used to draw tapered shafts up and retain the compression. They can also be used to hold both straight and tapered connections together after other methods of assembly. They should always be used with some form of retention, such as a tab washer or set screws. This prevents them from backing off in service.

***Hydraulic assist for keyless shafts***. Many tapered shafts have features that allow assembly using a hydraulic pump system. Typically there is a tap in the shaft that oil can be pumped into. The oil dilates the bore. The hub is then pushed up the shaft until the required amount of advance is obtained. The pressure is released, completing the assembly.

The amount of advance determines the interference obtained (sometimes called draw-up).

Advance can be calculated using Equation 6:

$$A_d = \delta t \quad (6)$$

where:
$A_d$ = advance
$\delta$ = diametral interference
$t$ = shaft taper

Because the advance controls the fit and thus the torque capacity, controlling the advance during assembly is very important. Setting up stops and fixturing to stop the hub advance at the proper location is advised. Leveling the shaft before assembly is also recommended. These simple tips will make for a smoother assembly.

The hub is typically fitted with O-rings to retain the oil. The O-rings may also be located in both shaft and hub. The location of the assembly tap could also be located in the hub. Lightly lubricating the O-rings at assembly will help to keep the O-rings in their grooves while assembling and also help prevent rolling or pinching during assembly.

***Bearing assembly***. Bearing assembly is critical to reliability and performance of any gearbox. Most of the above mentioned techniques can be used to mount bearings. Because the bearings are precise mechanisms, special care must be taken when assembling.

Bearings must never be hammered into place. This can cause the rollers to exceed the material limits of the race and dent it. This bearing failure mechanism is called brinelling. This damage will propagate and ultimately fail the bearing much sooner than its expected design life.

If the correct fit of the bearings is not obtained, the life of the bearings will be impacted. If the fit is too tight, the bearing can be pinched and cause the gearbox to run hot, and the bearing could seize.

It is also possible if the fit is too loose for one or both of the races to spin. This will damage the shaft or housing and could generate debris that will damage itself and other bearings, gears and seals in the system.

Depending on the type of bearing and the application, the axial location of the bearing can also be critical to achieve its design life expectations. Bearings shimmed too tightly will run hot and can seize just like pinched bearings.

***Seal assembly***. There are many different types of seals on the market. Assemble per manufacturer's instructions for best results. If seals must be pressed into place, make sure to use a ring approximately the same diameter as the seal, but one that will not interfere with any rubber lips or other components. Apply even pressure over the entire surface, so the seal assembles level and does not get hung up anywhere.

If lip seals are used, lubricate the shaft that the lip will slide over to prevent nicks to the surface. Also be cautious of threads or keyways the seal may have to travel over. These may have to be wrapped in plastic wrap so the seal can slide over easily without damage.

Consider the location of the seal before determining when to assemble it. It may be easy to assemble a seal on a shaft before the shaft is placed into the next assembly, but the seal may be damaged during that assembly. It may be better to assemble at final assembly to prevent damage and the leaks that come with damaged seals.

## Disassembly Techniques

***Press***. Using a mechanical or hydraulic press to separate parts is a very common practice. The same cautions for assembly also apply to disassembly, as the same large forces are involved. Presses come in a variety of sizes as well as vertical and horizontal versions. Make sure that the press is sized properly for the job you are attempting. Use a slow press speed, smoothly applying the load for best results.

If the interference is unknown, do a rough estimate by using the press calculation with 0.0015 inches per inch of diameter interference. This is a rule-of-thumb type number for a pressed-on fit. The rule of thumb for parts that have been assembled with the thermal differential method is interference of

0.0005 inches per inch of diametral interference. Apply a generous service factor to these calculations.

Higher fits than the rule-of-thumb fits are possible. It is also possible that the fit is galled, which will require additional force to remove. Make sure that the press equipment being used is adequately sized for safe operation.

Level the parts during setup to give an even press force on the shaft.

Rods similar in diameter to the shaft being pressed or other fixturing components are often necessary. In addition a method for catching the part that is being pressed out is also necessary. The parts will separate abruptly so this must be considered in advance.

Other techniques may need to be applied in addition to the press to release a very heavy press fit. Both thermal and hydraulic methods are commonly combined with press fits to remove large-diameter, heavy fits. Use caution when combining methods and consider operator safety.

***Pullers***. Pullers operate similarly to presses except the parts are pulled apart. There are both mechanical and hydraulic pullers. A jaw-type puller can be used anywhere you can get the jaws around the part. There are also bolt-on plates to extend the reach of the fingers. Designing in slots big enough for the jaws or shoulders wide enough to get puller jaws or plates behind makes disassembly faster and easier.

If slots or shoulders are not practical, taps of sufficient size can be located on the part and a puller similar to a wheel puller can be used. These pullers are constructed of high strength threaded rods and thick plates and are available with either hydraulic or mechanical jacks.

This method can also be used in combination with hydraulic and thermal techniques for stubborn fits. Always consider operator safety when combining methods.

***Thermal differential***. Heating or cooling the components for disassembly is difficult because the parts are physically connected and naturally want to reach the same temperature.

There are commercially available induction heaters for removal. They consist of either a coil or fixed diameter that wraps around the OD of the component to be removed. The heat must be applied very quickly so that the external part grows enough to release the fit before the internal component begins to grow also. This method is typically used in combination with a press. The heat expands the hub and much lower press force is required to remove the shaft.

It is possible to remove parts using gravity and a torch with a large diameter tip. This method must be monitored closely to make sure that the components are not heated beyond their temperature limits. Apply the heat to the outside of the part and keep the keep the heat moving so as not to overheat any one location. Closely monitor the temperatures of the components and discontinue attempts if too much of the heat is transferring into the shaft.

There is a real possibility that the component being heated may pass its thermal limit before removing. For this reason, this method is mostly used for removing parts that are being replaced, such as bearing races. Caution must be taken to make sure the part being reused is not damaged.

***Hydraulic assist***. Hydraulic removal of hubs works the same as assembly, except the location of the stop is different. There could also be no O-rings present if the hub was applied using heat. It is important to provide a stop for the hub to prevent it from being damaged. Once the hub is pressurized with oil, it will begin to slide down the taper. This may happen suddenly and with some force, so a fixture to stop the hub is advisable.

Hydraulic release may also be used in addition to a press in cases of extremely high fits. These may also appear on a straight bored shaft with a very heavy press fit.

## Design Features to Assist Assembly/Disassembly

Frequently a component is designed by one team and another one assembles it, then yet another team does the repair. This can cause a lack of communication that can make assembly and repair more time consuming and thus costly than it could be. Adding small features to assist assembly or disassembly may add a small cost to the initial production but can save significant time, and therefore cost, in the future.

***Lifting hole sizing***. Size lifting holes not only for the weight of the part to be lifted, but also the weight of any additional components that could be added to the part. Also consider using these holes for removal of spacers and bearings. Size each lifting hole assuming it will be used vertically. This will give additional margin if the parts are rigged differently.

Even smaller components that could be lifted by hand can benefit from small threaded holes for lifting if the assembly is complicated or the parts must be lubricated at assembly. For instance, spacers that must be heated for assembly may be small enough to be lifted by hand, but assembly is much easier if there are taps so that the components can be picked up level and lowered easily on to a pre-leveled shaft.

***Removal taps***. Are taps located in the part so that bolts (sometimes called push bolts or jacking bolts) can be inserted to push two components apart?

***Size and location of removal taps***. Placement of removal taps in covers and spacers can prevent damaging these components at repair. Two extra taps on a bolt pattern can be used to release a pilot without damage or bending a flange. Always add taps that are sized to be able to take the loading to release the fit on the part. See the calculations above to see what the force is required to release the fit.

Caution must be used on the location of removal taps. It is possible to bend hubs with thin flanges or gear rims if the force from the puller rods is sufficient to overcome their strength. Keep taps as close to the diameter of the fit as possible. If these components are damaged at disassembly it will increase the cost of that repair. Damaging components can make repair of the gearbox as costly as buying a new replacement.

***Hydraulic assist.*** If high torques and high interference fits are required, especially on tapered shafts, adding the taps for hydraulic assembly and disassembly is highly recommended. This process is very efficient when compared with other methods. When a pro-

cedure is followed, consistent results are obtainable.

***Bushings.*** Designing in shaft connections with bushings is particularly important when assembly or disassembly of these components may need to be done in the field. Bushings are operated by a series of smaller bolts. They start as a clearance fit that the bolts draw up until the connection is made. This is the easiest shaft connection for the user to apply.

## Bearing Location Features

There are many different kinds of bearings used in gearboxes. The individual designs have different requirements. Once the designs are determined, there are some key points to consider when working out the design.

Disassembly should also be considered when designing in shoulders and spacers for locating bearings. Taps in spacers or puller finger slots make assembling and disassembling bearings more efficient.

Some bearings do not require axial location by design, but are clamped with piloted covers to prevent the outer races from rotating during operation. Others require a preload or set axial location. Both of these can be accomplished with either a ground pilot on a cover or by shimming. The application usually guides which method is preferable. If there is a potential for multiple rebuilds or rebuilds in a remote location, shimming is usually preferred. If the rebuilds will always be done in a well-equipped facility, ground pilots are preferred. Please note that if shims are used, select the thicknesses such that the fewest number of shims is used and always sandwich the thinner shims within the thicker ones. Very thin shims can tear under load; the thicker ones on the outside give the pack more strength.

A method of preventing bearing outer races from spinning is to pin the outer races. This can be done by drilling a hole in a cover for a pin and chamfering a small slot in the outer race. Bearings can be ordered with this chamfer feature.

## Alignment

Alignment can be another critical factor in establishing a good reassembly. Poor alignment of bores from side to side as well as the parallelism of mating shafts can cause a huge impact in the design life of gears and bearings as well as cause the gearbox to run hotter than it should. Any time a gearbox is refurbished, these alignments should be checked to insure a reliable rebuild. This is especially true if the bores require repair due to previous damage. Bringing the parallelism of the shafts back to design specifications is the difference between a refurbishment that will retain the reliability of the original design and one that will not.

Another issue that must be checked at refurbishment is parallelism of the mounting base to the internal shafting. If this is skewed when the gearbox is bolted into place, the case can flex and cause internal misalignment of the gears and shafts. This in turn can impact the life of the gearbox in service. It can easily be repaired by milling material off the bottom of the mounting feet. This repair helps to facilitate a better alignment when the gearbox is mounted in service.

(*It is recommended that the referenced specifications be reviewed in detail when used by the design engineer. A proper design requires more calculations than discussed in the scope of this paper.*)

## Summary

- Basic principles of assembly and disassembly have been discussed above. None of these techniques are new. They are time-honored practices that have been passed down from person to person for years.
- This used to be accomplished through apprenticeships and mentoring. Most of those programs have fallen by the wayside.
- With this paper we are trying to collect that knowledge as a training tool for new design engineers, or as a convenient reference for engineers writing assembly or disassembly procedures.
- Adopting these procedures can make gearbox building and rebuilding more cost-effective while preserving reliability.

Ultimately, that is what all our customers — both internal and external — are looking for. **PTE**

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# Investigations of Bearing Failures Associated with White Etching Areas (WEAs) in Wind Turbine Gearboxes

Robert Errichello, Robert Budny and Rainer Eckert

A critical problem for wind turbine gearboxes is failure of rolling element bearings where axial cracks form on the inner rings. This article presents field experience from operating wind turbines that compares the performance of through-hardened and carburized materials. It reveals that through-hardened bearings develop WEA/WECs and fail with axial cracks, whereas carburized bearings do not. The field experience further shows that a carburized bearing with a core having low carbon content, high nickel content, greater compressive residual stresses, and a higher amount of retained austenite provides higher fracture resistance and makes carburized bearings more durable than through-hardened bearings in the wind turbine environment.

## Introduction

Microstructural alterations have been studied since 1947 (Ref. 1): From the late 1960s through the 1980s, classic, subsurface-initiated fatigue was investigated (Refs. 2 – 9), including the well-documented, slow, structural breakdown (martensite decay) — a progressive change in the steel matrix that occurs under moderately high Hertzian stresses. The decay creates dark etching areas followed by white etching bands (Ref. 1). Flat white bands (WBs) first form at an angle of 30 – 40° to the surface (Refs. 1, 7), and steep WBs form later at an angle of 70 – 80° to the surface (Refs. 1, 7). Steep bands are located closer to the surface in the area of the greatest density of the flat WBs. Hertzian stress and the number of cycles are the controlling parameters for dark etching areas and WBs. And as the number of load cycles increase, 1) the hardness drops in areas of structural changes; 2) the hardness minima displace toward the surface; and 3) the X-ray diffraction half-value breadth decreases (Refs. 1, 3, 7). The Hertzian stress limit for the development of WBs is $p_o \sim 2{,}500$ MPa (Refs. 1, 7).

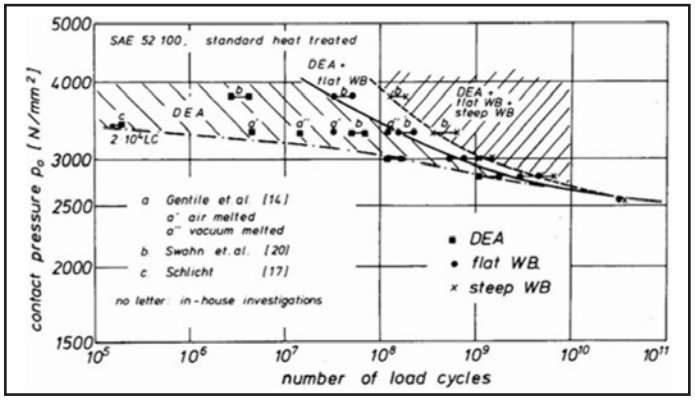


**Figure 1** Correlation between Hertzian stress, load cycles and microstructural alterations (Ref. 6).

WBs consist of nanosized, ferrite cellular structures that — due to their fine-grained, cellular structure — have a hardness that is 30 – 50% higher than the hardness of the surrounding matrix (Refs. 10 – 13).

When residual stresses are superimposed on Hertzian stresses, it is found that flat WBs are perpendicular to the effective tensile stress, and steep WBs coincide with the direction of the maximum shear stress (Ref. 7).

Figure 1 shows that it is possible to draw conclusions about the Hertzian stress that was effective at the time of formation of WBs from the position, density, and direction of the WBs (Ref. 7).

## WEA Morphology and Characteristics of Butterflies

Stress concentrations occur around inhomogeneities (nonmetallic inclusions and large carbides) due to elastoplastic strain incompatibility between the inhomogeneities and the martensitic matrix (Ref. 14). Once the yield strength of the matrix is exceeded, a plastic strain is induced in a small domain surrounding the inhomogeneities. Under repeated Hertzian stress dislocations shuttle back and forth and accumulate in this domain. This process causes localized changes in microstructure — such as white etching areas (WEAs) — with what look like "butterfly wings." Cracks nucleate in this domain once a critical density of dislocations is reached. The origin of a subsurface-initiated macropit most often occurs at the depth of the maximum, orthogonal alternating shear stress — and which is the basis of the Lundberg-Palmgren theory for rating bearing life.

WEAs with the appearance of butterflies form adjacent to nonmetallic inclusions in planes 40 – 50° from the surface, corresponding to planes of maximum, unidirectional shear stresses (Refs. 1, 3, 15). According to References 11 and 16, butterflies form with AISI 52100 steel when the maximum shear stress $\tau_{max} > 400$ MPa.

No simple relationship between Hertzian stress and microcracks exists because the relationship is related to applied stress, local matrix conditions and the composition, shape, size and alignment of the inclusion with the stress field (Ref. 11).

Heat treatment conditions do not significantly affect butterfly development. However, inclusion type, inclusion size, inclusion distribution and forging reduction ratio do (Ref. 11). Well-dispersed, small spherical inclusions ($< 13\,\mu m$) and high forging reduction ratios ($\geq 7{:}1$) maximize resistance to cracks associated with butterflies (Ref. 11).

Plate-like (lenticular) carbides are thin, carbide discs sandwiched between WEAs (Refs. 1, 3); lenticular carbides appear dark black on etching (Refs. 1, 3).

WEAs will increase in number with longer cycling time. Their density varies in a manner consistent with the variation in shear stress, and WEAs form at a rapid rate around nonmetallic inclusions (Ref. 3). The maximum density of WEAs occurs at the depth of the maximum, unidirectional shear stress (Ref. 3).

Butterflies are the result of an accumulation of localized plastic deformation at inhomogeneities, such as non-metallic inclusions and large carbides (Refs. 14, 17).

Cracks tend to propagate along the boundary of WEAs; yet it is not resolved whether WEAs precede cracking (Ref. 17) or cracking precedes WEAs (Refs. 12, 15, 18).

Many microcracks are nucleated at inclusion butterflies early in the fatigue life, but most do not grow beyond the WEAs unless the inclusions are located at Hertzian depths where the cyclic shear stress is high (Refs. 11and 12).

Transmission electron microscope investigations (Refs. 10, 17) show that WEAs consist of ultrafine, nanocrystalline ferrite grains. Researchers (Refs. 10, 11) concluded that WEAs result from recrystallization, where new grains grow from a highly deformed steel matrix.

Though WEAs have been the subject of considerable study, there has been no clear link between WEAs and Hertzian fatigue. Grabulov (Ref. 10) and others have found that the microstructure of classic, subsurface-initiated macropitting is very different from the WEAs observed at inclusion butterflies. Therefore, WEAs are not an essential step in classic subsurface-initiated macropitting.

WEAs are not limited to wind turbine gearbox bearings; they occur in many other industries as well (Refs. 12, 16, 19, 20). Furthermore, WEAs are not limited to any one gear manufacturer, bearing manufacturer, or wind turbine manufacturer (Refs. 16, 19, 20, 21).

Currently, there is no calculation method that is recognized for predicting WEAs, and the root cause and significance of WEAs are not clearly understood (Refs. 13, 16, 19, 20, 21, 22, 24, 25).

## Morphology and Characteristics of Irregular White Etching Areas and White Etching Cracks

An immediate, critical problem for wind turbine gearboxes is a failure of rolling element bearings in which axial cracks form on the inner rings. Metallurgical analyses show that the failure mode is associated with microstructural alterations manifested by irregular white etching areas (irWEAs) and white etching cracks (WECs). IrWEAs are branching crack networks that follow pre-austenite grain boundaries and form crack networks with white etching borders. WECs can be straight-growing cracks that are parallel to the surface, or branching crack networks (Ref. 12), i.e. — irWEAs. Both are associated with axial cracks in wind turbine bearings. There are several hypotheses for the root cause of irWEAs, WECs and axial cracks, including impact loads (Ref. 13, 19, 20, 22); sliding (Refs. 16, 19, 22); hydrogen embrittlement (Refs. 16, 18, 21); electrostatic discharge (Refs. 19, 21); corrosion fatigue (Ref. 16), and adiabatic shear (Ref. 20). However, none of the hypotheses has been proven, and it is currently an active field of research (Refs. 13, 16, 19, 20, 21, 22).

It is known that WBs, WECs and irWEAs share similar, microstructural morphologies. They are nanosized, ferrite cellular structures that result from recrystallization of new grains that grow from the highly deformed steel matrix. Therefore WBs, WECs and irWEAs are in fact different development stages of the same phenomenon (Ref. 11).

How irWEAs and WECs develop and progress is not yet understood — both have been characterized as brittle fracture modes that generate cleavage fractures. It might be a single-step or a multiple-step process that generates cleavage cracks and WBs (Refs. 13, 16, 19, 20, 21, 22).

It is also not yet understood how a chemical conversion coating such as black oxide helps to prevent irWEAs and axial cracks. It might reduce tractional stresses, damp vibrations, or prevent hydrogen diffusion. On the other hand, the temperatures used to treat the components might beneficially alter the bearing metallurgy (Refs. 16, 19, 20, 22).

We usually do not find moisture corrosion, severe wear, or electric discharge damage in wind turbine gearboxes. Therefore, hydrogen absorption due to water in oil can be excluded and hydrogen generation due to sliding or electric discharge and diffusion into the bearing seems unlikely. Furthermore, although the authors have seen butterflies in wind turbine bearings, there is little evidence to support butterfly cracks propagating into irWEAs or WEC networks.

## Description of Wind Turbine Bearing Failures

In the following sections we present actual field experience with active wind turbines that compares the performance of rolling element bearings manufactured from both through-hardened and carburized materials. The wind turbines are utility-scale and have been operating for up to six years; There are over 500 turbines of this type currently in operation.

***Through-hardened vs. carburized intermediate bearings.*** The wind turbine utilizes an NJ 2334 cylindrical roller bearing at each end of the four intermediate (INT) shafts in the gearbox. The bearings are manufactured by two different manufacturers, designated here as bearings INT–A and INT–B. The INT–B bearing is through-hardened and the INT–A bearing is carburized. The failure rate of the INT–B through-hardened bearings is 16%, with a mean time-to-failure rate of 27,200 h ($1.4 \times 10^8$ cycles). To date, there has been only one failure of an INT–A carburized bearing, and that single failure is believed to be of a secondary nature that occurred due to the presence of a surface defect of unknown origin.

Table 1 compares data for the INT bearings and Table 2 compares chemistry for the INT bearings.

Figures 2a and 2b show a failed INT–B bearing inner ring (IR) that had operated for 18,000 h ($9.3 \times 10^7$ cycles) when the failure was discovered. There are numerous axial cracks concentrated toward the flange end of the IR. Figure 3 is a micrograph of a circumferential metallurgical section through an axial crack. The section has been nital-etched to display the irWEAs associated with the crack. Figure 4 is a scanning electron microscope image of an axial crack that was opened in the laboratory to expose the fracture surface. The crack morphology is typical of axial cracks found on through-hardened bearings from wind turbines (Refs. 13, 16, 19, 20, 21, 22). The origin of the fracture is believed to be at the center of the smooth circular "lens" (Ref. 16).

Residual stresses and retained austenite were measured on new, unused intermediate bearings. Figure 5 shows residual stresses on INT bearings determined by X-ray diffraction (XRD), per ASTM E915. The residual stress for the INT–B through-hardened bearing is compressive up to –700 MPa at the surface, decreases to zero at a depth of 12 $\mu$m, and is tensile (ranging from 35 – 100 MPa) at depths greater than 13 $\mu$m. The residual stress for the INT–A carburized bearing is entirely compressive up to –1,000 MPa at the surface, and greater than –400 MPa to a depth of 500 $\mu$m.

Figure 6 shows retained austenite on INT bearings determined by XRD, per ASTM E975. The retained austenite for the INT–B through-hardened bearing is less than 1%. The retained austenite for the INT–A carburized bearing ranges from 23 – 31%.

***Carburized rotor bearings.*** The wind turbine utilizes a tapered roller bearing at each end of the rotor shaft. The bearings are manufactured by two different manufacturers, designated here as bearings ROT–C and ROT–D; both are car-

**Table 1 Data for intermediate bearings**

| Parameter | INT-A | INT-B |
|---|---|---|
| Bore, *d* (mm) | 170 | 170 |
| Outside diameter, *D* (mm) | 360 | 360 |
| Width, *T* (mm) | 120 | 120 |
| Dynamic capacity, *C* (kN) | 1,840 | 1,660 |
| Static capacity, $C_o$ (kN) | 2,110 | 2,040 |
| Fatigue limit load, $P_u$ (kN) | 332 | 204 |
| Number of rollers, *z* | 14 | 14 |
| Roller pitch diameter, *Dpw* (mm) | 268 | 266 |
| Roller mean diameter, $D_w$ (mm) | 52 | 50 |
| Roller total length, $l_w$ (mm) | 85 | 85 |
| Roller effective length, $l_{weff}$ (mm) | 81 | 81 |
| Roller crown type | Circular | End reliefs |
| Roller crown magnitude (mm) | 0.030 | 0.036 |
| Nominal contact angle, $\alpha_o$ (°) | 0 | 0 |
| Heat treatment | Carburized | Through-hardened |
| IR case depth, $E_{hr}$ (mm) | 3.5 | N/A |
| Cage type | Brass | Brass |
| Hertzian stress (MPa) | 1,583 | 1,756 |
| Hertzian stress max (MPa) | 1,869 | 2,056 |
| Shaft speed (rpm) | 86.12 | 86.12 |
| DIN ISO 281-4 life (h) | 212,200 | 178,500 |

**Table 2 Chemical composition for intermediate bearings**

| Element | INT-A IR (% wt.) | INT-B IR (% wt.) |
|---|---|---|
| Carbon, C | 0.227 | 1.02 |
| Silicon, Si | 0.288 | 0.270 |
| Manganese, Mn | 0.774 | 0.280 |
| Chromium, Cr | 0.660 | 1.69 |
| Nickel, Ni | 1.67 | 0.130 |
| Molybdenum, Mo | 0.226 | 0.210 |
| Sulfur, S | 0.017 | 0.013 |
| Phosphorus, P | 0.010 | 0.015 |
| Copper, Cu | 0.190 | 0.260 |
| Aluminum, Al | 0.045 | Not reported |
| Cobalt, Co | 0.019 | Not reported |
| Columbium, Cb | 0.011 | Not reported |
| Titanium, Ti | 0.005 | Not reported |
| Boron, B | <0.001 | Not reported |
| Vanadium, V | 0.006 | Not reported |
| Tin, Sn | 0.005 | Not reported |

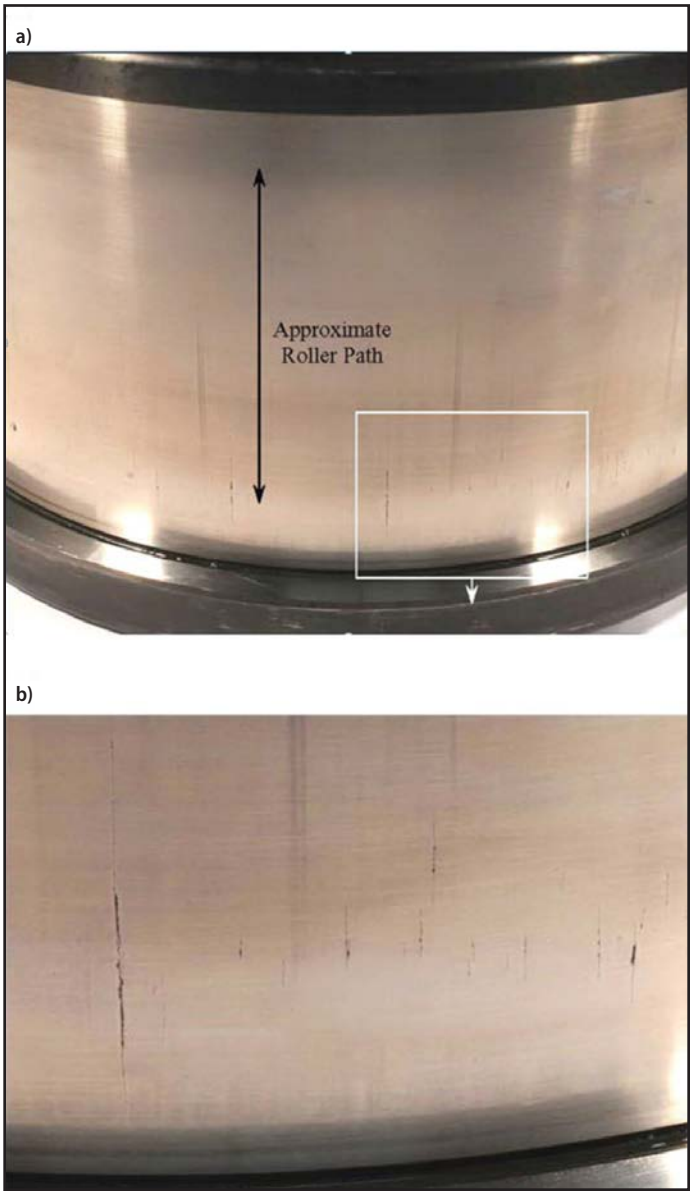


**Figure 2 (a) Axial cracks on intermediate bearing INT–B IR; (b) axial cracks on intermediate bearing INT–B IR.**

burized. The failure rate of the ROT–D bearings is 17%, with a mean time-to-failure of 26,690 h ($2.2 \times 10^7$ cycles). As this article is written, there have been no failures of a ROT–C bearing.

Table 3 compares data for the rotor bearings; Table 4 compares chemistry for the rotor bearings.


Figure 3 Irregular white etching areas on axial crack.

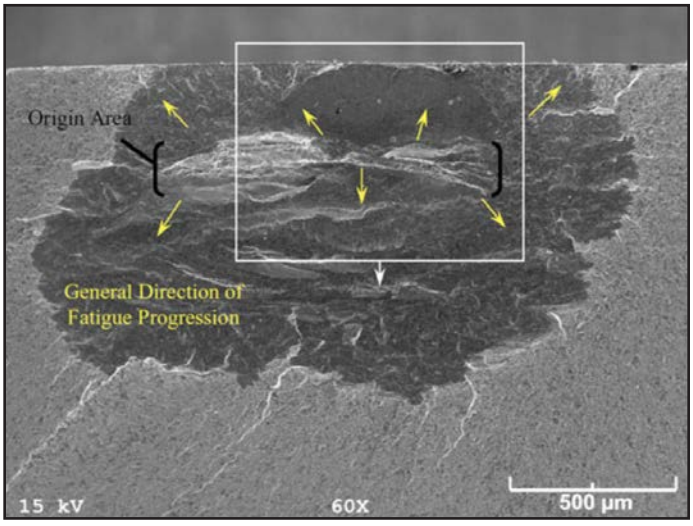


Figure 4 Opened axial crack on intermediate bearing INT–B IR.

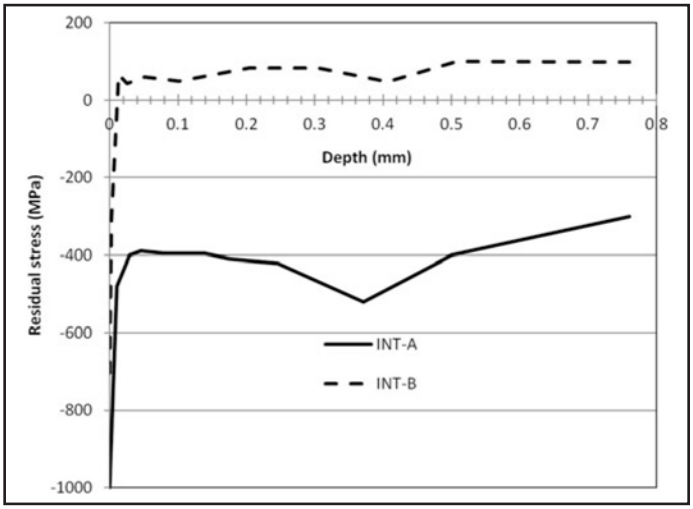


Figure 5 Residual stresses for intermediate bearings.

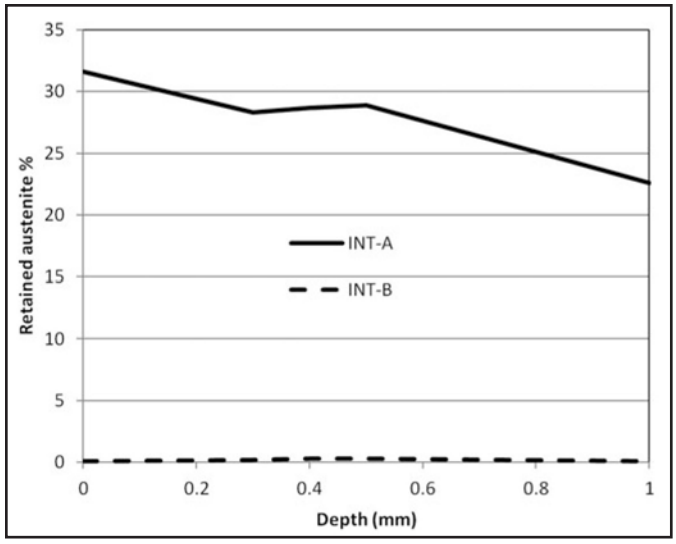


Figure 6 Retained austenite for intermediate bearings.

Table 3 Data for rotor bearings

| Parameter | ROT-C | ROT-D |
|---|---|---|
| Bore, $d$ (mm) | 749.3 | 749.3 |
| Outside diameter, $D$ (mm) | 990.6 | 990.6 |
| Width, $T$ (mm) | 159.5 | 159.5 |
| Dynamic capacity, $C$ (kN) | 4,460 | 5,330 |
| Static capacity, $C_o$ (kN) | 13,200 | 13,110 |
| Fatigue limit load, $P_u$ (kN) | 1,477 | 1,467 |
| Number of rollers, $z$ | 43 | 43 |
| Roller pitch diameter, $D_{pw}$ (mm) | 868.2 | 869.95 |
| Roller mean diameter, $D_w$ (mm) | 58.5 | 60.15 |
| Roller total length, $l_w$ (mm) | 118.1 | 118.1 |
| Roller effective length, $l_{weff}$ (mm) | 114.1 | 107.1 |
| Roller crown type | Circular | End reliefs |
| Roller crown magnitude (mm) | 0.030 | 0.053 |
| Nominal contact angle, $\alpha_o$ (°) | 12.5 | 12.5 |
| Axial preload, $G_{ao}$ (mm) | 0.2 | 0.3 |
| Heat treatment | Carburized | Carburized |
| IR case depth, $E_{hr}$ (mm) | 3.5 | 3.5 |
| Cage type | Stamped | Pinned |
| Hertzian stress (MPa) | 1,634 | 1,798 |
| Hertzian stress max (MPa) | 1,886 | 2,075 |
| Shaft speed (rpm) | 13.66 | 13.66 |
| DIN ISO 281-4 life (h) | 146,000 | 121,300 |

Table 4 Chemical composition for rotor bearings

| Element | ROT-C IR (% wt.) | ROT-D IR (% wt.) |
|---|---|---|
| Carbon, C | 0.126 | 0.199 |
| Silicon, Si | 0.217 | 0.265 |
| Manganese, Mn | 0.405 | 0.453 |
| Chromium, Cr | 1.29 | 1.32 |
| Nickel, Ni | 3.30 | 3.44 |
| Molybdenum, Mo | 0.099 | 0.190 |
| Sulfur, S | 0.016 | 0.003 |
| Phosphorus, P | 0.013 | 0.009 |
| Copper, Cu | 0.218 | 0.130 |
| Aluminum, Al | 0.030 | 0.029 |
| Cobalt, Co | 0.017 | 0.018 |
| Columbium, Cb | 0.013 | < 0.001 |
| Titanium, Ti | 0.005 | < 0.001 |
| Boron, B | < 0.001 | < 0.001 |
| Vanadium, V | 0.008 | < 0.001 |
| Tin, Sn | 0.023 | 0.018 |

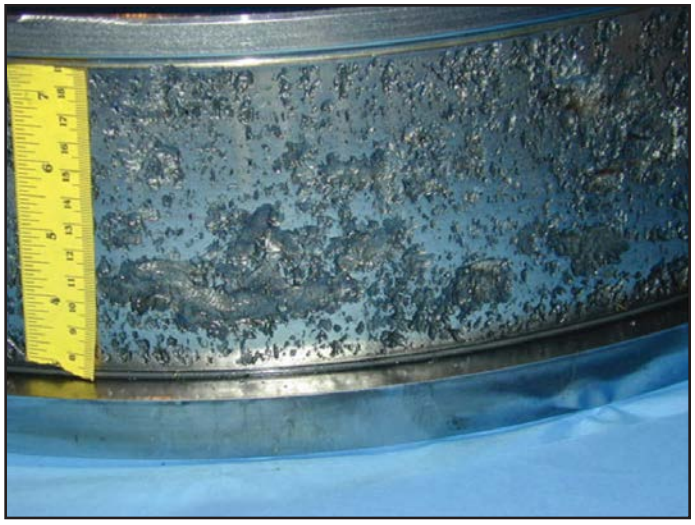

Figure 7 Macropitting on rotor bearing ROT–D IR.

a)


b)

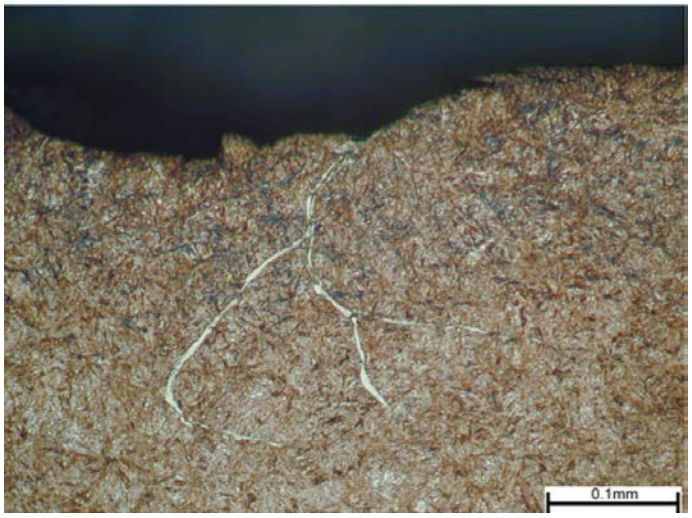


Figure 8 (a) Macropits and irWEAs on rotor bearing ROT–D IR; (b) macropits and irWEAs on rotor bearing ROT–D IR.

Figure 7 shows a failed ROT–D rotor bearing — IR — that had operated for 22,000 h ($1.8 \times 10^7$ cycles) when the failure was discovered. The entire circumference of the IR is covered with severe macropitting.

Figure 8a is a micrograph of a circumferential, metallurgical section through a macropit. The section has been nital-etched to display the irWEAs associated with the macropits. Figure 8b is at a higher magnification and shows cracks within the irWEAs. The crack morphology is typical of macropitting found on carburized bearings from wind turbines (Refs. 12, 13, 19).

Residual stresses and retained austenite were measured on new, unused rotor bearings. Figure 9 shows residual stresses on rotor bearings determined by XRD, per ASTM E915. The residual stresses for the ROT–C and ROT–D bearings are entirely compressive to a depth of 500 $\mu$m. For depths below 20 $\mu$m, the residual stress for the ROT–D bearing is –250 MPa near the surface, and it fades to zero IMPa at a depth of 500 $\mu$m; whereas the residual stress for the ROT–C bearing increases from –250 MPa near the surface to a maximum of –350 MPa at a depth of 300 $\mu$m and fades to –100 MPa at a depth of 500 $\mu$m.

Figure 10 shows retained austenite on rotor bearings determined by XRD, per ASTM E975. The retained austenite for the ROT–D bearing ranges from 12 – 17%; the retained austenite for the ROT–C bearing ranges from 20 – 26%.

Two non-failing rotor bearings (a ROT–C and a ROT–D) were removed from service after 25,000 h and metallurgically examined. The ROT–C bearing had butterflies at depths ranging from 100 – 400 $\mu$m, but *no* irWEAs. The ROT–D bearing had numerous irWEAs at depths ranging from 400 – 600 $\mu$m (Fig. 11).

## Discussion

The wind turbine gearbox failures have shown that through-hardened bearing failure is caused by axial cracks, whereas carburized bearing failure is due to macropitting. This is consistent with the findings of other investigators (Refs. 16, 19, 20, 22).

***Through-hardened vs. carburized intermediate bearings***. Table 1 shows that the INT–A and INT–B bearings have similar geometries. However, Table 2 also shows that the INT–B through-hardened bearing and INT–A carburized bearing have very different chemistries. Furthermore, Figures 5 and 6 show that the INT–B through-hardened bearings have tensile residual stresses and very little retained austenite, whereas the INT–A carburized bearings have significantly higher compressive, residual stresses and greater amounts of retained austenite.

To compare the properties of the bearings to other industries, the evolution of bearing materials for gas turbines has shown that a carburized bearing with a core having a low-carbon, high-nickel content — such as M50NiL (Ref. 23) — has a relatively high fracture resistance compared to an M50 through-hardened bearing. Furthermore, Forster (Ref. 23) found WEAs in AISI 52100 and AISI M50 bearings — but no WEAs in M50NiL bearings.

Figure 4 shows that the origin of the brittle fracture lens is about 300 $\mu$m below the surface. Figure 5 shows that the residual stress at this depth is about +85 MPa tensile for the INT–B through-hardened bearing, and about –450 MPa com-

pressive for the INT–A carburized bearing. We believe that the compressive, residual stress increases fracture resistance and is the principal reason the INT–A carburized bearing is immune to axial cracks.

In summary, the intermediate bearings have similar geometry but very different chemistry, residual stresses, and retained austenite. Therefore, it is believed that the better performance of the INT–A carburized bearing is due to different chemistry with a core having a low-carbon, high-nickel content; greater compressive residual stress; and a higher amount of retained austenite. All of these properties provide higher fracture resistance and make carburized bearings more durable in the wind turbine environment than through-hardened bearings.

***Carburized rotor bearings.*** Tables 3 and 4 show that the ROT–C and ROT–D rotor bearings have similar geometries and chemistries. Yet Figure 10 shows that the ROT–C bearings have a significantly greater amount of retained austenite — at *all* depths. Furthermore, metallurgical analyses of non-failing bearings have shown that no irWEAs form in the ROT–C bearing, whereas irWEAs form in the ROT–D bearing at depths ranging from 400 to 600 $\mu$m (Fig. 11). Figure 9 shows that the residual stresses for the ROT–C and ROT–D bearings are very similar at the depths of the irWEAs. In summary, the carburized rotor bearings ROT–C and ROT–D have similar macrogeometries, chemistries, and residual compressive stresses — *but different levels of retained austenite*. There are also differences in the design roller profiles between the two bearings, and analysis of the profiles predicts higher peak stress for the ROT–D profile under many operating conditions. Furthermore, coordinate measuring machine (CMM) measurements made on actual components suggest that the as-built roller geometry of ROT–D bearings results in even higher peak stress under many operating conditions than do the nominal profiles. It is therefore believed that the better performance of ROT–C bearings is due to their higher amount of retained austenite, superior roller profile design, and reduced variation in manufacturing.

## Through-Hardened vs. Carburized Bearing Performance: A Summary

The authors' experience shows that through-hardened bearings display irWEAs on axial cracks that propagate radially through the bearing IR section (Fig. 3), whereas carburized bearings display irWEAs on crack networks that occur over large, subsurface areas at depths ranging from near the surface to the depth of the maximum shear stress (Fig. 11). Eventually the cracks reach the surface, where they form macropits; this is consistent with the findings of other investigators (Refs. 16, 20, 22). This failure mode is sometimes known as "white structure flaking (Ref. 21)."

The authors' experience, and that of others — (Refs. 15, 20, 22) — has shown that carburized bearings *with a proper microstructure* can be immune to the axial crack failure mode and are more durable in a wind turbine environment than through-hardened bearings. Furthermore, the authors' results show that if the carburized microstructure has at least 20% retained austenite, irWEAs do not form and premature macropitting is avoided.

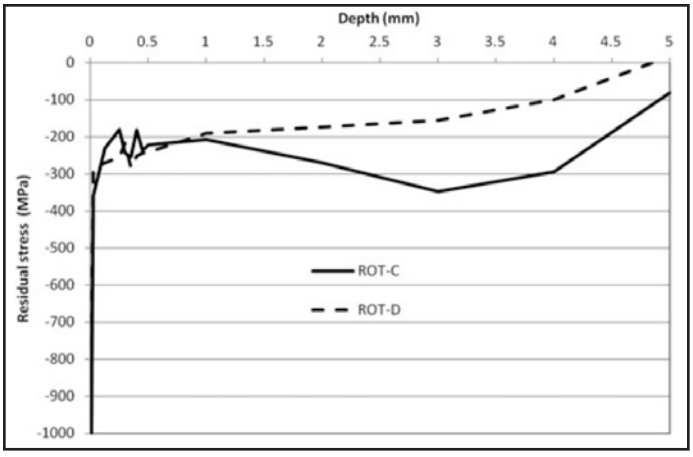


Figure 9 Residual stresses for rotor bearings.

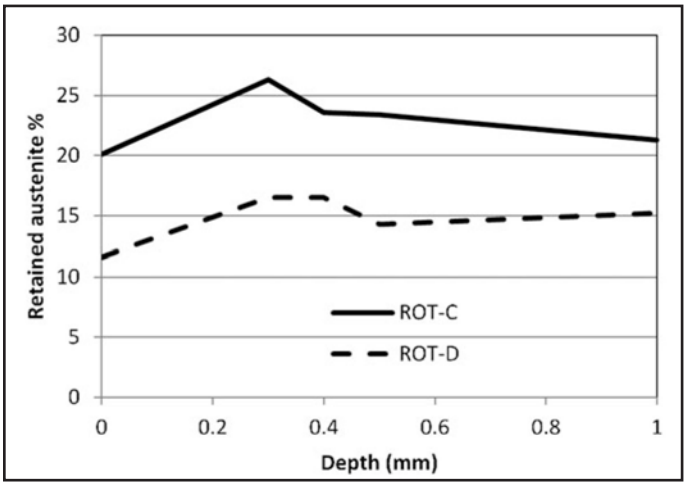


Figure 10 Retained austenite for rotor bearings.


Figure 11 irWEAs on rotor bearing ROT–D IR.

## Conclusions

The following conclusions are drawn from field experience working with operating wind turbines that compares the performance of through-hardened and carburized, intermediate bearings, and two rotor bearings with different carburized metallurgies. The conclusions are intended to apply to wind turbine gearbox bearings. They may — or may not — apply to other applications.

Through-hardened bearings fail by axial cracks; carburized bearings fail by macropitting.

Through-hardened bearings display irWEAs on axial cracks that propagate radially through the bearing IR section.

Carburized bearings are more durable in the wind turbine environment than through-hardened bearings, and might be immune to irWEAs and the axial crack failure mode if they have at least 20% retained austenite.

Carburized bearings with less than 20% retained austenite display irWEAs on crack networks that occur over large subsurface areas at depths ranging from the near surface to the depth of the maximum shear stress. When the cracks reach the surface, they form macropits.

Carburized bearings with at least 20% retained austenite might be immune to irWEAs and avoid premature macropitting. **PTE**

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**Robert Errichello** heads his own gear consulting firm—GEARTECH—and is a founder of GEARTECH Software, Inc. He is a registered professional engineer and a graduate of the University of California at Berkeley. He holds B.S. and M.S. degrees in mechanical engineering and a master of engineering degree in structural dynamics. Errichello has over 34 years of industrial experience and has worked for several gear companies. He has been a consultant to the gear industry for the past 19 years; has taught courses in material science, fracture mechanics, vibration and machine design at San Francisco State University and the University of California at Berkeley; and is a member of ASM International, STLE, ASME Power Transmission and Gearing Committee, AGMA Gear Rating Committee and the AGMA/AWEA Wind Turbine Committee. Errichello has published over 40 articles on design, analysis and the application of gears and is the author of three widely used computer programs for the design and analysis of gears. He is a technical editor for Gear Technology magazine and STLE Tribology Transactions and has presented numerous seminars on design, analysis, lubrication and failure analysis of gears. Errichello is a recipient of the AGMA TDEC Award and the STLE Wilbur Deutch Memorial Award.

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

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

**Randy Stott,**

**Associate Publisher & Managing Editor**

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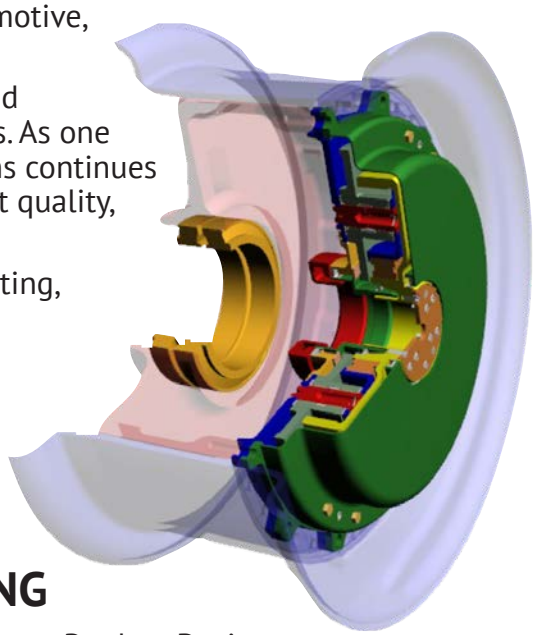

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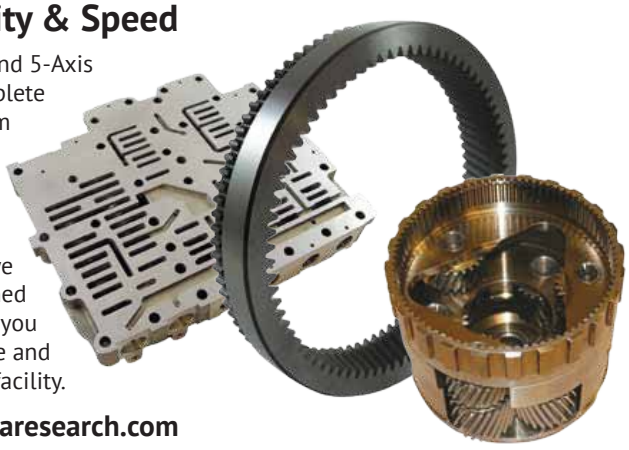

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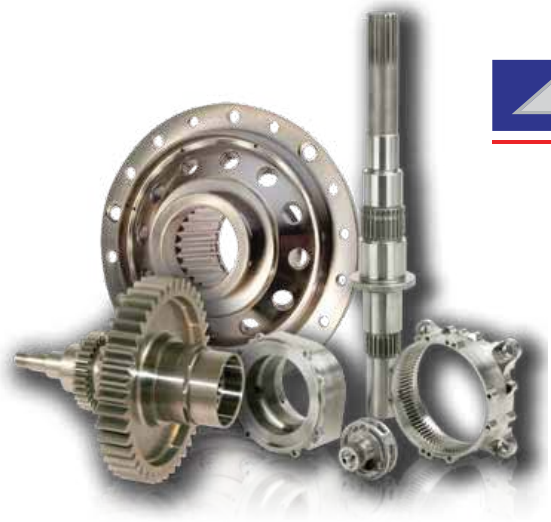

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SDP/SI consists of Stock Drive Products (ISO 9001 Registered) and Sterling Instrument (AS9100 Registered), both of which are Designatronics companies. Stock Drive Products offers an astounding selection of standard and custom components, including timing belts and pulleys, and Sterling Instrument boasts a world-class facility for gear-cutting and assembly that serves the biggest names in the Defense and Aerospace Industries. But it's about more than that. SDP/SI is committed to having the latest manufacturing technology and the brightest engineers around to ensure that you can find or design your perfect drive component every single time.

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Quality Bearings and Components, a division of Designatronics Inc., is an industry leader for all things bearing related. We offer a wide selection of all types of commercial and precision grade bearings, as well as a number of bearing maintenance products.

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Quality Transmission Components (QTC), a division of Designatronics Inc., is a leading supplier of nearly 13,000 gear products designed for power transmission in industrial automation applications. QTC is the largest North American distributor of stock metric gears. This includes spur gears, helical gears, racks, miter gears, bevel gears, worms, worm gears, gear couplings and gearboxes. All products are detailed in catalog Q420, and at *www.qtcgears.com*.

The United States is the only country that uses English units as an official standard of measurement. Naturally, this presents problems when dealing with international products. A common scenario is when a machine is purchased from overseas, and a component needs to be replaced. Traditionally, it was difficult to source these replacements, or lead times would be excessive. Quality Transmission Components (QTC) was established in 1993 in response to this issue. We serve as the exclusive North American distributor of Kohara Gear from Japan, and as a licensed distributor of Davall Gears from the United Kingdom. Having such a wide selection of stock metric components in one place makes it easy for the customer to get everything they need with significant time and cost savings. Overall, when it comes to metric power transmission components, QTC is the obvious choice.

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# Global Industrial Outlook: Don't Step in the C.R.A.P.

By Brian Langenberg, CFA

Fourth quarter results were above expectations for most U.S. machinery companies, including significant revenue beats at Cummins, Caterpillar, Oshkosh Corp and PACCAR with strong North American truck demand, improving construction equipment markets and general stability elsewhere.

Regionally speaking, U.S. industrial growth was solid; Europe picked up slightly and Asia grew. We also gleaned generally positive comments and results from the Middle East and broader Asia, excluding of course Australia and mining. Conversely, Latin America and Canada have slowed. The questions are a) why? b) is it sustainable? and c) is it broad-based or sector-specific? This is where it is critical to bore down from the general to the particular.

We are starting to talk with our clients about watching out for C.R.A.P. No, not that kind; but rather, currencies that are tied to resource extraction. In this case C.R.A.P. stands for Canada, Russia, Australia and Peru (really Latin America). Each of these currencies is off 10% or more, year-over-year, and primarily attributable to concerns about anticipated resource demand from China.

If the above trends are telling us something deeper and these currencies continued to fall, we would need to reconsider. We don't think it plays out that way. China steel production grew 8% y/y in the fourth quarter, Korean shipbuilding activity is strengthening somewhat and engineering & construction firms continue to sport strong order books and project activity. Additionally, European industrial production for export markets is stronger and machine tool builders are active. In the end we continue to see solid growth in the global economy.

***Oil & Gas.*** Chatter persists of slowing capital spending activity as large oil companies focus on driving returns and efficiency. General Electric Oil & Gas equipment orders were down y/y, but attributable to a tough comparison. Core sales growth was up 8% and we saw growth at other companies. While pockets of slack are likely, global activity remains solid, including offshore Brazil (Petrobras), the Middle East and Russia. Within the U.S. momentum continues in pipeline building, LNG infrastructure and petrochemicals.

***Mining.*** Still awful — fourth-quarter mining sales at Caterpillar fell 47%. Every major mining company has announced capital spending cuts of another 25-35% in 2014, and the likelihood of further cuts in the next. The silver lining is high utilization driving continued stability in consumables and service. Atlas-Copco and Sandvik saw "only" a 20% decline in 4Q.

***Power Generation.*** Capacity is being added internationally while dormant in the U.S. GE booked 45% order growth in 4Q, including 12 steam turbines and 22 for the full year vs. only 8 in 2012. Gas turbine orders were okay — 24 units vs. 26. U.S. demand is soft overall, given economic efficiency

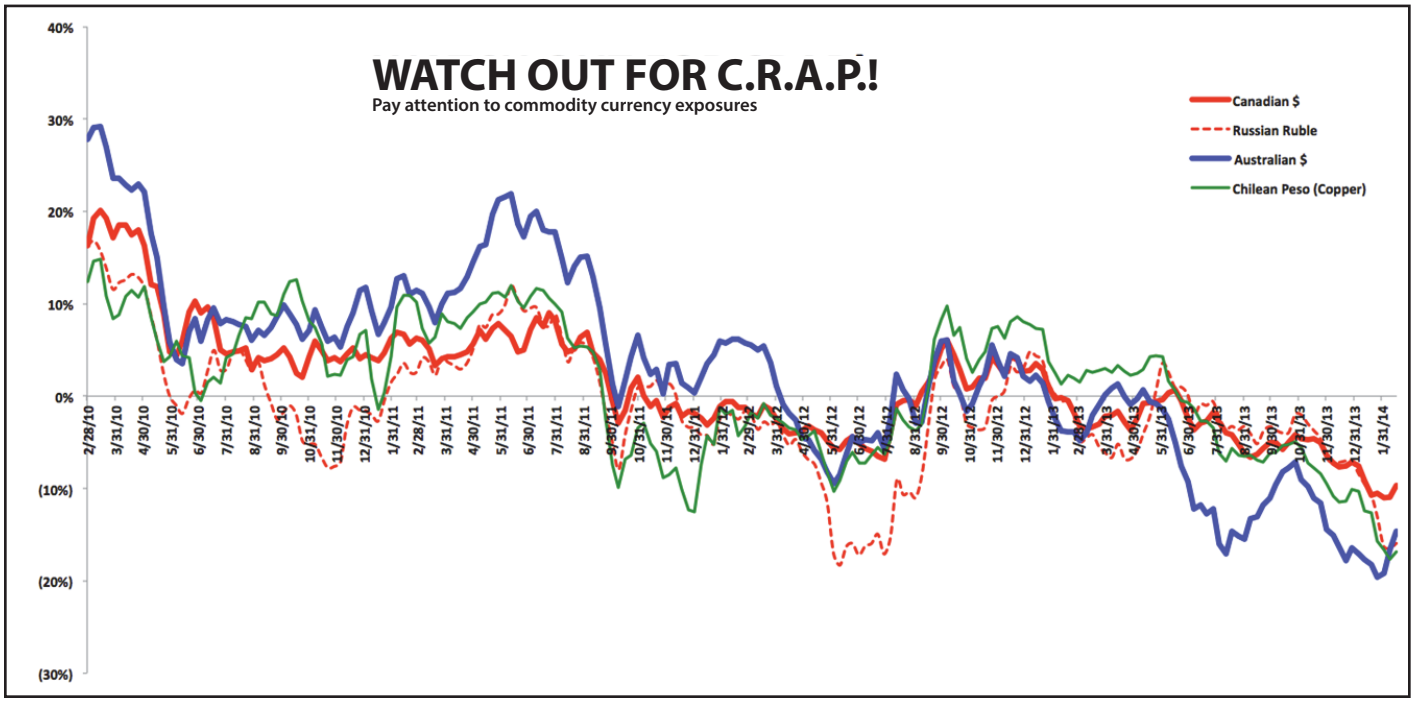


**Figure 1** China continues to grow at a solid pace, but slower by historical standards. As a result markets have sought to price in slowing emerging market demand, which in turn takes down resource currencies.

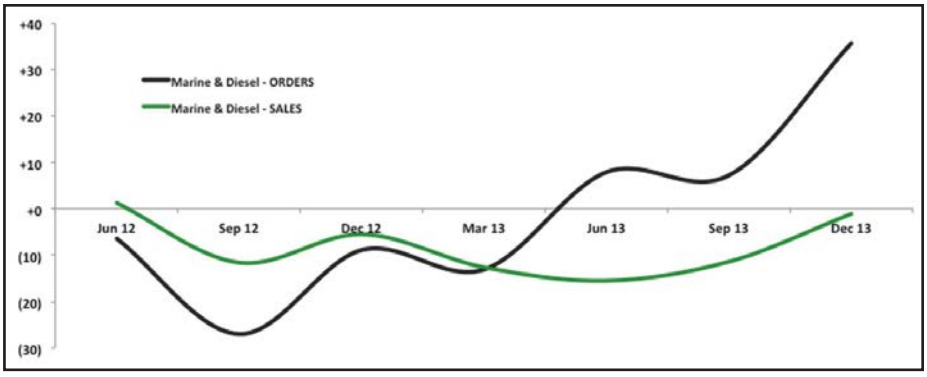


**Figure 2** For those of you who sell into marine transportation, I do think the worst is over. Focus Company: Manitowoc Company (MTW)

gains and regulatory hostility to new investment. The exception is wind turbines — a.k.a. Band-Aids — with orders of 875 units in 4Q vs. 412 y/y. Wind turbines are less efficient, but cost only $2-4M each; and nobody complains, so up they go.

***Transportation Infrastructure.*** 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*. But we are seeing improved shipbuilding activity, particularly energy-related LNG and offshore processing capacity. Alfa-Laval has achieved positive order growth in its Marine & Diesel segment three straight quarters now.

***Water & Environmental.*** Municipal demand is improved with positive sales momentum the past two quarters. Improved home prices are contributing to better tone; industrial markets are stable.

***Machinery.*** Overall picture continues to improve — particularly in truck as well as construction equipment. **Construction equipment** – Caterpillar reported 24% growth in 4Q and the industry outlook for '14 is +5-8%. Growth was broad-based: OSK commercial +9%, United Rentals +7% and Manitowoc Company are bullish on 2014 orders. **Mining equipment** remains dismal as miners are projecting 25-35% reductions in capital spending and straining to conserve cash — particularly U.S. coal miners. **Truck**: Continuing growth and acceleration, driven by replacement demand and new product launches versus fleet growth.

***Agricultural Equipment.*** John Deere is calling for 4-6% declines in their fiscal 2014, and we suspect that with declining farm income and a push out of an ethanol mandate that it could be even a bit softer. The international growth focus remains Brazil, Russia and (for AGCO) Africa.

***Consumer (auto, appliances).*** Expect continued strength in automotive production — even as expansion capital spending has flattened out at a high level. Despite some concerns about capacity, we maintain the fleet is old so utilization will remain high. Demand for appliances remains strong, as does refurbishing activity.

***Aerospace/Defense.*** Commercial aviation remains strong at GE Aircraft Engines and Pratt & Whitney, with growth in OE, spares and shop visits as the heavy overhaul work is finally hitting. No reason for conditions to soften. Defense — while the worst is over, the trends should remain soft.

And rather than displaying our Global Industrial Dashboard this time — take a look instead at the improving orders and sales trends for the Marine & Diesel division of Alfa Laval. While freight rates in global shipping remain hideous, there *is* activity – much of it LNG, offshore energy-related — but shipyard work is strong, and on the power generation side there are environmental systems retrofits and power plant related work.

Late-cycle, big-construction projects — wind, power plants, non-residential construction — they all need BIG CRANES. Manitowoc Company was founded as a shipyard in 1905 and now operates in two segments – Crane and Foodservice. Crane orders were up 42% in the fourth quarter — even as backlog fell on improving throughput. But the future is bright; wind turbine activity is already strong, construction markets continue to improve and non-residential construction should uptick in 2014. Globally we see improving demand for cranes, particularly in the Middle East, but also better in Europe.

The company launched 10 new crane products at ConExpo in March, and we suspect the company can generate strong revenue growth in 2014 and beyond.

(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.*

**April 1–2—Human Error Prevention Seminar.** Charlotte, North Carolina. The principles and practices of human error prevention are universally applicable regardless of the type of industrial, commercial or governmental enterprise, and regardless of the type of function performed within the enterprise. This seminar is truly unique and up to date with the latest developments in human error prevention. Ben Marguglio's new taxonomy of human error causal factors and his human error-related models demonstrate his leadership in this subject. Examples and case studies amply reinforce the human error prevention principles and practices. Upon seminar completion, attendees will be able to: improve process productivity, safety and quality using new and unique techniques, tools and behaviors for error prevention, detection and mitigation; Address the four fields of focus – (1) hazards and barriers, (2) error-inducing conditions and counteracting behaviors, (3) non-conservative decisions and counteracting behaviors and (4) prevention of error recurrence; design, implement, manage and assess a Human Error Prevention initiative. For more information, visit *www.hightechnologyseminars.com*.

**April 7–11—Basic Training for Gear Manufacturing.** Richard J. Daley College, Chicago. The AGMA Training School for Gear Manufacturing will enable you to become more knowledgeable and productive. The Basic Course teaches students to set up machines for maximum efficiency, to inspect gears accurately, and to understand basic gearing. Although the Basic Course is designed primarily for newer employees with at least six months' experience in setup or machine operation, it has proved beneficial to quality control managers, sales representatives, management, and executives. This course offers training in: gearing and nomenclature, principles of inspection, gear manufacturing methods, hobbing, shaping and more. Although all training is basic, on manual machines, everything that students learn is valid and applicable with the CNC equipment commonly in use. By using manual machines, students can see the interaction between the cutting tool and the workpiece. They understand the process and the physics of making a gear. For more information, visit *www.agma.org*.

**April 7–11—Hannover Messe 2014.** Hannover Fairgrounds, Hannover, Germany. The world's leading trade show for industrial technology returns in 2014 with a full lineup of trade shows under the banner "Integrated Industry-Next Steps." The seven co-located shows include Industrial Automation; MobiliTec; Digital Factory; Industrial Supply; IndustrialGreen Tec and Research and Technology and Energy. The Netherlands is the official partner country in 2014. Discover new perspectives on energy, automation and industrial supply and engineering topics as well as a broad range of events and displays affecting the global industrial market today. Other Hannover highlights include the Robotics Award, the 11th WoMenPower Conference, Metropolitan Solutions, economic forums, job and career fair and more. For more information, visit *www.hannovermesse.de*.

**April 10–12—AGMA/ABMA Annual Meeting.** Vinoy Renaissance Resort and Golf Club, St. Petersburg, -Florida. Expert presentation topics include "Accountability and Achievement," "Global Megatrends; Major Forces in Manufacturing," "Unconventional Oil and Gas: Game Changer If We Don't Screw it Up," "Economic Outlook" and "How to Turn Republicans and Democrats into Americans." The annual golf tournament returns as well as the First Timer's Reception on Thursday night prior to the Welcome Reception. Friday night features the "Sounds of Soul" and Saturday night features "Hot Havana Nights" with a cigar-making demonstration. The hotel features an 18-hole golf course, private marina, and 12 tennis courts, in addition to newly renovated meeting, gathering and sleeping rooms. It is ideally located near Tampa International Airport, St. Pete Beach and downtown St. Petersburg, home to the Salvador Dali and Chihuly Museums. For more information, visit *www.agma.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 it 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*.


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# Gear Motions

## COLLABORATION KEY TO PAST, PRESENT AND FUTURE SUCCESS

The journey for Gear Motions began in the 1960s when Rawling Gear was acquired by Samuel T. Haines. Gear Motions was formed in 1973 when his son and current CEO Samuel R. Haines joined the company with a business plan to develop a network of companies with unique specialties that could be leveraged to better serve the wide-ranging needs of gear customers.

"In that same year, Oliver Gear was acquired, and along with Rawling Gear, became the foundation for Gear Motions," said Dean Burrows, president of Gear Motions. "Oliver Gear has roots dating back to 1892 and has a long history of supplying gearing to manufacturers all over the world. In 1978, Gear Motions acquired Nixon Gear, which began operating in 1920."

In the early 1980s, Gear Motions created its Plastic Gearing Services Division to provide the design and development of high-strength strength plastic gearing. By 1988, Gear Motions acquired Gear Supply and Broaching, a California gear-manufacturing company.

"During the 1990s and early 2000s, these businesses were either consolidated into existing facilities or sold," Burrows said. "In 2012, Gear Motions acquired Pro-Gear Co. Inc., a gear-grind-only manufacturer in Buffalo, New York. In 2014, Gear Motions acquired Niagara Gear in Buffalo, which was founded in the early 1940s."

This latest acquisition occurred because Gear Motions and Niagara had a long history of collaborating with customers on projects, despite having completely different customer bases. "This allows the combined companies to share their distinct capabilities with a whole new market," Burrows said. "Each company within the Gear Motions family has a specialty that makes it unique to the industry."

Today, the company plans to continue to add new equipment to meet customers' growing demands. "We have added turning, milling, broaching, hobbing, gear grinding and inspection equipment in recent years. Our focus in 2014 will continue to be investing in the technology and equipment needed to remain world-class. Specifically, we will add new inspection and hobbing capabilities and capacity," Burrows said.

In an effort to provide a single point of contact for existing as well as new customers, Gear Motions has recently created a new website (*www.gearmotions.com*) and logo. "To heighten awareness of our capabilities, we have begun a new marketing campaign in various channels, including the website and print. We will also continue to meet face to face with our customers. Nothing is stronger in a business relationship than sitting across the table and talking," Burrows said.

The collaborative philosophy at Gear Motions paid off recently when the company was requested to design, prototype and build its first gearbox. "This project required a team of local and international partners to complete. Working hand in hand with these partners, we were able to exceed the customer's design expectations and produce a world-class gearbox. We never would have been able to do this project without our partners, and this is the business model for companies like Gear Motions."

Like many manufacturing companies, Gear Motions has daily challenges that must be met in order to stay successful now and in the future. "Our biggest challenge is how to 'go to market' so that new customers fall in love with us like our current customers have," Burrows said. "Our next challenge is developing the workforce of tomorrow that is trained for the technologies of today and the ones yet to come. We have accomplished this through internal and external training programs. Third, as an employee-owned company, we challenge ourselves daily to instill the ownership culture in our business. Employee-owned companies have historically been higher-performing, more agile and more stable companies. Since beginning our employee stock ownership plan (ESOP) in 2005, we continue to develop the employee-owned culture for even more success in the future."

The company expects 2014 to be a good year leading into an exceptional 2015 as the markets continue to strengthen and the economy continues to recover. "With the addition of Niagara Gear, we are confident that we can capture more opportunities in 2014 than in past years," Burrows said. "Our plan is to continue our growth organically and through acquisitions. We will add more capabilities and more diverse products. We will continue to invest in new technologies and will continue the ESOP development, so we can always exceed our customers' expectations."

# Weiss

ANNOUNCES KEY HIRES

With an aggressive product growth trajectory to coincide with its planned 15,000 square foot manufacturing facility expansion, Weiss recently welcomed Josh Treter to the position of product sales manager-direct drives and Keith Griffin as business unit manager. In addition to recent extensive experience as a sales engineer at Nook Industries (Cleveland, Ohio), Treter brings a heavy technical background dating back to years in the aviation sector – even as a former pilot.

Josh Treter

Given this depth of hands-on technical expertise, Treter will focus his attention on expanding sales of Weiss' dynamic Direct Drive line of linear and torque motor products in the marketplace. According to Treter, "All products in the line offer exemplary quality, speed, and accuracy for a wide-range of automated small parts assembly applications including automotive, packaging, medical, and beyond."

At the epicenter of new products on the immediate horizon is the introduction of Weiss' HP 70T which features a unique 'knuckle' design on the y/z axis that essentially eliminates the need for another linear motor for the z axis. Treter plans on working hands-on with sales reps in key growth territories throughout the U.S., Canada and Mexico. "The goal is to supply them with extensive engineering and marketing support to help educate the market as to the lines' advanced benefits while providing complex, customer-specific solutions," Treter said.

Treter also noted that an essential part of this education will focus on implementing the user-friendly Weiss Application Software (WAS) in the field for clients. Used throughout all freely programmable Weiss products, the graphic user interface series is highly intuitive and uniform — providing faster set-up and smooth operation to save customers valuable time and cost.

Leveraging over twenty years of engineering experience with Fusion Systems Group (Willoughby, Ohio), Griffin will serve as Weiss' business unit manager — spearheading a focus on assisting integrators from A-Z on comprehensive Weiss systems.

Keith Griffin

With an extensive history in designing and fabricating custom automation machines, Griffin's focus at Weiss will be to get involved with machine builders and engineers upfront in designing a core package and designing out for more efficient production results. "Our problem-solving, consultative approach will encompass a broad spectrum ranging from machine frames, risers for index tables, stationary plates, CAD models, pick-place systems, indexing units, etc. The goal is to design a one-stop, ship assembled, value-added framework for optimal results." To streamline this process further, Griffin is also at the forefront of launching a SolidWorks portal that will allow customers to quickly share CAD files.

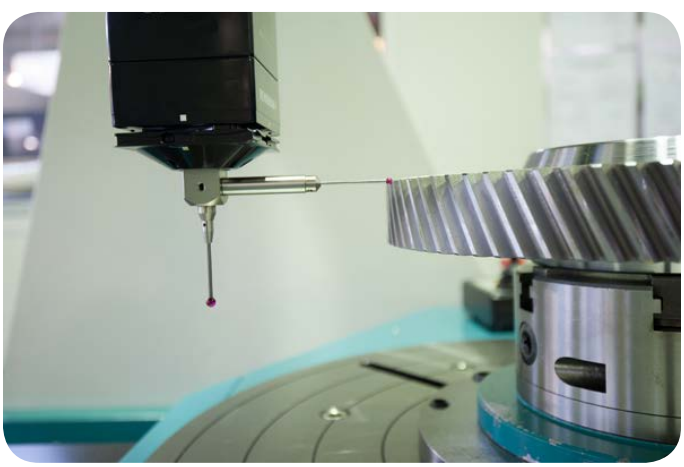
Griffin also noted that the 2014 expansion of the Weiss manufacturing facility will drive this philosophy even further stating, "New capital equipment will vastly increase our in-house capabilities of tool plate machining and machine frame fabrication. Ultimately it will drive our goals of more efficient production, faster turnaround, better pricing and delivery."

# Ronson Gear

RECEIVES AEROSPACE ACCREDITATION

Australian gear manufacturer Ronson Gears has been awarded accreditation to AS9100C Quality Management System Standard (Aerospace), paving the way for the company's expansion into new markets internationally. U.K. based Lloyd's Register Quality Assurance Limited conducted the audit late last year and awarded Ronson Gears the accreditation for its gear manufacturing and quality systems.

According to Ronson Gears' Managing Director, Gordon New, the accreditation is recognition of the company's long-standing focus on quality, customer service and its ongoing investment in state-of-the-art equipment, providing the capability to service the high demands of customers in the aerospace and defence industries.



"We achieved ISO9001 accreditation in 1998 and have a proven record of providing quality services to Original Equipment Manufacturers (OEMs) in a broad range of industries," New said. "We've supplied BAE Systems for many years as well as indirectly supplying well-known companies including Boeing and Lockheed Martin,"

"The new accreditation means the company's expertise will be more widely recognized globally," he said. "Our agent in North America is already in contact with a number of potential new customers and we hope to branch into Europe as well in years to come."

# Lafert N.A.

## WINS GREEN BUILDING AWARD

Lafert North America's High Performance Metric Motors won first place in the Green Building category in the annual AHR Innovation Awards Competition. Sean Hickey, president of Lafert NA accepted the Innovation Award, which had been selected by a panel of industry professionals with pronounced knowledge and expertise in the HVACR industry. The AHR competition is sponsored by ASHRAE, the air-conditioning, heating, and refrigeration institute (AHRI) and the


**Bill Bahnfleth, ASHRAE president, Sean Hickey, Lafert North America president and on the right is Bob McDonough, chairman of AHRI**

International Exposition Company (IEC). The HCACR show hosted nearly 2,000 manufacturers and suppliers and more than 55,000 industry professionals from around the world. Lafert's award winning High Performance Metric Motors come in speeds ranging from 1,500-4,500 rpm and in metric frame sizes from 71 to 132 mm, with a power rating of 0.75 hp to 40 hp and an IP55 degree of protection for the whole range. These permanent magnet motors are suited for applications involving pumps, fans and compressors with an emphasis on reducing size, weight and operating costs while achieving an IE4 efficiency rating, combined with a simple-set up and integration to the application. Permanent magnet compatible variable frequency drives can be utilized with Lafert's HPS (high performance stand alone) motors, while the HPI(high performance integrated) design offers drives are integrated into the motor.

# Heidenhain

## APPOINTS PRODUCT SPECIALIST

Recently acquiring the responsibility for the North American sales and marketing of ETEL products (manufactured in Switzerland), Heidenhain Corporation announces the appointment of Brian Zlotorzycki as product specialist, ETEL Motors. Based in Schaumburg, IL, Zlotorzycki is responsible for ETEL linear and torque motor product support. ETEL provides the largest direct drive motor range available on the market today, and Zlotorzycki is poised to be instrumental in providing solutions in industrial motor applications, including those requiring high torque/force. Zlotorzycki holds a mechanical engineering degree from Northern Illinois University. Born and raised in Des Plaines, Illinois, Zlotorzycki will travel to Switzerland as needed but reside in the U.S. to support North American customers.

# Aerotech

## MOVES TO LARGER FACILITY IN UNITED KINGDOM

As part of continued expansion in the global precision motion and automation systems arena, Aerotech Inc. - the Pittsburgh-USA headquartered high-technology mechatronic motion products designer and manufacturer - has relocated its U.K. subsidiary to a new and larger facility in Ramsdell near Tadley. With additional office and operational logistics space as well as considerably more room for customer demonstration, training and conferencing, the well-equipped 500 m2 building will allow Aerotech Ltd to build upon and enhance its position as a premier motion system supplier to the U.K. and Europe. The move to the new building complements Aerotech's recent manufacturing and engineering facility expansion in Pittsburgh and significantly reflects its determination to provide world-class sales and service with similarly equipped subsidiaries in Germany, Japan, Taiwan and China.

The new facility at Ramsdell represents a real progression of Aerotech's proven track record in the U.K. and Europe that began almost 33 years ago when the subsidiary was first established. Aerotech works with industrial manufacturers and research institutions, designing and building precision mechanics, motion controls and drive electronics as integrated electromechanical subsystems that enable the customer to concentrate, specialise and develop its own core manufacturing technologies and research goals. From the U.K., Aerotech makes an active contribution to Europe and has partnerships with many universities and manufacturers for the production, test and/or research of high-technology equipment in semiconductor, electronics, medical, military and laser processing, amongst others. Solutions range from single-axis positioners chosen from a wide standard range to innovative custom manufactured multi-axis systems.

# PTDA Foundation

## ESTABLISHES WENDY B. MCDONALD AWARD

To honor the memory of Wendy B. McDonald, one of the power transmission/motion control industry's true pioneers, the PTDA Foundation has established the Wendy B. McDonald Award. The award acknowledges a woman who has established herself as a critical contributor to her company's success and has affected positive change within the power transmission/motion control industry.

McDonald, known as "Mrs. Mac," served over 60 years as a leader in her family-owned international industrial distribution company, BC Bearings Engineers Limited, which was acquired by Motion Industries, Inc. A trailblazing woman business owner, McDonald left many legacies through her long career in the industry. Her charm and grace are legendary as well as her philanthropy and commitment to give back to the industry and the communities that led to her success.

When merited, the Wendy B. McDonald Award will be presented annually during the PTDA Industry Summit. Nominations are now being accepted through May 31, 2014, and will be judged by the following criteria:

- Nominees must be female and employed by a PTDA member company in any capacity. There are no criteria with respect to title, position in company or years of experience.
- Nominees must exemplify leadership and integrity in all business relationships.
- Although all nominees are considered, those employed by Canadian companies or distributors receive extra consideration.

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For publication guidelines and more information, please contact Jack McGuinn at *jmcguinn@powertransmission.com*.

## ADVERTISING INDEX

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**4** → How is THIS LOCATION involved with power transmission products? (Check all that apply)

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☐ Other (please describe) (15)_____

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# Kids Don't Have to Become President to Become Deciders

**Finding picture books for kids old enough to appreciate them can be a daunting task.** There are, of course, the usual suspects—celebs, athletes, boy bands, girl bands, and so on, but not much of substance.

That's where David Janosz Jr. enters the picture. With his 2014 picture book release, *Engineers Decide,* an interactive iBook available free through March 31 in 51 countries and supported by iBooks, Janosz hopes to fill a void. Indeed, turns out he could find *no* books related to engineering when looking for his son. (Janosz, with 18 years' experience designing and delivering STEM education programs nationally and internationally, focuses on technology and engineering topics.)

"I wrote and published *Engineers Decide* because I want every young person to be able to envision him or herself doing engineering," Janosz says. "I know that most will not become engineers, but too many children never even see the possibility."

Backing up those words with deeds, Janosz and iBooks are making *Engineers Decide* available absolutely free through March 31.

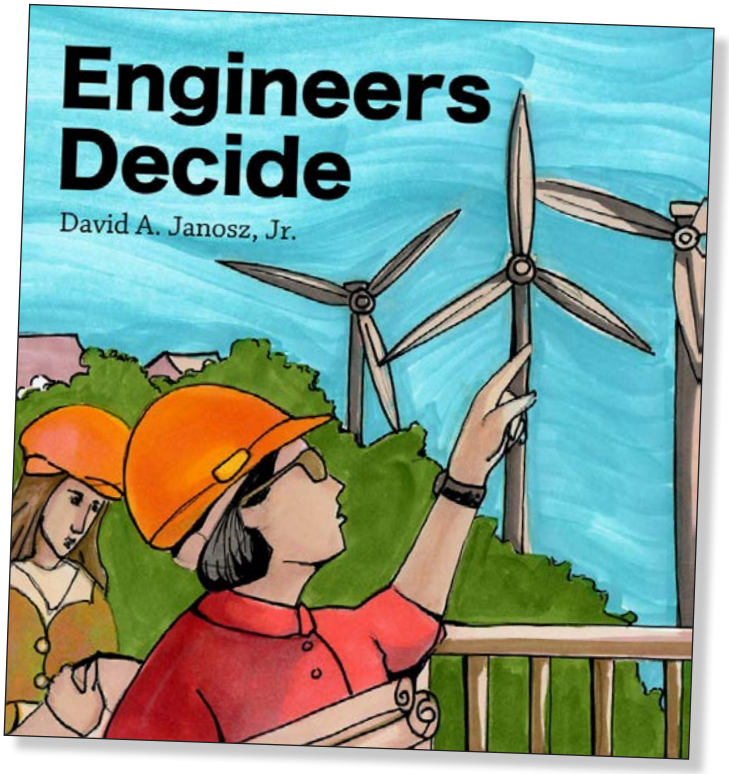
Curious? Here's a brief synopsis from the publisher:

Awaken the young engineer within your student or child. Ideal for ages five through ten, *Engineers Decide* explains that engineering isn't about "things" but about individuals, inspired to bring forth the discoveries that will change our world. By instilling the joy of designing the future – whether as part of a team or working solo – *Engineers Decide* ignites children's curiosity to the wonders of applying their imagination to meet fresh challenges. Engineers deciding upon solutions for product development, as well as all sorts of inventions familiar to children, are described simply and depicted with colorful artwork. And photos show children actively participating in the adventure of discovering next-generation technology. Filled with interactive graphics and videos, *Engineers Decide* stirs tomorrow's engineers to realize their potential by exploring this exciting field.

According the publisher's press release, "The book tackles subject matter that has, to date, never been published in an interactive, electronic format." And, it is loaded with interactive multimedia and multi-touch tools available through iBooks Author and is exclusively made for iBooks—Apple's leading eBook platform.

Janosz called upon his valuable years of experience as a teacher in creating a book that would look good and read well.

"We used colorful, vibrant artwork and simple, effective language," Janosz says. "Photos show children actively participating in the adventure of discovering next-generation technology. Further, the iBook is filled with interactive graphics, videos and a drawing scratchpad. It's truly about exploration, not just teaching."



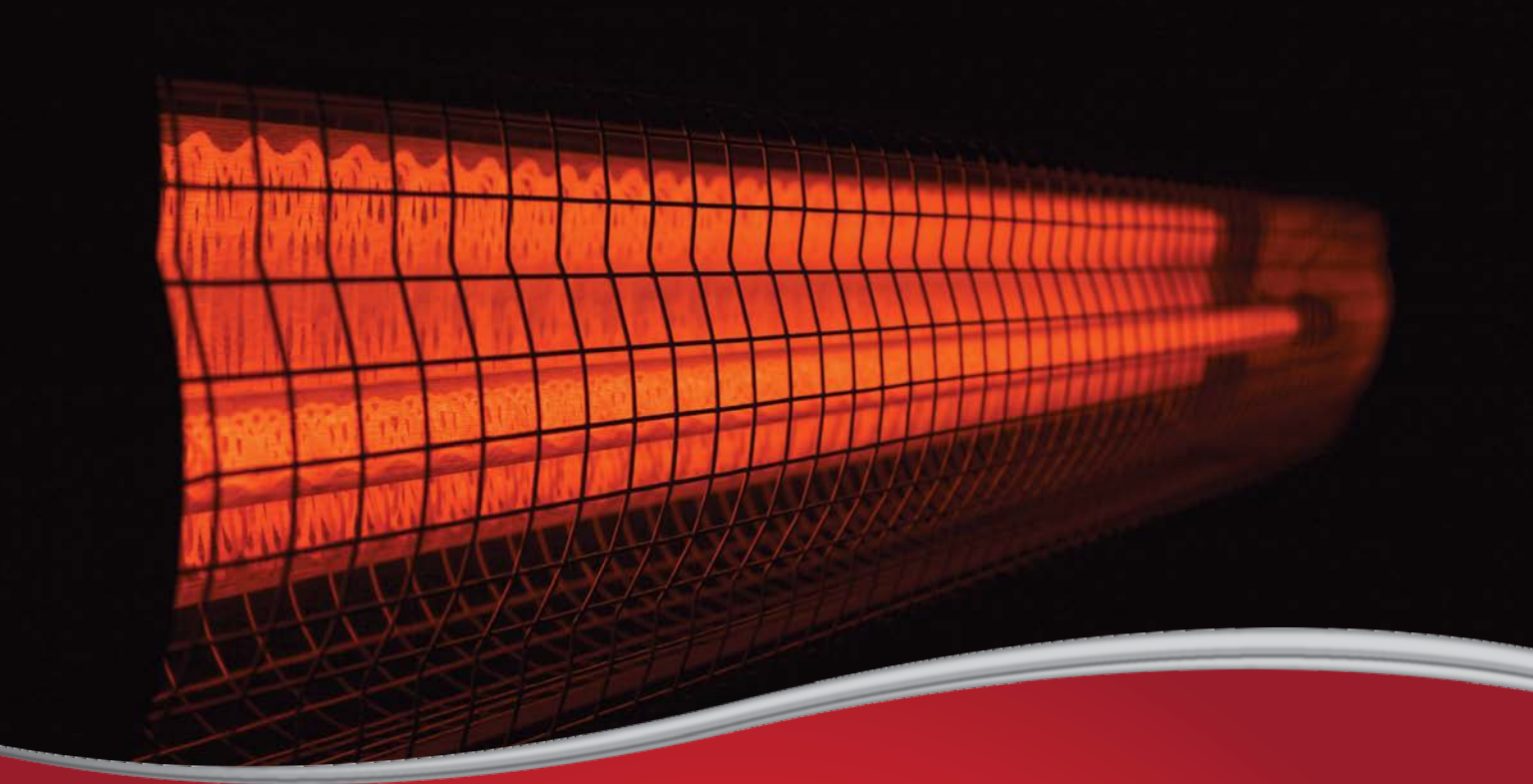

But perhaps the flavor of the book is best captured in a blog (*kjwwblog.com*) by Kelly Altes, an engineer and mother of two boys:

"The book is published electronically, so it can be downloaded to an iPad or a Mac. The best part about digital books is the ability for the author to create interactive opportunities. No longer is book reading just about just reading the words on the page. When reading *Engineers Decide*, children can touch/click on the interactive window on each page and see more pictures, draw a picture of their own, or watch a video.

"I scanned through the book and thought it was pretty good, but I decided to give it the true test by reading it to my boys, and letting them interact. My husband and I are both engineers, and are always looking for educational books the boys will enjoy. My boys are 4 and 2, so they are a little younger than the recommended 5-to-10 age, but no matter. They sat quietly and listened to me read, then anxiously touched the pictures to see what would happen. I asked my oldest boy at the end of the book, 'Alexander, what do engineers do?'

"He replied, 'Mommy, *engineers decide*!'" **PTE**

*(Engineers Decide* is available now (free until March 31) and can be downloaded from the iBooks Store on an iPad or *OSX Mavericks*. To download the iBook, visit *http://tinyurl.com/engineersdecide.)*



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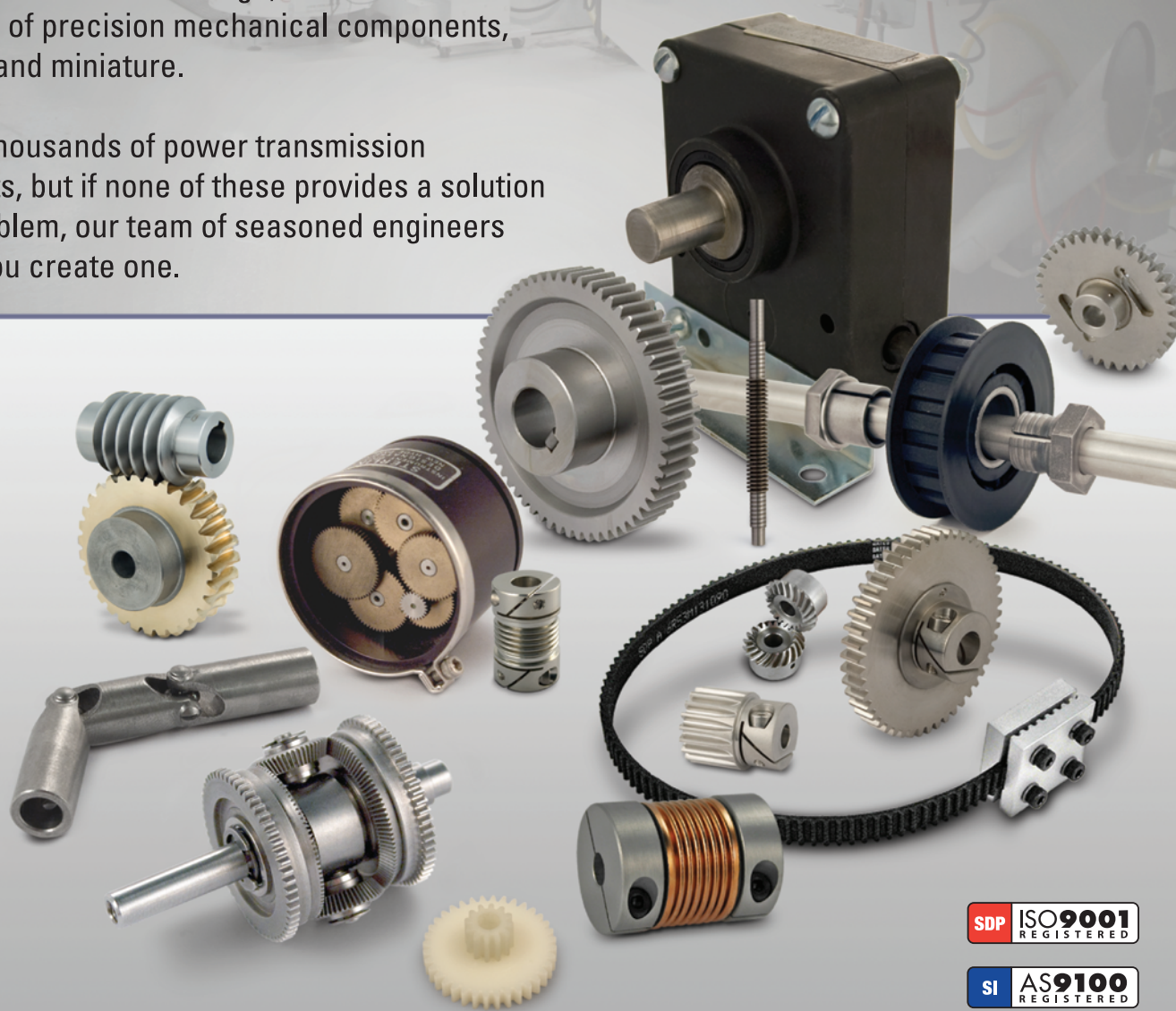

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