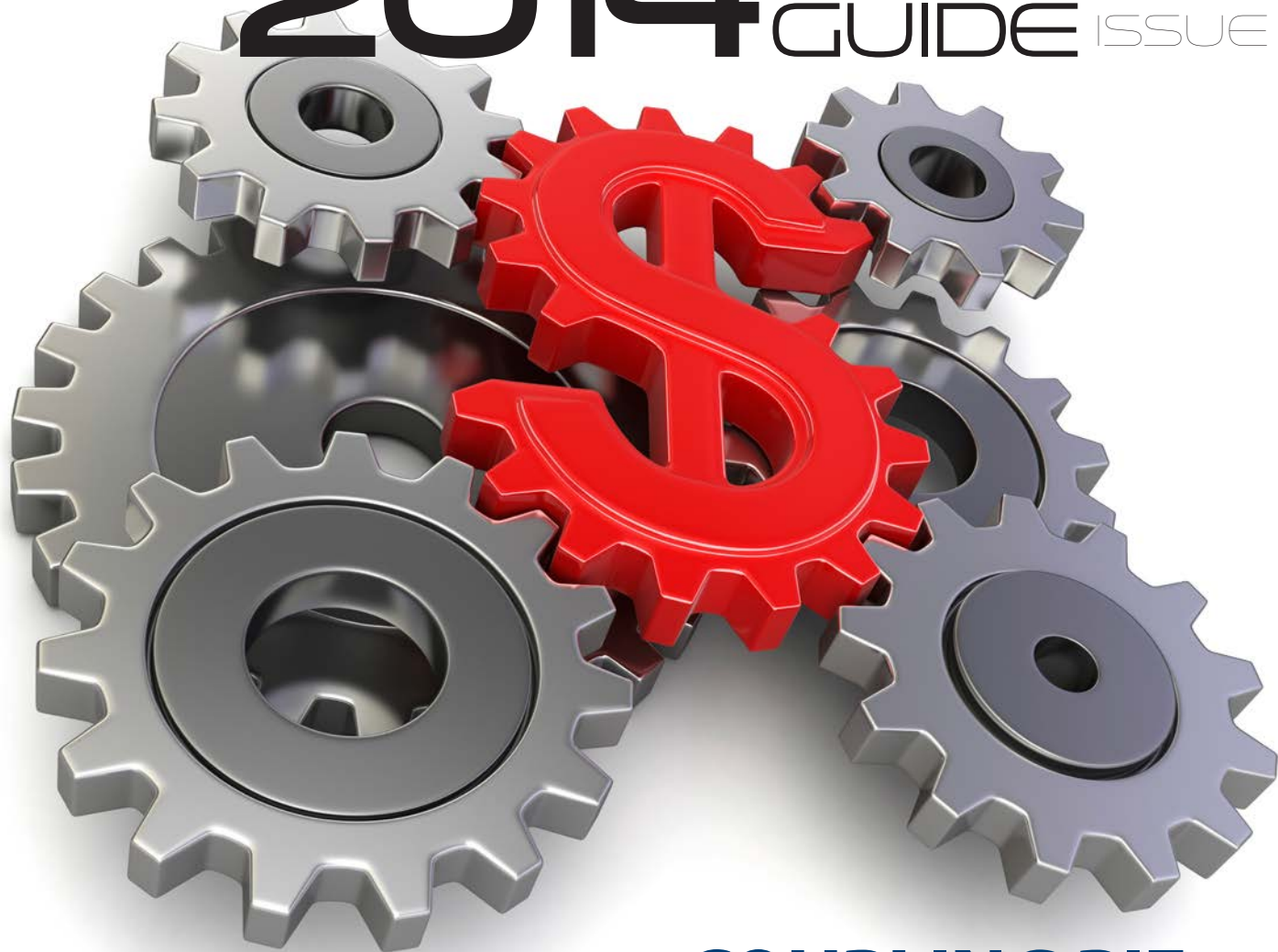


Power Transmission Engineering®

DECEMBER 2014

THE **2014** BUYER'S
GUIDE ISSUE



COUPLING PIE
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A COMPLETE RUNDOWN OF
THE SMALL MOTOR RULE

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IronHorse worm gearboxes are manufactured using only the highest quality materials and are designed to withstand the toughest international and U.S. testing standards. Our gearboxes interface with C-face motors and provide reliable speed reduction, increased torque and dual load capabilities wherever it is needed.



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Features

- **Three output types: Dual Shaft, Right Hand Shaft and Hollow Shaft**
- **Four frame sizes: 1.75", 2.06", 2.37", 2.62" models with parallel or right-angle gear shafts**
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Vol. 8, No. 8. POWER TRANSMISSION ENGINEERING (ISSN 2331-2483) is published monthly except in January, May, July and November by Randall Publications LLC, 1840 Jarvis Ave., Elk Grove Village, IL 60007, (847) 437-6604. Cover price \$7.00. U.S. Application to Mail at Periodicals Postage Prices is Pending at Palatine, IL and at additional mailing offices. Send address changes to POWER TRANSMISSION ENGINEERING, 1840 Jarvis Ave., Elk Grove Village, IL 60007.

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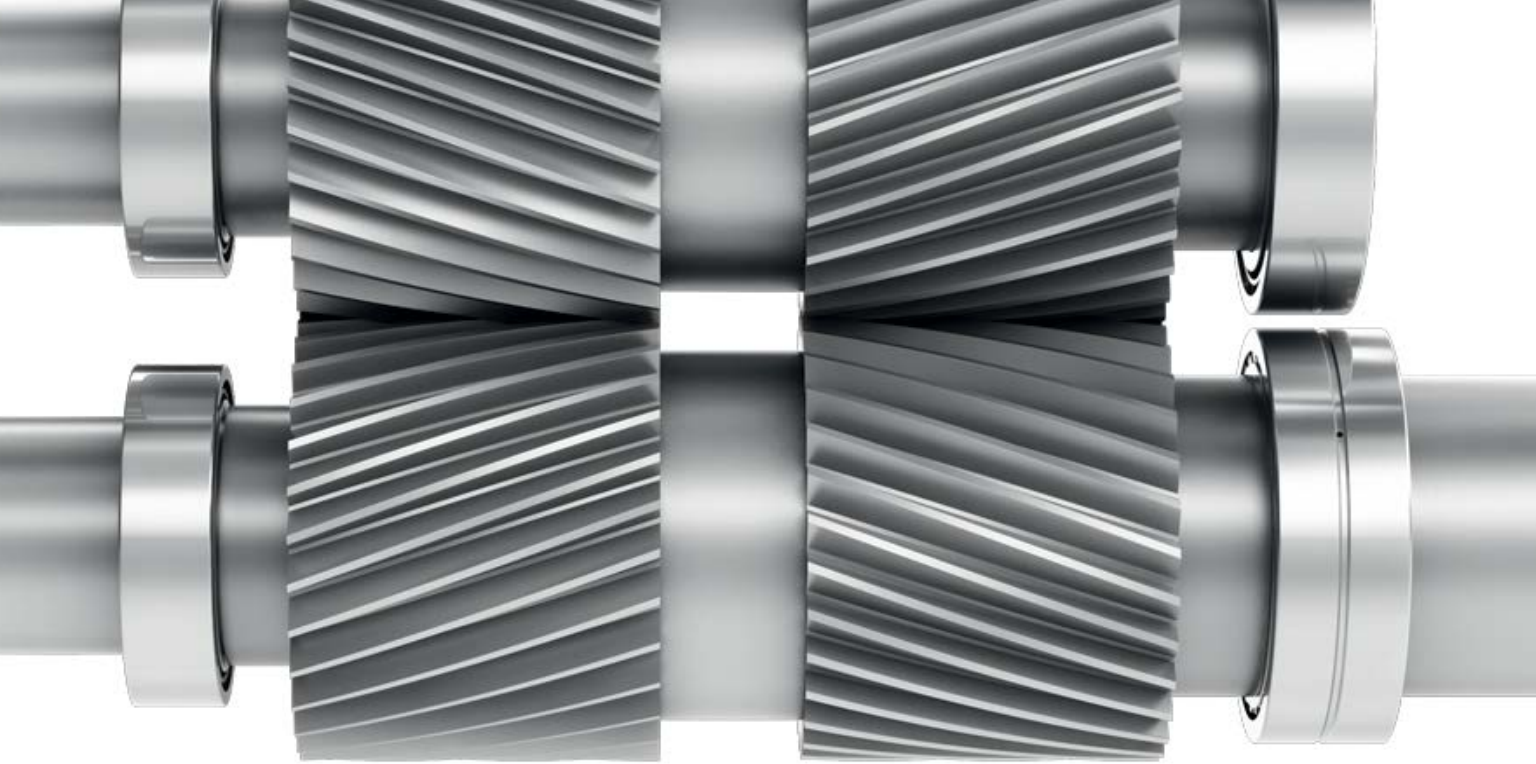
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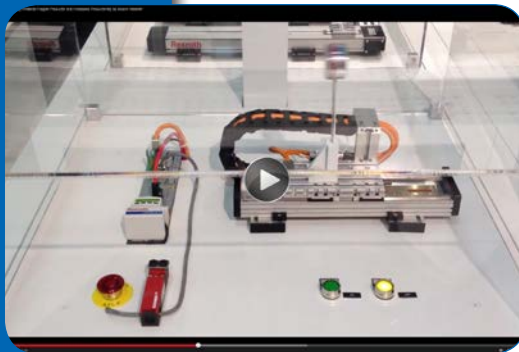
With expertise in bearings, sealing, and lubrication solutions, SKF engineers can add value to the complete gear unit by enhancing reliability and performance, while improving the cost-effectiveness of the complete solution.

For more information, please visit [skf.com](https://www.skf.com) or contact your local SKF representative.

PTE Videos

Vibration Damping and Anti-Sloshing

Demonstrated at Pack Expo in November, Bosch Rexroth's vibration damping technology addresses vibration reduction at the drive level, making it easier to implement on any master or controller. The unintended consequences of machinery vibration have negative effects on both your equipment and the products you manufacture. See an explanatory video at www.powertransmission.com.



Proper Bearing Handling and Storage

Motion Industries' Tom Clark discusses proper bearing handling and storage in this Tom's Toolbox MiHow2. Learn the requirements SKF uses to ensure the proper handling and storage and the ways they maintain those requirements. See the video online at www.powertransmission.com.



Flashback: Planetary Gears

This video, produced in 1953 by the U.S. Department of Defense, demonstrates the operating principles of planetary gear sets used in automotive transmissions. Includes a short review of the three planet carrier laws. See it at www.powertransmission.com.



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I Rely on Arrow Gear



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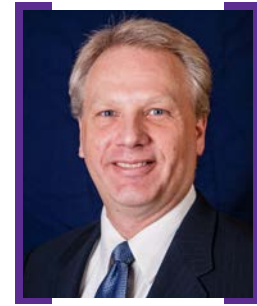
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Encouragement and Enthusiasm



In the Stott household, we love math.

Well, maybe not *everyone* in my household loves it equally, but since they were in kindergarten, whenever one of my children asked me for help with math homework, my reply has been an instant and cheerful “We love math!”

In fact, that ritual has occurred so often that the mantra of “we love math” has become ingrained. Ask any of my four kids what the family motto is, and they know the drill. They’ll respond with “We love math,” even if they do roll their eyes when they say it. The point is, my wife and I have tried to encourage in our children an enthusiasm for learning—not just for math, but also for science, foreign languages, music, literature and a wide variety of other subjects. Without that encouragement, the Stott family motto could easily have been “We love ice cream”—trust me on this one—but instead, it’s “We love math.”

So I was delighted when my eighth grade daughter, Emily, invited me to go with her to a STEM (science, technology, engineering and mathematics) event sponsored by our county’s regional office of education. The event was set up specifically for girls and their parents, and it was designed to encourage young women to pursue studies and careers in technical fields.



Emily Stott closing the circuit on her “Bristle Bot.”

Since, you know — we love math — we just had to go.

It was a prestigious honor for my daughter. A maximum of three kids from each school were invited, and it took place at Argonne National Laboratory near Lemont, IL. More importantly, it was a great opportunity for her to hear from a number of women working in STEM fields about what they do on a day-to-day basis and how they got there.

The keynote speaker was Jillian Arnold, a cinematographer and work flow specialist. You might not think that cinematography has much to do with STEM careers, but that’s before you learn that Arnold shoots video for NASA’s Jet Propulsion Laboratory and that a “workflow specialist” is someone who handles and processes digital media between the time it’s shot in production to the time it’s edited in studio.

Her job involves computers, software and technical equipment, and she has to understand the technology of that equipment as well as the physics of lighting. Her talk was not only inspirational, but also put a face and a personality with the technology.

The event also included break-out sessions where the students were able to do some hands-on projects, such as building a table out of newspaper and masking tape, and constructing a miniature robot. They also heard from a panel of speakers including a computer simulation specialist from Argonne National Laboratory, a mechanical engineer specializing in nuclear power plants and a zookeeper from Brookfield Zoo.

For me, the most important part about this event was connecting the dots. Kids go to school, and they study math and science because they have to, but nobody explains how these often abstract concepts will ever relate to their real life. When will they ever have to solve for X or prove that two corresponding angles are equal? Shooting videos of rocket launches is a lot more interesting to kids than doing math problems. So is being a zookeeper. So is working in a nuclear power plant or programming one of the world’s most powerful supercomputers. There are a wide variety of STEM-related careers, but if kids aren’t exposed to them, they’ll never connect the dots, and they’ll see their schoolwork as drudgery.

If you’re reading this, you probably work in a STEM-related field—maybe even one of the really cool and interesting ones. You probably also know some young people who haven’t yet decided what they want to be when they grow up. I challenge you to share your enthusiasm and help them see the possibilities.

Maybe they’ll learn to love math, too.

Randy Stott

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Stop Downtime from Bottling Up Your Profits!

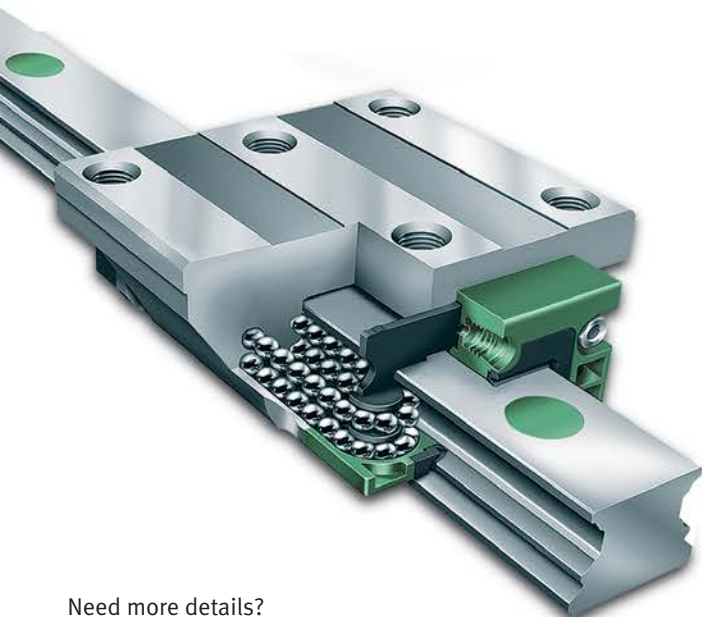
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The American Industrial Renaissance

Tom Johnstone, President and CEO, SKF Group



At SKF, we believe in the long-term development of the U.S. industrial economy.

The reindustrialization is supported by a strong university-based research network, a competitive workforce and energy supply from domestic energy resources. However, there are still challenges, particularly regarding the availability of skilled labor. Business, education and governments have a responsibility to work together to ensure this is not the bottleneck in U.S. industrial development. I am particularly pleased with and support the work the National Association of Manufacturers is doing in this area.

I also welcome the recent joint U.S.-China announcement on climate change, which states “technological innovation is essential... for new zero- and low-carbon technologies.” I think this will be a driver for upgrading or replacing older, less efficient plants and equipment, whether it’s for the latest generation of electric vehicles, jet engines or multi-megawatt wind turbines. There is a growing demand for highly efficient, highly reliable solutions, and SKF can play an important role in this development.

Over the last few years SKF has stepped up its investment in innovation and in our North American presence. We have been active in the United States since 1912, but during the last five years we have invested over \$2.5 billion in North America in acquisitions, new facilities and upgrades. The single largest SKF Group investment to date has been the acquisition of U.S.-based Kaydon Corporation in 2013. This helped complete our bearing and sealing solution product portfolios, strengthening our offerings in industries from renewables, marine and medical, to oil and gas.

Kaydon also quickly expanded our manufacturing footprint in the U.S.,

adding 13 manufacturing facilities to our existing 33 U.S. plant locations.

Innovation is the lifeblood for a company like SKF, and we are continuing to step up our investments in this area. We have just broken ground on a new \$30 million Global Technical Center - Americas, located near Chicago. It will focus on working closely with our customers to develop even more energy-efficient solutions, which will become part of our BeyondZero portfolio. This portfolio brings together many products and applications that deliver real energy savings for our customers. One good example in the United States is how we have worked closely with Spencer Pump on an aeration blower pump using our magnetic bearing system and permanent magnet motors to help significantly reduce energy used in waste water treatment.

The new U.S. technical center, scheduled to open by the end of next



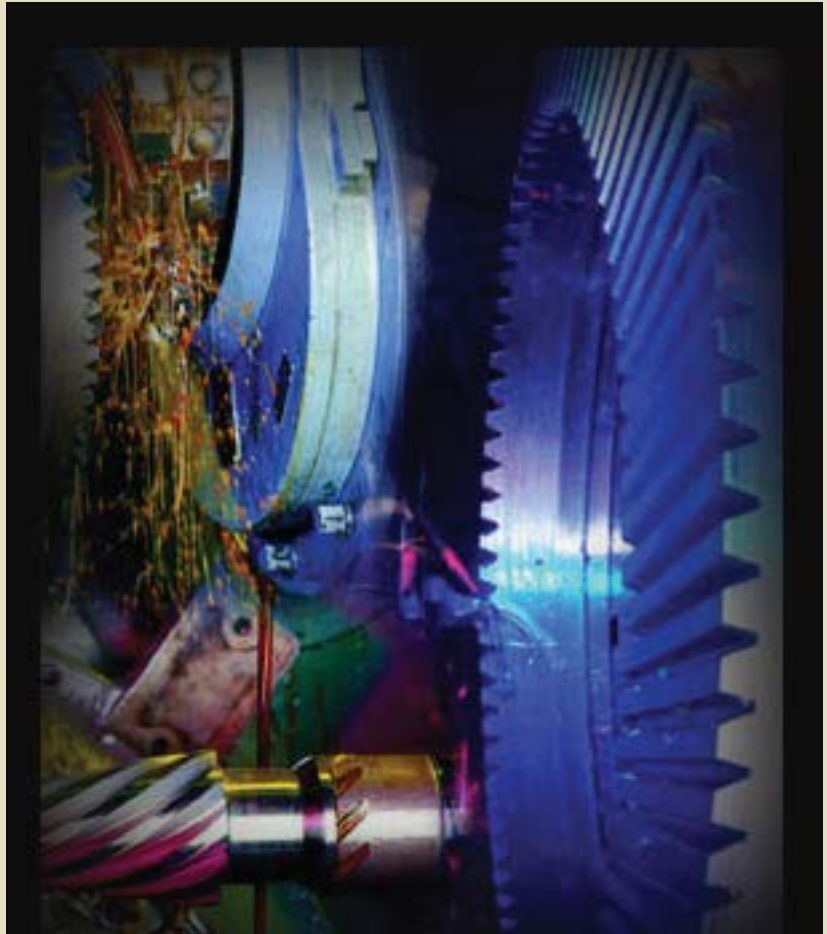
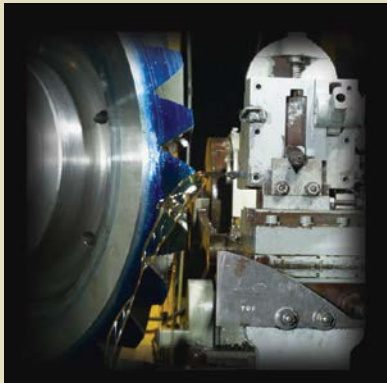
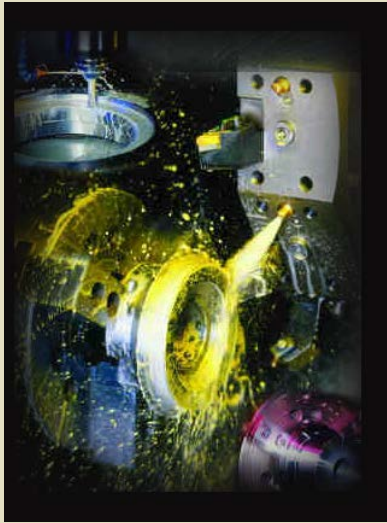
(From left): Poul Jeppesen, President and CEO of SKF USA Inc., A. George Pradel, Mayor of Naperville, IL, and Tom Johnstone, President and CEO of the SKF Group, break ground on the company's new Global Technical Center - America. The groundbreaking took place in November, and the facility should be open by the end of 2015.



Artist's rendering of the new SKF technical center being built near Chicago.

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year, completes a global network of centers including new facilities in India, China, the Netherlands and Sweden. It is part of our strategy to more rapidly bring our technology even closer to where it's most needed—to our customers. As part of this effort, the center will include something we call an SKF Solution Factory. It is part engineering center, part manufacturing center, and it helps apply and

“We believe that the United States will play an important role in the development of a new low-carbon economy and in the industrial ‘smart’ revolution, or the internet of things that now includes industrial devices.”

deliver technology solutions to meet the needs of its local customers. We opened our sixth in North America in Birmingham, AL in October and it was our 29th in the world.

In summary, I think we are in the early stages of an industrial renaissance in the United States. We believe that the United States will play an important role in the development of a new low-carbon economy and in the industrial “smart” revolution, or the internet of things that now includes industrial devices. We are embedding sensors in our components and linking them into intelligent systems that can reach new levels of energy efficiency, reliability and cost effectiveness. Today SKF is already a leader in stand-alone condition monitoring systems, and for tomorrow we see these self-powered, micro-sized sensors as key additions to bearings and related components in critical applications.

With our global technologies, combined with the local investments we have been making, I am confident SKF will play a key role in the development of sustainable solutions to secure profitable and responsible growth in this dynamic market. **PTE**

YOUR MECHANICAL ADVANTAGE



Every detail matters. Consistency, precision and quality are key. Fortunately for you, that's where First Gear excels.

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Maxon Motor

EXPANDS X DRIVES LINE

Two years ago, Maxon Motor introduced a new generation of brushed DC motors – the Maxon X drives.

Now, four more motor sizes are being added to the existing portfolio. The 14, 16, 22 and 26 millimeter diameter models are now each available in a long version (L), which offers higher continuous torque and higher continuous output power.

At the same time, Maxon Motor is introducing four new GPX planetary gearheads, in the sizes 14, 19, 26 and 37 millimeters, compatible with existing products in



the program. These gearheads are designed with scaled gear stages. Each of the new three-stage gearheads can be driven with the next smaller motor. This results in the drive system being smaller, lighter and more economical.

The existing GPX 16 and GPX 32 models are available in various versions and can be equipped with ceramic axles to reduce wear. Customers looking for a particularly low-noise gearhead have the option of choosing plastic planetary gears.

Maxon also expanded its encoder portfolio. The new ENX 16 Easy absolute encoder is available as an SSI or BiSS-C version, according to the customer's requirements.

For more information:

Maxon Motor
Phone: (508) 677-0520 ext. 113
www.maxonmotorusa.com

LM76

DEBUTS THREE NEW LINEAR ROLLER BLOCK AND RAIL SYSTEMS

Low cost, Saibo SB-LGB linear roller block and rail systems are now available from LM76 in three sizes to meet load requirements up to 1,200 newtons (270 pounds).

These narrow profile linear motion systems feature low noise, smooth travel, high speed up to 10 meters per second, high acceleration up to 50 meters per second, low weight, high linear accuracy, sealed radial low friction bearings and low cost. Due to their narrow profile they are easy to install into new and existing applications.

Saibo SB-LGB linear roller block and rail systems have an adjustable preload system to control the required level of precision needed for most applications. The roller block has six drilled and tapped holes for mounting tooling, cameras, test equipment and more. They can be used in robotics, assembly, pick-and-place, sorting, pack-



aging, manufacturing, sampling, laser cutting, wafer handling and other precision applications. The rail systems are protected from debris, dust, chips and contaminates by plastic end caps with spring loaded oil filled felt pads. The felt wiper pads also deliver lubrication to the guide and rollers. The wipers are easily re-lubricated through convenient oil ports in the end cap.

For more information:

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Redex

OFFERS INCREASED VERSATILITY WITH NEW GEARS

Versatility is the key issue for manufacturers of multi-axis milling machines and vertical turning lathes. The same machine must be able to perform various milling and lathing operations so that machining operations can be carried out with the highest accuracy (without part disassembly) and the highest productivity.

Until now, these constraints meant that manufacturers had to use drives that were generally complex and did not necessarily meet every technical requirement. Redex offers two complementary integrated drives for tables used on milling machines and vertical lathes. They allow designers to choose the right drive for each application and

based on their priorities of speed, power, accuracy and rigidity.

Redex's high-speed versions of its DRP, KRP and KRPX ranges complement the features of its MSR range of drives. They simplify the design of the mechanical transmission systems of both large rotary tables used on vertical lathes (over 2,000



From the Forest City Gear Family To You and Yours...Merry Christmas

The Holiday Season gives us an opportunity to pause in our busy schedules and reflect on the many blessings we've received throughout the year. We give thanks for our great customers, our skilled and dedicated family of employees, friends and family and the continued joy of working in the industry we love.

From all of us at Forest City Gear, we wish you a very Merry Christmas and may your 2015 be a joyous and prosperous one.

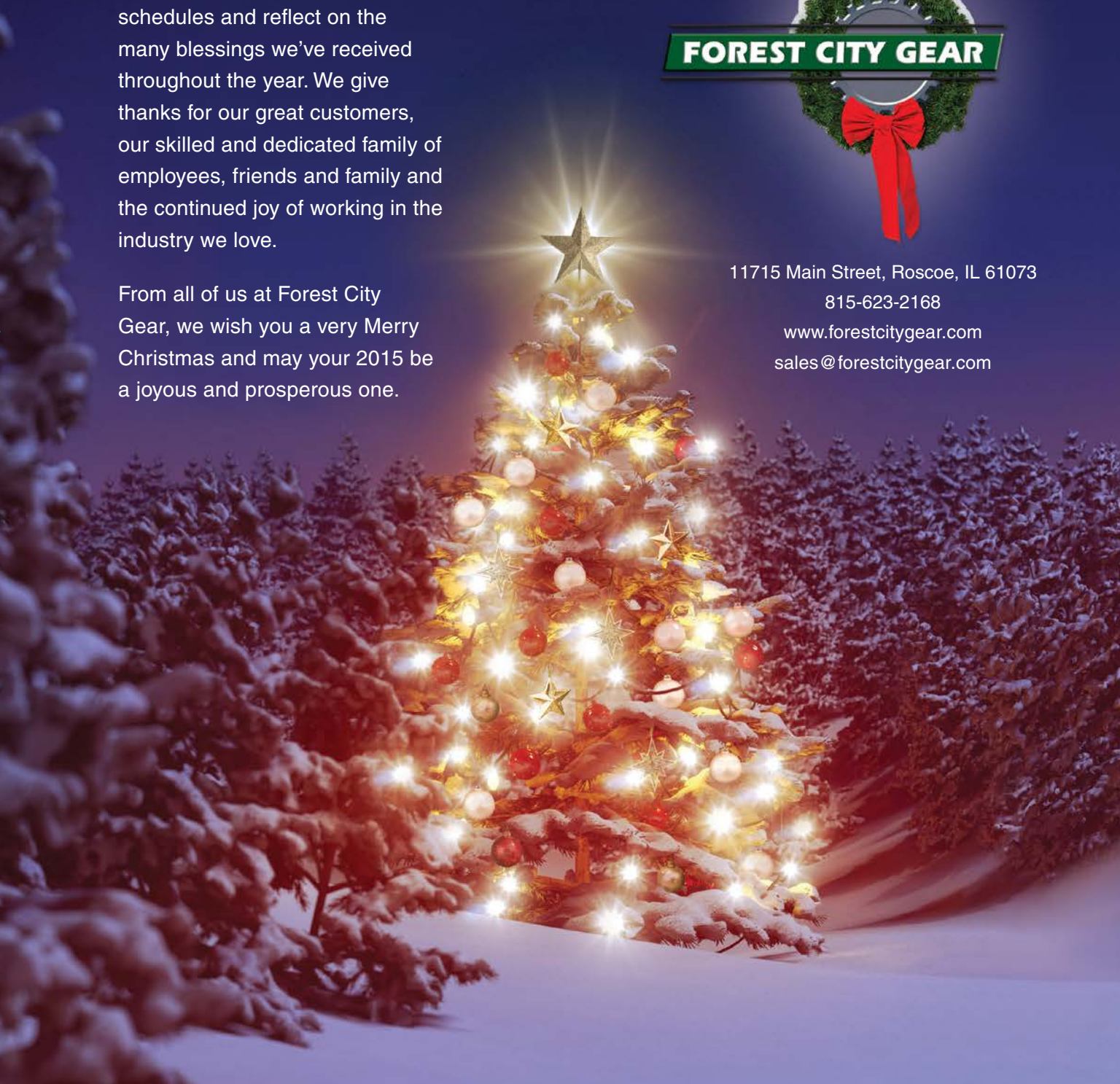


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sales@forestcitygear.com



meters) and smaller tables used on milling machines. They also improve machine accuracy and allow for smaller machine footprints.

When meshed with a drive gear, the two reducers on Redex TwinDrive and DualDrive solutions cancel 100 percent of backlash. These high-speed reducers have been hardened to allow continuous operating cycles and meet the specific requirements of rotary tables. As a result, Redex high-speed TwinDrive and DualDrive units can achieve rotational speeds of up to 28 rotations per minute.

Although the Redex MSR range offers higher rotational speeds, the high-speed versions of its DRP, KRP and KRXP drives offer greater accuracy, rigidity and momentum. They are the standard drives with the highest positioning accuracy.

The complementarity of both solutions allows manufacturers to design the right rotary-table drives for specific applications and thus their priorities of speed, power, accuracy and rigidity.

Redex solutions make it possible to execute additional functions on the C-axis without any additional mechanical devices or the use of position locking. This maximum accuracy is maintained during milling and/or positioning operations particularly by the electrical or mechanical preload system, which continuously manages the counter-torque between the pinions.

Solutions that use two reducers, and thus two motors, are more cost effective and easier to manage in most cases. Compared to heavy-duty rotary tables used in conventional configurations that require a 160-kW motor, the TwinDrive solution uses two 80-kW motors, which are more standard and often less expensive. Maintenance and spare-parts management is also simplified by the use of the smaller, standard motors. This simplifies rotary-table design because it eliminates the need for machine-tool manufacturers to design and build their own gearboxes with all the necessary components.

For more information:

Redex SA
Phone: +(33) 2 38 94 42 62
www.cfourtune@redex.fr

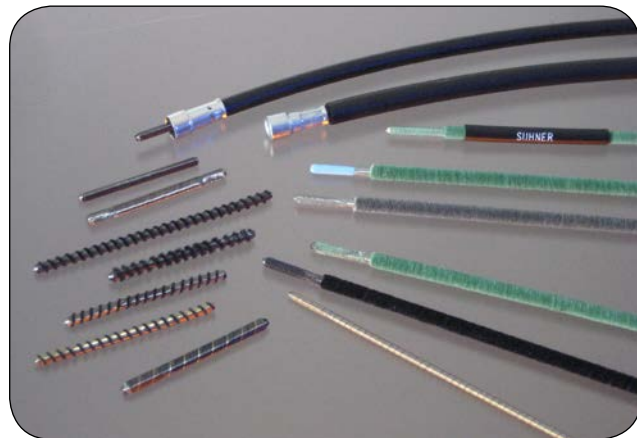
Suhner

SOLVES NOISE ABSORPTION FOR POWER SEAT

Less noise, less vibrations, less distractions, more comfort; all this is required in today's global automotive industry. The power seat manufacturers are demanding innovation on the level of the component manufacturer.

Using patented innovations in conjunction with state-of-the-art manufacturing technologies, Suhner addresses these needs.

Through scientific experiments in Suhner's R&D laboratory as well as through a well-respected university in the United States, Suhner has found the ideal combination of materials together with the best manufacturing techniques.



Suhner's research found that the main noise source is the drive motor and its load, so the mission was to dampen these noise levels with the components that Suhner is manufacturing - the flexible drive shaft that is rotating inside a plastic casing. The combination of materials used together with how they are manufactured is the secret to the lowest noise levels for the entire power seat system.

For more information:

Suhner Manufacturing, Inc.
Phone: (706) 235-8046
www.suhner.com

Siemens

UPGRADES SIMATIC 427D MICROBOX IPC WITH THIRD GENERATION INTEL PROCESSOR

Siemens Simatic 427D Microbox IPC has been upgraded with the third generation Intel Core i7 (1.7 GHz) processor for high system performance in demanding industrial applications. A turbo-boost feature delivers up to 2.4 GHz for maximum computing and control performance.

The IPC's DDR3 memory technology offers up to 8-GB RAM. The expandable mass memory is configurable with Fast Cards up to 16 GB, SSD (Solid State Drive) with 50 GB (high endurance) or 80 GB (standard) for robust requirements or a 2.5" hard disk with 250 GB. Memory options include a 250 GB hard disk, a DVD drive and a non-volatile memory of up to 512 KB for non-battery applications.

The fanless IPC operates in temperatures up to 55 degrees Celsius. Highly reliable where vibration and shock loads are present, it safeguards against voltage failure with NVRAM for WINAC RTX (soft PLC). It also offers a retentive signaling buffer for WinCC and image security with an enhanced write filter function.

The rugged housing has good chemical resistance against oil and grease with a smooth front to resist dirt build-up.

Downtime is also reduced and fault recognition enhanced with a self-diagnostic feature.

The unit offers up to two PCIe expansion slots. Four USB 3.0 interfaces located on the back of the IPC and one USB 2.0 interface in front quickly

ATC Diversified Electronics

INTRODUCES LATEST SUMP PUMP MOTOR

ATC Diversified Electronics, a division of Marsh Bellofram Corporation, has introduced the Model SPM 120AAA single-channel shaft seal monitoring module for submersible pump motor applications.

Model SPM 120AAA provides early warning of possible motor shaft seal leakages and failures. When used as part of an effective predictive maintenance strategy, the module can help reduce the risks of premature equipment failure and downtime over 10 million mechanical cycles and fifty thousand electrical operations. Offered with choices of both fixed and adjustable sensitivities, the Model SPM 120AAA detects a pump motor shaft seal leak by sensing the position of a resistive float switch or pair of conductive probes installed within the seal cavity. When the resistance drops below the sensi-



tivity rating and a possible leak is detected, the output relay energizes and the LED illuminates to red. When the submersible pump seal fault condition is cleared, the output relay automatically resets. Units operate from a 120 VAC 50/60 Hz supply voltage.

The Model SPM 120AAA is ideal for OEM submersible pumps, potable or

wastewater sump pumps, industrial or municipal pump monitoring, control package manufacturing and general industrial leak detection. Units are UL Recognized and include a 10-year comprehensive product warranty.

For more information:

ATC Diversified Electronics
Phone: (304) 387-1200
www.marshbellofram.com



connect hardware components. Additionally, the 427D is easily integrated into the fieldbus level with built-in PROFIBUS DP/MPI or PROFINET (IRT, 3 PORTS; CP1616-compatible) and 2-Gigabit Ethernet (IE/PN) ports.

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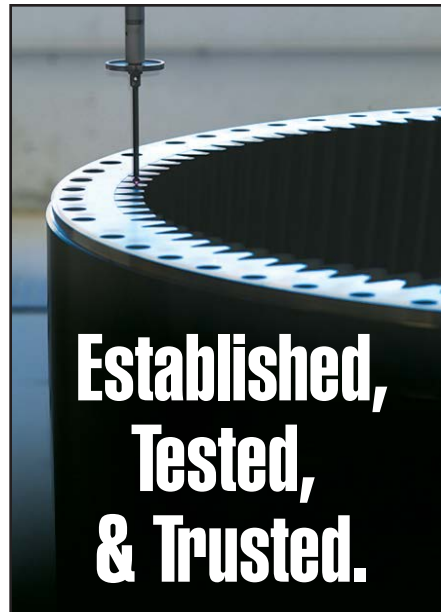
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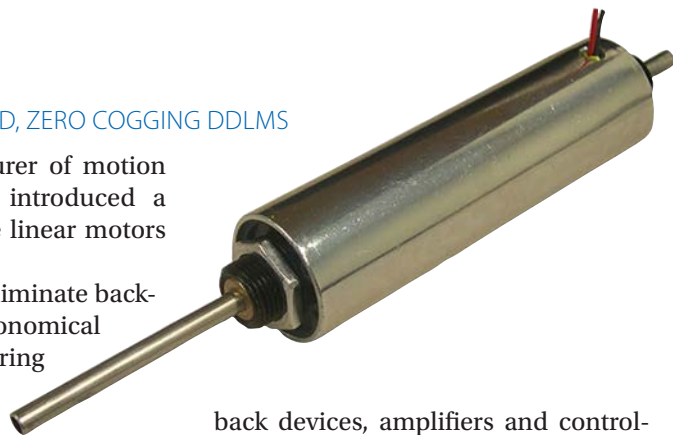
INTRODUCES HIGH SPEED, ZERO COGGING DDLMS

MotiCont, a manufacturer of motion control products, has introduced a new line of direct-drive linear motors (DDLMS).

MotiCont's DDLMS eliminate backlash and provide an economical solution for users requiring high acceleration, high speed, and long life. They are available in three off-the-shelf models.

The compact DDLM-019-044-01 linear motor is only 0.75 inches in diameter and 1.75 inches long. It has a stroke of 0.46 inches and features 11 ounces of continuous force and a 34.8 ounce peak. The compact, longer stroke DDLM-019-070-01 linear motor is also only 0.75 inches in diameter but is 2.75 inches long. It has a stroke of 0.96 inches and features 10.1 ounces of continuous force and a 32.1 ounce peak. For higher force applications the DDLM-038-051-01 linear motor is 1.5 inches in diameter and 2 inches long. It has a stroke of 0.375 inches with a continuous force of 3.1 pounds and a 9.9 pound peak.

These compact motors can be integrated into new and existing applications using threaded features on the front and rear faces of the motor, as well as each end of the shaft. The feed-



back devices, amplifiers and controllers are also available.

Non-commutated, moving magnet motors have zero cogging and the light mass of the moving part allows for high acceleration/deceleration for higher throughput, and direct coupling to the load increases accuracy. All DDLM linear motors are also available with internal springs to retract the shaft to a home position in the event of a sudden shutdown.

Typical DDLM direct drive motor applications include: Automated assembly, component insertion, fluid dispensing, pick-and-place, robotics, wafer handling, sorting, valve and flow control, labeling, tension control, and laser machining in the processing, manufacturing, medical, inspection, metrology and other industries.

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www.moticont.com

GAM

RELEASES LINEAR MOUNT PRODUCTS BROCHURE

GAM, a manufacturer of precision gear reducers, servo couplings and linear mounting kits, announced the release of its new linear mount products brochure on Nov. 11.

GAM's linear mount products are a line of products designed to mount directly to actuators. This offering started with just a single item, the linear slide kit, after GAM noticed customers having difficulty mounting motors to actuators. Over the years, it has evolved into a complete range of gearboxes, couplings, and adapter kits. The product range expanded even further as GAM leveraged its manufacturing operations and engineering resources

to integrate individual products into complete system solutions as a service to customers.

"We really wanted to highlight our flexibility and capabilities beyond what customers may have known about or have seen in previous catalogs," said Craig Van den Avont, president of GAM. "This brochure really captures the essence of the level of value added service that we provide to our customer base."

For more information:

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Helix Linear Technologies

UNVEILS MINIATURE LINEAR GUIDANCE PRODUCTS

This new family of linear guidance products from Helix offers precision, accuracy and flexibility, and consists of an embedded inverse hook design. It's designed to tightly secure block components, which in turn helps them to better handle impact forces as they work to distribute stress over a larger area of the system.

Linear guidance systems offer accurate positioning, are often high speed and energy saving and can maintain accuracy for long periods of time in their respective applications.

Additional benefits of the Helix Miniature Linear Guides include:

Unique design: The miniature guides consist of a ball re-circulating design along with an embedded inverse hook design, which helps to reduce noise while at the same time extend life, re-

duce maintenance and improve high speed running capability.

Reinforced plates: The HMR-EE series stainless steel reinforced plates help to make this product line able to handle the operation of high running speeds.

Lubrication: Included in the design is an embedded lubrication pad, which works to oil balls and the raceway.

Greater surface contact: This feature allows the miniature guides to work with high load and high moment capacity when compared to competing products.

Dust-proof: Designed so that dust contamination is restricted, thereby enabling prolonged life.

For more information:

Helix Linear Technologies
Phone: (855) 435-4958
www.helixlinear.com

J.W. Winco

ANNOUNCES EN 450 BALL-SHAPED DOOR CATCHES

J.W. Winco, Inc., a supplier of standard industrial machine components, announced it now offers EN 450 ball-shaped door catches, in metric sizes.

These RoHS-compliant door catches were designed for use with both shutter doors and sliding doors. The ball-shaped door catch consists of a catch body to be fixed to a frame and a ball to be fixed to a door. The catch body is technopolymer plastic and matte black, and the ball is glass fiber reinforced plastic.

Under specific tests, the catch showed constant performances for more than 20,000 cycles.



Also available are EN 450.1 plastic spacers for ball-shaped door catches, made of glass fiber reinforced plastic. In addition to the basic spacing distances of 5, 10 and 15 millimeters, combinations of spacers can provide distances of 20, 25 and 30 millimeters as well.

J.W. Winco offers an extensive selection of inch and metric size adjustable levers, cabinet U-handles, plastic and steel hinges and locking mechanisms, revolving and retractable handles, hand wheels, hand cranks, tube connection and conveyor components, inch and metric construction tubing, shock absorption mounts, leveling mounts, hand knobs, spring, ball and indexing plungers, jig, fixture and fastening components, retaining magnet assemblies, toggle clamps, metric casters and wheels, universal joints, oil sight glasses, and metric tools for the industrial and commercial equipment industries.

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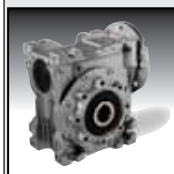
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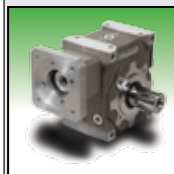
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Planetary Gearheads



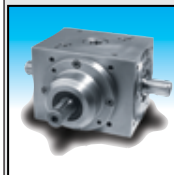
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Servo Worm Gearheads



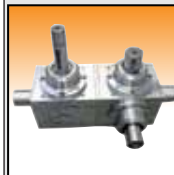
- 3 Backlash Levels
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Getting a Piece of that Sweet Coupling Pie

Success of oil and gas buoys industry in 'very, very good year'

Erik Schmidt, Assistant Editor

He was out.

Nine years ago, Ross Rivard left the coupling industry for the shimmering new world of luxury automotive components at Lacks Enterprises, where he was immediately enveloped by platinum trim systems and chrome composite wheels. It was glitz and glam and as sparkly clean as the fresh-from-the-dealership cars his products were embellished onto.

But for a self-proclaimed "shop rat" like Rivard, it was all a smidge too hoity-toity and entirely too hollow.

"I like to see how things work and what they do and how they come together," Rivard said. "The product [at Lacks] was shiny - but it didn't do anything. So I was kind of out of my element. It's a great company, really well run with wonderful products and they do very well in the marketplace. It just wasn't my thing."

So after nearly a decade removed from the industry, Rivard decided to return to his grime-covered roots earlier this year and get down and dirty with couplings once more. Turns out he couldn't have picked a better time.

"The industrial sector by itself is doing very well," Rivard said. "It continues to expand and the various sub-segments of the marketplace are doing very well, like energy and gas and oil. Others, like mining, are not doing as well. But overall it's doing very well."

"It was absolutely a good time to return."

Rivard, who became president of Ringfeder Power Transmission USA in Westwood, NJ back in April, moseys back into town as a prodigal son of sorts, both signifying and confirming the undeniable appeal of an industry that has enjoyed robust growth - most of all in 2014 - since his departure.

Fueling the Fire

Figuratively and literally speaking, oil and gas make most things in this world go - and in 2014 the coupling industry was of little exception.

Buoyed by an increased demand in fossil fuels over the past 12 months, the industry as a whole experienced one of its best calendar years in over a decade, according to Lovejoy (Downers Grove, IL) general manager Elliot Wilson.

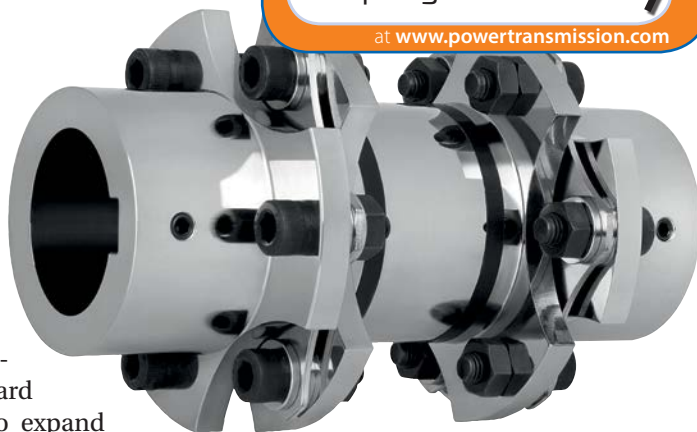
"It was one of the best years [in a long time]," Wilson said. "Given the economic conditions we did not do a price increase this year, but we still saw significant growth. It was a very, very good year."

While companies remained tight-lipped and opaquely vague

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couplings

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about specific empirical data and exactly *how good* 2014 was, the general consensus was simple: pretty darn.

"My understanding is that there was a very big demand for oil and gas extraction equipment," said Andy Lechner, sales manager of R+W America in Bensenville, IL. "There was kind of a boom over the last couple of years. It's been especially interesting for R+W here in the U.S. because Houston tends to be the technological center for the world when it comes to fossil fuels and petroleum. So a lot of the engineering and capital equipment gets made - if not in Houston - then somehow Houston tends to be involved in some way."

Of course, getting a piece of that sweet, oil and gas-soaked coupling pie wasn't as simple for a smaller, niche company like R+W as, say, a market power such as Lovejoy. The problem is the monolithic bulwark of carefully constructed guidelines and requirements imposed by the American Petroleum Institute (API) that date back to the 1940s.

As a producer of ATEX-certified, explosion-proof elastomer jaw couplings used on centrifugal pumps packages for over 10 years, R+W was already a player in the oil and gas industry in a limited capacity - but it didn't yet manufacture a product that met the regimented restrictions put forth by the API, and thus is stood on the outside looking in as other companies reaped the benefits of the world's newly accessible fuel extraction.

In mid-2013 Lechner and R+W had the opportunity - and the foresight - to



A production supervisor from KTR Corporation loads a large brake disc onto the vertical lathe machine.

EXPERIENCE



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Ringfeder Power Transmission USA employee Jaime Fiorilo tests couplings.

expand their coupling offering by introducing its Survivor line of disc pack couplings.

“The (API) specifies that a certain, heavy-duty metallic coupling be used in pump drives – and that’s a disc pack coupling,” Lechner said. “There was an opportunity for R+W to expand its reach in the oil and gas market, and that was through the API version of the disc pack coupling. Our [disc pack coupling] uses a pure-friction drive to transfer the power. So we decided we had an opportunity to bring a technical advantage to that field, while at the same time expanding our offering.

“Out of those disc park couplings that R+W developed, one line called the LPA – which is especially intended for API610 pump systems – was made and marketed, and as we’ve gotten a little bit closer to the users of those couplings in the industry we’ve decided to work on a new series that incorporates some new features that we learned would be desirable for those engineers.

“We’re planning on rolling that product out in 2015.”

Like R+W, Michigan-based KTR Corporation decided to up its metaphorical ante in 2014 in order to fully tap into the thriving oil and gas marketplace.

“I think in general, and you’ll probably get the same response from everybody, is that [2014] was stronger than in years past,” said Chris Hatseras, KTR’s engineering and marketing manager. “Couplings service many different industries; you’re never in the same industry, so it’s just a mix of

different markets coming back up – oil and gas being one of them.”

Though Hatseras said that most of the new products KTR released in the United States over the past year were not technically designed to “spring-board” them off the swelling wave of oil and gas sales in 2014, the company did introduce the Rigiflex-HP – an

API-approved coupling used on turbo compressors, high-speed pump drives, generator drives and turbine drives – overseas in late 2013 specifically to capitalize on the oil and gas boom that carried over into last year.

KTR also released the ROTEX line of couplings with T-PUR improved polyurethane material, as well as the BoWex GT line, in 2014.

“These [products] were more complementary,” Hatseras said of the T-PUR and BoWex GT. “In some years we will introduce something that’s new. For instance, in oil and gas we introduced the [Rigiflex-HP] this year, but not in the U.S. So that’s an example of saying, ‘Here’s a new product, here’s a bunch of new sales and we’re really going to go after it.’ Typically, we’re a little more conservative on how we innovate.”

That last sentiment, though subtle, is a telling one. Even a company priding itself on conservatism, like KTR, found reason to exert itself beyond its normal means in 2014 – an irrefutable sign that

this past year was a grand one indeed, and also a grim revelation that perhaps 2015 won’t enjoy such fortuitousness.

“Oil and gas prices have gotten so low, how can there be a continuing need for this volume of capital equipment, like fuel pumps and so on?” Lechner asked rhetorically.

It’s a question that doesn’t have to be answered just yet, as most companies still seem to be riding high off the euphoric successes of 2014. Yet it’s out there, nonetheless – hovering ominously beyond the gilded sheen of cartoonish Scrooge McDuck money bags and vertical arrows exploding out the top of display charts.

“We think [the coupling industry] is going to be maybe not as strong in 2015 [as in 2014],” Hatseras said.

Reinventing the Wheel

One company that didn’t seem all that infatuated with the rampant rise of oil and gas, nor the (alleged) impending down year to come, was Lovejoy – a giant in the industry that seems to keep churning its massive legs no matter how flat or hilly the horizon.

“We saw an uptick [in 2014] pretty much across the board,” Wilson said. “There were industries that were down, like in the coal industry, but we were encouraged by seeing growth in multiple areas. It wasn’t really limited to just oil and gas.

“One thing about our company, probably more so than a lot of multinationals, is we are U.S.-centric. When you look at the global economy, the U.S. is doing really well right now. Our flexible coupling and our jaw couplings, these are products that go into a tremendous amount of industries;



Pictured are KTR Corporation’s ROTEX coupling and T-PUR spider products, released in 2014.

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they're multiuse couplings that go into everything from devices at home to factories all over the country - and those products were up solidly for us.

"So we saw strength universally across the country."

While several companies have recently come out with innovations specifically targeted towards hopping on the oil and gas bandwagon, Lovejoy - already firmly entrenched in the industry - spent 2014 stripping down the

wagon itself and completely reinventing the wheel, so to speak.

"We took a two-year deep-dive into trying to reinvent the gear coupling," Wilson said. "The gear coupling was created long, long before there was proper analysis and modern software. So we used countless optimization techniques and came up with the industry's best gear coupling..."

"...the HercuFlex is what we're calling it."

It's certainly an ambitious name for an ambitious product, and while it doesn't exactly conjure up images of a chiseled Greek demigod lambasting serpentine monsters with a heavy wooden club, the stout, platinum coupling is still a fairly Herculean engineering feat, according to Wilson.

"This is a truly new product," Wilson said. "This is a clean slate approach where we gave

our design engineers a blank canvas and said, 'look at everything out there and come up with what is absolutely the best gear coupling in the marketplace.'"

According to Wilson, the HercuFlex offers "increased torque and bore capacity, combined with a robust design that increases service life."

"There are a lot of people, and we're the same way, where you do little spins or little tweaks and call it a new product or innovation," Wilson said. "I can't tell you the last time the coupling industry saw a clean-slate, newly optimized solution. I've been in the industry five years and I'm not sure I've seen it."

Going Global ... and Beyond

In a loopy, roundabout way, this brings us back to Rivard and Ringfeder, who didn't revolutionize the world of couplings with any bold new products in 2014, but made one of the industry's most audible splashes nonetheless.

For Ringfeder, a global enterprise with a reach expanding from America's East Coast to the literal Far East of Ji-



Pictured are several products from R+W's EK line of elastomer couplings.



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Ringfeder Power Transmission USA employee Wanda Boguslawski assembles a metal bellows coupling.

slightly in the rigid disc couplings. It allowed us to penetrate new markets where we had previously played on the fringe.”

And while Ringfeder sets its sights on broadening its global position in 2015, R+W has slightly loftier goals – goals that expand past the constrictions of man’s earthly domain and up towards the heavens.

“Our company is actually branching off into a number of other areas, including torque limiters and couplings for aerospace equipment,” Lechner said. “We’re working on projects for NASA... and we’re in the process of pursuing a certificate called AS90120, which is an aerospace-quality certification that we’re hoping to have wrapped up here in the next six months.

“I wish [I could tell you more], but I’m afraid it’s top secret stuff.”

angsu Province, China, the big news over the past 12 months was the acquisition of Tschan, a German-based producer and developer of shaft-coupling technology.

“It expanded our product line, giving us a full-complement,” Rivard said. “That’s the exciting thing for us.

“We acquired it in June of 2014, and what it did was expand our capability in the elastomer couplings and

So there it is – as 2014’s lucrative year comes to an end and companies look ahead to days and months that are likely to be less fruitful due to falling oil and gas prices, among other depressions, there remains reason for great optimism.

Couplings in space? It doesn’t get any more fulfilling than that.

Yeah, Rivard was right. He came back at the perfect time. **PTE**

For more information:

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The Small Motor Rule, How Will This Affect You?

New Federal Regulations Take Effect in March 2015

Chris Medinger



According to the Department of Energy (DOE), more than half of all electrical energy consumed in the U.S. is used by electric motors. To address this, several years ago, the DOE conducted a technical study as to what could be done to raise the efficiency levels of “small” motors. After years of study and litigation, the Small Motor Rule (SMR) was passed that covers two-digit NEMA frame single- and three-phase ¼ through 3 horsepower motors in open enclosures.

Facility managers are increasingly under pressure to reduce energy costs, increase productivity and reduce greenhouse gas emissions. To that end, this mandate is anticipated to have significant positive effects for products shipped from 2016–2045:

- Save approximately seven quads of energy (one quad is equivalent to the annual energy consumption of ten million U.S. households)
- Reduce \$41.4 billion in energy costs
- Cut 395 million metric tons of carbon dioxide emissions
- Eliminate the need for approximately eight new 250-megawatt (MW) power plants (Ref. 1)

The purchase price for an average motor makes up approximately three percent of the total lifecycle cost to own and operate. Energy costs make up the rest (Ref. 2). Managing motors

could pay big dividends in reducing energy costs and increasing process reliability.

But how will this mandate affect OEMs and end-users? Let’s examine the various aspects needed for complying with the new legislation taking effect March 9, 2015. Motors requiring outside agency approval, such as UL or CSA, have a two year extension and need to comply by March 9, 2017.

Motor Designs

One unique aspect about small electric motors is there are many design possibilities. Some motors’ designs employ magnets to assist with rotation and increase efficiency, while other designs, such as switch reluctance, are being improved with controls, making significant increases in efficiency. Older existing designs, such as shaded pole motors, may be phased out over time as they exhibit efficiencies much lower than new designs and products available. New motors require electronic control, increasing costs, but they have tremendous energy saving benefits (Ref. 3).

Tables 1 and 2 show the new minimum efficiency standard levels, which apply to all small electric motors manufactured for sale in the United States, or imported into the U.S. either as standalone items or as a part of a system (Ref. 4).

“Now, rising energy costs and the new legislation are moving efficiency to the top of everyone’s checklist.”

Who Is Affected?

Prior to this legislation, from an OEM designer’s point of view, motor choice focused primarily, in descending order, on price, size, noise-level, and weight. Until the Energy Independence and Security ACT (EISA) legislation, neither the OEMs nor their customers considered efficiency important enough to factor into a machine’s overall design. Now, rising energy costs and the new legislation are moving efficiency to the top of everyone’s checklist (Ref. 2).

End users will not have to replace machinery currently in use, but if they want to replace a motor in an existing machine, they may have to call the OEM to supply them with a motor that meets the most current regulations.

OEMs considering replacement of shaded pole or capacitor type motors with these new emerging designs will need to re-engineer their products and validate their motors. OEMs will incur costs to redesign their products to accommodate larger, more efficient motors, or to purchase a stockpile of replacement motors of the correct size.

Table 1 Standard levels for polyphase small electric motors

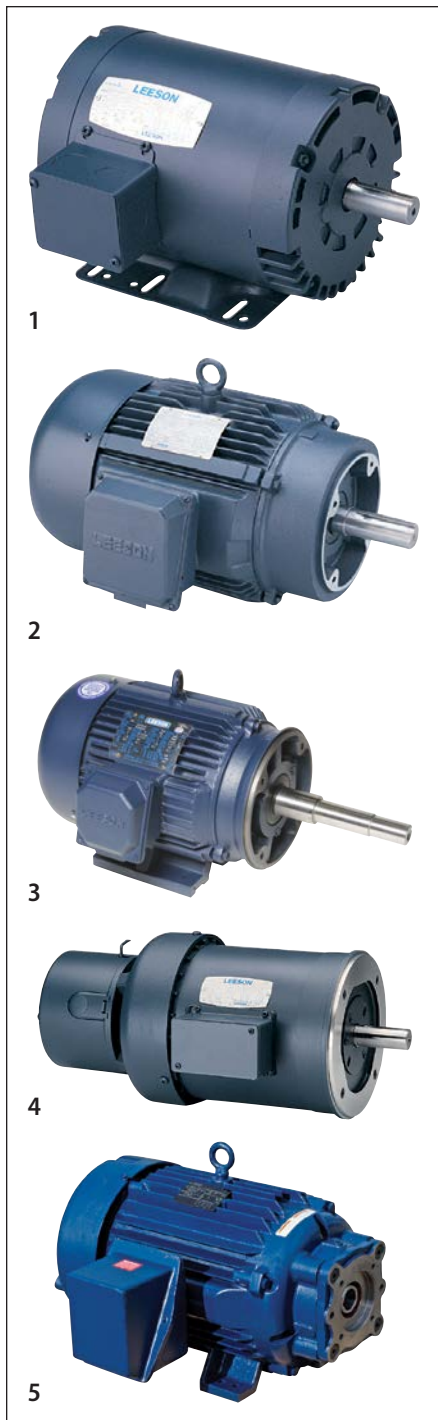
Motor Output Power	Six Poles	Four Poles	Two Poles
0.25 hp/0.18 kW	67.5	69.5	65.6
0.33 hp/0.25 kW	71.4	73.4	69.5
0.5 hp/0.37 kW	75.3	78.2	73.4
0.75 hp/0.55 kW	81.7	81.1	76.8
1 hp/0.75 kW	82.5	83.5	77.0
1.5 hp/1.1 kW	83.8	86.5	84.0
2 hp/1.5 kW	N/A	86.5	85.5
3 hp/2.2 kW	N/A	86.9	85.5

*Standard levels are expressed in terms of full-load efficiency

Table 2 Standard levels for capacitor-start induction-run and capacitor-start capacitor-run small electric motors.

Motor Output Power	Six Poles	Four Poles	Two Poles
0.25 hp/0.18 kW	62.2	68.5	66.6
0.33 hp/0.25 kW	66.6	72.4	70.5
0.5 hp/0.37 kW	76.2	76.2	72.4
0.75 hp/0.55 kW	80.2	81.8	76.2
1 hp/0.75 kW	81.1	82.6	80.4
1.5 hp/1.1 kW	N/A	83.8	81.5
2 hp/1.5 kW	N/A	84.5	82.9
3 hp/2.2 kW	N/A	N/A	84.1

*Standard levels are expressed in terms of full-load efficiency



Do you use motors like these? You may soon be affected by the Small Motor Rule, which goes into effect March 9, 2015. Shown here are just some of the motor types that will be affected, including: 1) three-phase ODP motors, designed for air compressor, pump, fan and blower duty applications; 2) three-phase C-Face motors used on pumps, compressors, blowers, fans and other industrial applications; 3) NEMA JP pump motors, used in continuous-duty applications where the pump impeller is mounted directly on the motor shaft; 4) brake motors, used in conveyors, hoists and packaging equipment; and 5) hydraulic SAE pump motors, used in oilfield applications and the hydraulic pump industry.

The proposed rules cover capacitor design motors as described, which impact many different types of OEMs, such as appliance manufacturers, pool pumps, and residential and commercial HVAC equipment.

To comply with the new regulations, motor manufacturers will need to change original motor designs significantly. Since additional active materials, like copper and steel, will be needed in motor designs to increase efficiency, the overall cost of motors

will likely increase. Additionally, manufacturers will face the tooling cost for each separate design at each incremental efficiency level. Besides these capital expenditures, manufacturers will incur equipment conversion expenses such as research and development, testing, and product literature development associated with the new energy conservation standards. The DOE admits that the rule “may require expenditures of \$100 million or more on the private sector...” (Ref. 5).



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"To comply with the new regulations, motor manufacturers will need to change original motor designs significantly."

The good news for end users at all levels is these regulations will result in reduced energy consumption. End users have no direct compliance requirements with the DOE like motor manufacturers and OEMs. They do not need to concern themselves with equipment design issues related to motor changes nor do they need to submit compliance paperwork to the DOE.

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A Change in Topology

To meet these higher efficiency levels, many motors will change in topology. Based on meeting higher efficiency levels there may be potential impact on the mounting and alignment.

The Nuts and Bolts (SMR & EISA Expansion)

In May 2014, the DOE released communications with required expansions of three-phase, single-speed, low voltage, integral HP motors, 1-500 HP to meet NEMA Premium efficiency levels, excluding some exceptions. This ruling, which goes into effect on June 1, 2016, expands current motor regulation for motors that were not previously covered in the EISA 2010 regulations. These families of motors are also listed below.

For the SMR, the motors that are in scope include:

- 2-digit frame numbers - 42, 48 and 56 frame motors and their IEC equivalent frame size motors
- The Speed or Poles of the motors would include 2, 4 and 6 pole designs from 1/4 to 3 HP
- Open construction motors that are either 3 phase (Polyphase), Cap Start- Induction Run or Cap Start/ Cap Run designs
- Continuous duty rated and also meet NEMA Service Factor

Exemptions to this rule include:

- Definite or Special Purpose OPEN construction design motors
- Motor speeds that are outside of the 2, 4 and 6-pole speeds
- Enclosed motors
- Motor types that are not classified as being three-phase, cap start-induction run or cap start/cap run
- Intermittent duty motors as well as designs outside the HP and frame size listing as described above
- Motors that are already covered by other efficiency legislation are also not covered by this rule

The Energy Independence and Security Act (EISA) expansion and compliance rule, sometimes referred to as the EISA Expansion Rule, expands the following list of motor designs to meet NEMA Premium efficiency. 1 - 500 HP, NEMA Design A, B & C (1-200 HP only today for Design A & B motors); IEC Design N, H, 8 Pole designs, enclosed

56 Frame IHP (1 HP and larger) that are either of General Purpose, Special or Definite Purpose design electric motors.

The Efficiency levels must meet NEMA Premium levels as listed in Table 12-12 (IE3 – 60Hz).

Motors that are now affected by this Expansion Rule include:

- NEMA Design A & B motors from 201 to 500HP
- NEMA Design C motors from 1 to 500 HP
- All voltages ≤ 600 volts
- 8-pole motors
- Electric motors with non-standard endshields, flanges or shafts
- Motors with moisture resistant windings, like encapsulated or sealed windings
- Motors that use any non-standard mounting like a base or cradle
- Motors that do not have a base or cradle – footless designs
- Partial designed electric motors - but not rotor and stator sets
- Vertical hollow shaft motors
- TENV designed motors
- JM and JP Pump motors
- Electric motors having thrust or roller bearings
- Integral brake motors
- Motors with separately cooled blowers on them
- Enclosed 56 frame 1HP and larger – 56 Open motors are covered by the SMR
- Gearmotors if the motor can be removed from the reducer and work as independent motor

Exempt Motors from the 2010 Expansion Rule include:

- Fire Pump motors
- Liquid cooled motors
- Submersible motors
- Air over design motors
- Component sets (stator, rotor sets)
- Small electric motors below 56 frame – See SMR Rules
- Advanced Motor Technology motors which include PMAC, ECM, Brushless DC, etc.
- Inverter Duty only motors

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Conclusion

The electric motor is a critical component in many plant applications and in most equipment and is used in a wide range of equipment in almost every sector of the economy. Given this, the impact of this regulation will be significant for overall energy consumption in the United States. **PTE**

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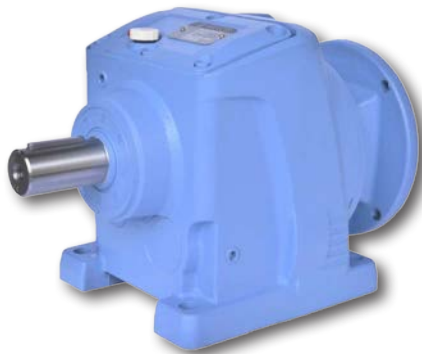
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Pragati Transmission Pvt Ltd
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RJ Link International, Inc.
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Pre-Tension Thrust Bearings

THE QUESTION

What is the recommended method of gripping a spinning shaft (with up to 130 hp of rotational energy) to install pre-tension thrust bearings and conventional thrust bearings (load = hundreds of pounds) when the shaft cannot have any high points because it must pass through an area of tight clearances to assemble? Will snap rings still withstand the harsh vibration of this environment?

Expert response provided by Norm Parker, bearing technical specialist for the driveline division at GM Milford (MI) Proving Grounds

Despite their unassuming demeanor, retaining rings are big business. Their relatively easy production—in addition to their massive global demand—make for an attractive market for many small manufacturers.

Retaining rings come in just about every shape and size imaginable, but we can break them into two main groups: internal and external.

Internal rings are installed on an internal housing bore; these are frequently used to retain a seal or bearing in a housing.

External rings—or rings that install on an outer diameter—are commonly used on shafts. The primary function of this style is to locate bearings, gears or other components on a rotating shaft. These are available in radial and axial installation styles, often referred to as “C” clips.

Retaining rings are available for just about every duty cycle needed—from lightweight retaining rings to rings that can hold several hundred thousand pounds of axial load.

The two main considerations in designing for a loaded retaining ring is the load capability of the retaining ring and the load capability of the groove the ring will be located in. Often, the groove is the weak point in the system.



Figure 1 Internal retaining ring.

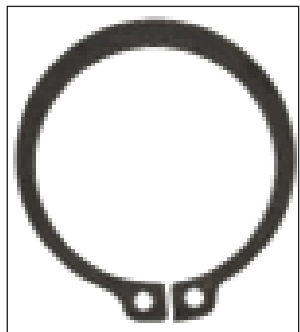


Figure 2 External axial retaining ring.

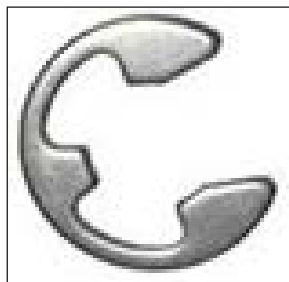


Figure 3 External radial retaining ring.

All of the recommended groove dimensions and tolerancing will be listed for every snap ring in any basic catalog.

While all of the dimensions will be listed in the catalog for every retaining ring, it is often useful to do a little work up front to make some loose determination on what size ranges you will be looking at. The equations for ring shear and groove deformation can literally be done in a few minutes.

Based on the magnitude of load and precision needed, a wide range of thicknesses, precision and styles are available. However, many heavy-duty applications supporting full gear loads, clutch reactions, wheel ends, primary drive shafts, and many others use retaining rings in situations where solid shoulders on shafts and housings are not practical or feasible.

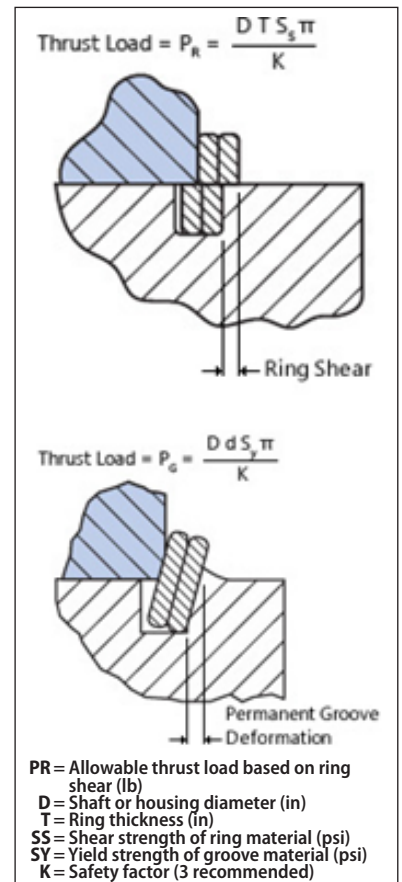


Figure 4 Groove deformation equation.

As a GM bearing technical specialist, **Norm Parker** is tasked with testing theoretical models in the real world, in real time. In keeping with his strong academic background, Parker has also developed a keen interest in the commercial and engineering aspects of the bearing industry. Parker plans to continue expanding his expertise and providing substantial personal contributions to bearing technology through metallurgy, design and processing.



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The Applications of Bevel Gears

Dr. Hermann J. Stadtfeld

EDITORS' NOTE: *"The Applications of Bevel Gears" is the excerpted third chapter of Dr. Hermann Stadtfeld's latest book — Gleason Bevel Gear Technology (The Gleason Works, Rochester, New York, USA; All rights reserved. 2014; ISBN 978-0-615-96492-8.), which appears here unabridged through the kind graces of Dr. Stadtfeld and Gleason Corp. Future installments will appear exclusively in Power Transmission Engineering and Gear Technology magazine over the next 12 to 18 months.*

A Word From the Author

Much has occurred in our industry over the past 10 to 15 years. A singular example is the heightened complexity — and opportunity — that now exists in making "best choices" for optimal transmission elements.

Indeed — 21st Century gear technology not only offers methods for the calculation and manufacture of classical bevel and hypoid gears; it also now presents a variety of possibilities for the three-dimensional transmission of power via gear types that — once-upon-a-time — could only be manufactured on special machines with exotic, expensive tools.

This book was written and is intended for specialists in Planning, Engineering, Gear Design and Manufacturing. It also serves to help meet the technical information needs of those researchers, scientists and students who deal with the theory and practice of bevel gears and other angular gear systems on a regular basis.

What's more, Gleason Bevel Gear Technology is the first multi-translated textbook available worldwide that goes beyond explicating the abovementioned methods. It also imparts practical suggestions for their application.

The basics-oriented, introductory chapters of this book guide both engineers and students with no gear experience in an easy, reader-friendly way through the basics of modern cylindrical and bevel gear technology. A vector math is introduced that enables every gear specialist to create an Excel spreadsheet and conduct their own experiments in order to gain a better understanding of the complex bevel gear geometry.

It must be noted and acknowledged that The Gear Praxis — published by Karl Friedrich Keck in 1958 — is the inspiration for this book; it describes, in comprehensive detail, bevel gear technology from a mid-20th-Century perspective. Indeed, The Gear Praxis in turn inspired me to write this book, addressing all aspects of the state of actual bevel gear technology — but with an early 21st Century perspective.

Introduction

An introduction to gear theory and the fundamental, gear-mathematical explanations required to understand the geometry of bevel gears has been provided in the preceding chapters. Thus informed, Chapter 3 will introduce examples of everyday applications in the industry that serve to estab-

lish the basis for the practical-oriented chapters to come. Similar to cylindrical gears — used to reduce the RPM of a prime mover and to bridge the distance between gear shafts (parallel axes) — bevel gears are also used to reduce input RPM and to transmit motion between two axes that include an angle which can be not just 90°. This physical property of bevel gears allows the orientation between input and output shaft to be under almost any angle. The results translate to design solutions for industrial gear boxes, vehicles and aircrafts which are — due to their use of bevel gears — less complex and best-performing in their function.

Automotive

Luxury-market automobiles have optimal traction due to sophisticated weight distribution design and a "pushing" — rather than "pulling" — propulsion. A longitudinally installed engine drives via manual or automatic transmission a propeller shaft whose rotation is re-directed in the direction of the driving rear wheels by a bevel gearset with pinion shaft offset; i.e. — a hypoid gearset. In addition to enhanced



Figure 1 Rear-axle-drive of a passenger car (Source: Daimler AG).



Figure 2 Shows a luxury vehicle with longitudinally oriented combustion engine and a driven rear axle. This concept is used by all automobile manufacturers worldwide on luxury-class vehicles that feature one driven axle.

weight distribution and ideal vehicle handling, the common, disturbing tilt motion and “torque steer” — as in cases of fast gas pedal actuation — are eliminated. While it is more cost-effective to manufacture front-wheel-drive vehicles with “east/west-oriented” engines, these vehicles present for the operator a combination of disadvantages which include, along with handling, higher fuel consumption.

The cross-section of a typical passenger car rear-axle drive unit is shown in Figure 1. The input shaft offset positions the pinion below the ring gear axis; the input is on the right side and comes from the propeller shaft. Both flanges in front of and behind the ring gear will be connected to the rear wheels with driveshafts. The differential carrier with four straight bevel gears is located inside the ring gear. The two differential gears, which are on the ring gear axis, are rigidly connected to the drive flanges. The two radially oriented differential gears are connected with center pins to the differential carrier on which the ring is rigidly bolted. This configuration enables different RPM of the two driving wheels — while the vehicle is negotiating curves, for example — where the wheel towards the inside of the curve requires a lower number of revolutions than the outside wheel. (Fig. 2 shows a luxury-class vehicle with a longitudinally oriented combustion engine and driven rear axle. This concept is used by automobile manufacturers worldwide on luxury-class vehicles that feature one driven axle.)

Maximum traction is achieved in every vehicle if all wheels are driven; i.e. — all-wheel-drive (AWD) automobiles. Figure 3 shows the drive units of a vehicle with a longitudinally oriented engine and a transmission with a propeller shaft connection to the rear axle. In addition, a transfer case is mounted to the transmission exit that transfers rotation from the transmission exit to the front axle drive. Typically, transfer cases feature mechanical and electromechanical components that allow for differences in RPM and load between the front and rear axle. This is required in order to accommodate a variance in slippage between front and rear axle without winding up the geartrain, as well as the transmission of different torques to the front and rear axle. Eighty percent of the bevel gears in passenger cars are ground, while the remaining 20% are lapped.

Light and Heavy Trucks

Starting with light trucks, those with one-ton payloads are usually driven by one rear axle — with one bevel gearset in each axle unit. For both light *and* heavy trucks, the propulsion via the rear axle is considered the standard solution, while all-wheel-drive solutions are optionally available. Commercial trucks use rigid-beam-style axles, where the central transmission housing is welded to the axle tubes. The beam-style axles carry the brake mechanism in the wheel area and are connected to the truck frame with control arms. The driveshafts and their bearings are located within the axle tubes. The driveshafts have at their end, where they protrude beyond the tubes, flanges with the wheel interface. This simple design — as it is applied to trucks — shows no disadvantages. To the contrary, it is a solution that even offers good off-road capabilities.

Figure 4 shows a pick-up truck with 2.5-ton payload and a rigid-driven rear axle; the vehicle in Figure 5 is an AWD sport

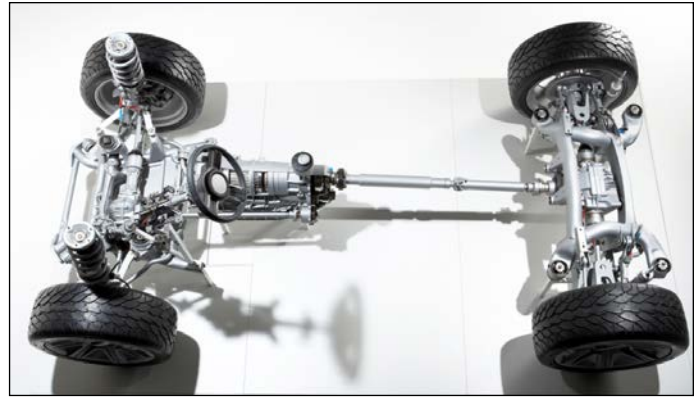


Figure 3 Drive components of a vehicle with all-wheel drive (Source: ZF Friedrichshafen AG).



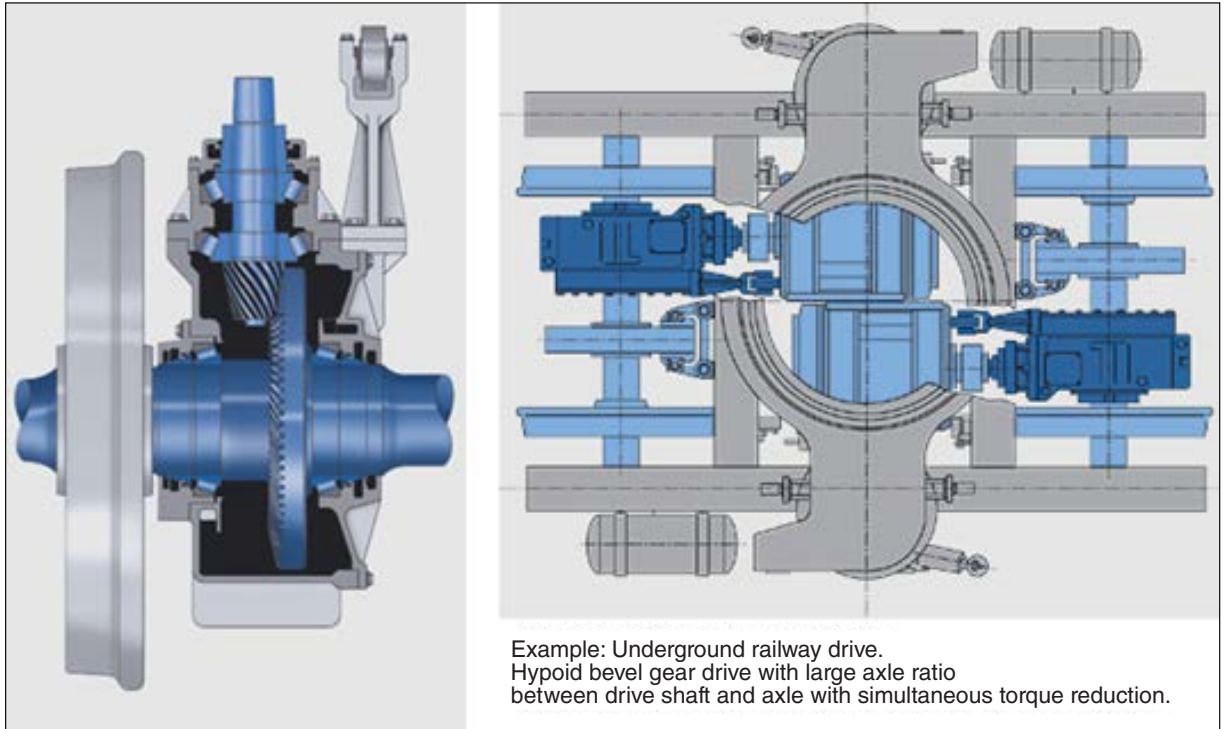
Figure 4 Light truck (Source: General Motors Corporation).



Figure 5 Sport Utility Vehicle (Source: Chrysler Group LLC).



Figure 6 Class 8 semi-truck, tractor with tandem axle.



Example: Underground railway drive.
Hypoid bevel gear drive with large axle ratio
between drive shaft and axle with simultaneous torque reduction.

Figure 7 Drive components of a driven subway car.



Figure 8 Backhoe.



Figure 9 Excavator and scraper (Source: Liebherr).

utility vehicle (SUV). Of additional interest is that even this mixture between light truck and station wagon is mostly equipped with a beam-style rear axle, and a driven, beam-style steering axle in the front.

The tractor of the Class 8 semi-truck in Figure 6 has under the trailer pivot a driven-tandem axle; the tandem axle consists of two independent, frame-connected, beam-style axles. The first is connected to the transmission and engine with a propeller shaft, while the second axle is connected with a short propeller shaft to a transfer case located in the housing of the first axle. The transfer case has a fixed ratio that precludes slippage between the axles.

Eighty percent of the bevel gears in commercial trucks are lapped after heat treatment as a hard finishing process, while 20% are ground.

Railroad Drives

Railroad engines powered with electric motors or diesel engines feature large, longitudinally oriented prime movers whose rotation and torque are transmitted to the wheel axles with driveshafts and bevel gear transmissions.

With trolleys, subway cars or commuter trains, smaller individual, electric motors are dedicated to each axle. Also, the longitudinal motor orientation is preferred and a redirection of the motion is realized by bevel gear transmissions (Fig. 7). The bevel gearsets are ground or skived after heat treatment.

Construction Equipment

Earth-moving equipment uses bevel gears for auxiliary purposes, as well as for their propulsion. The backhoe shown in Figure 8 is very similar to a farm tractor in its basic design concept. Backhoes feature a driven, beam-style rear axle with a spiral bevel gearset (no hypoid offset). Engine, shift trans-

mission and axle drive are connected in these tractors to one solid unit.

The excavator in Figure 9 (top) has four driven, dual wheels. Engine and transmission are located in the upper-rotatable operator cabin. The propulsion of the wheels is produced from the transmission via a bevel gearset to a vertical shaft through the center of the cabin pivot point; it is then redirected beneath the suspension frame with a second bevel gearset in the horizontal length direction. Two propeller shafts transmit the drive motion to each of the front and rear beam axles. The two beam axles also include bevel gearsets for the motion redirection to the wheel axles.

Modern scrapers, i.e. — bulldozers (Fig. 9, bottom) — apply hydrostatic-powered track chains; bevel gears are used only for the actuation of auxiliary units. Bevel gears in construction equipment are — depending upon their manufacture — either lapped, ground, skived or built — without any hard finishing operation after heat treatment.

Aviation

Jet airplane engines have all moving engine parts oriented around the main shaft. The connection of the turbine rotors is established with Curvic couplings. Auxiliary units require a power take-off from the main shaft, which is accomplished via bevel gear transmissions (Fig. 10).

Helicopters use internal combustion, or jet, engines. Modern jet engines for airplanes are designed as a turbofan, where the rotational power of the main shaft — which is generated behind the combustion chambers — is partially used to compress the air that flows into the combustion chambers, and partially to rotate one or several fans. This generates additional thrust to the thrust already generated at the engine exit. Helicopters for civil applications generate lift and thrust forces solely with the main rotor, which is why helicopter jet engines are designed to deliver all output energy on the main shaft, which in turn is used to power the main rotor instead of a turbofan. In both cases, piston or jet engine, there is a necessary redirection of the rotation from the near-horizontally oriented output shafts to the vertical direction of the main rotor axis.

The high, maximal RPM of 18,000 in cases of one or two turbines is reduced with a first bevel gearset by a factor of three, and further reduced by a factor of four-to-eight with the main rotor drive. The main rotor drive has a large ring gear — 80 to 120 teeth — that is driven by one or two pinions (depending on the number of engines). Additional pinions are grouped

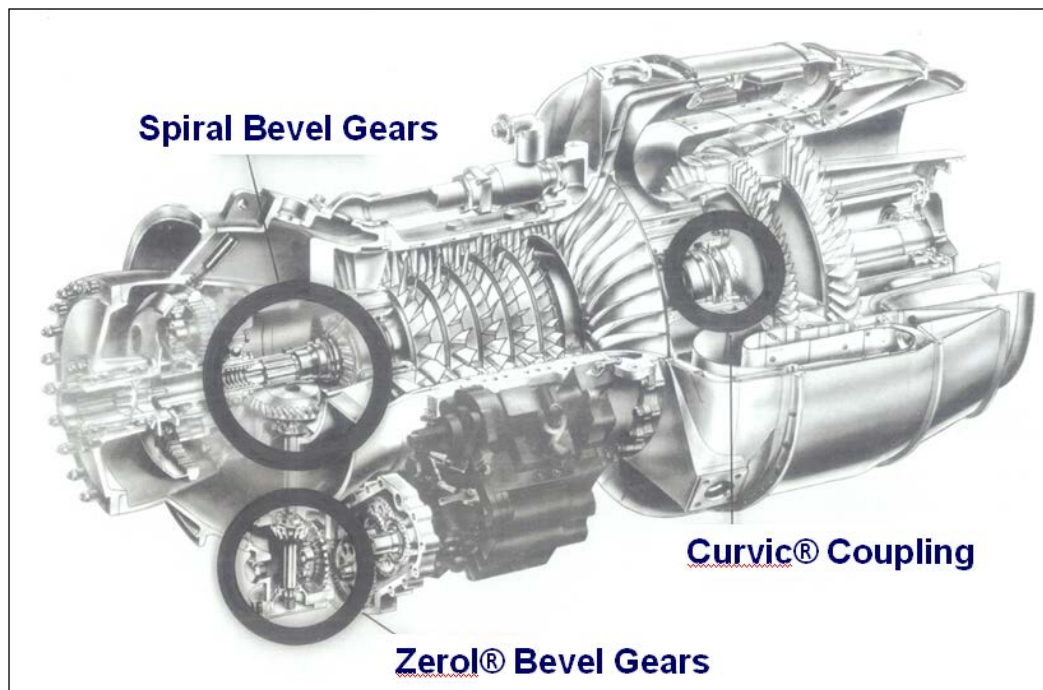


Figure 10 Jet engine with various bevel gear applications.



Figure 11 Helicopter with bevel gear actuated main and tail rotor (Source: Agusta Westland a FINMECCANICA Company).

around the circumference of the ring gear that take off redirect and power to auxiliary units such as a hydraulic pump and electrical generator. Also, energy for the tail rotor is branched off the main rotor ring gear by an additional pinion. At the tail rotor, another bevel gearset is utilized in order to redirect the rotation of the driveshaft running through the helicopter tail into the direction of the tail rotor axis.

Helicopter transmissions total about 10 bevel pinions and four ring gears — some of which have, for example, a hypoid offset in order to account for the asymmetric orientation of the tail rotor and its driveshaft. Because of space constraints and tight component packaging, almost all bevel gearsets are realized with shaft angles less than 90°. Helicopter transmissions are the most sophisticated and complex application for bevel gear systems. All aerospace power transmissions require ground flank surfaces and ground root fillets after heat treatment (Fig. 11).



Figure 12 Industrial gearboxes with different size.



Figure 13 Stern drive with two propellers (Dual-Prop) (Source: Konrad Marine).

Industrial Gearboxes

Industrial gearboxes are used in machines and equipment across many different industries. Redirection of motion is often required as the reduction of RPM between parallel axes. A typical industrial gearbox similar in appearance to what is used to actuate escalators, assembly line belts, lifting devices, and special machines is shown (Fig. 12, left). The efficiency of these gearboxes becomes increasingly important, as many of them have a 24/7 duty cycle. Industrial gearboxes are available with ring gear diameters ranging from below 50 mm up to diameters of 2,000 mm — due to their many different industrial applications. In Figure 12 (right) an angular transmission that drives a larger pump with a ring gear diameter of 1,000 mm is shown. Industrial gearboxes are hard-finished with skiving or grinding after their heat treatment.

Marine Transmissions

Stern drives (more commonly known as “outboard motors”) require two bevel gearsets between the motor and propeller. The high-power unit (Fig. 13) has two opposite hand propellers that rotate in opposite directions (twin-prop). The drivetrain of this unit is equipped with CONIFLEX straight bevel gears that are not hard-finished after heat treatment. Straight bevel gears — with optimized root fillet and a strength-increasing shot peening treatment — show for this particular application a higher root bending strength than spiral bevel gears.

Oceangoing vessels with a central, inboard motor utilize bevel gears to run the propeller shafts with changing angles along the hull to the ship’s stern. A power split onto two stern propellers — typical in many large ships — is handled by bevel gearsets with low shaft angles between 5° and 20°.

Thrusters (Fig. 14) have been used for many decades in ocean exploration platforms such as those used for pumping crude oil. On each of the four corners of such platforms a thruster with a propeller diameter of several meters is attached. The thrusters are used to maneuver the platform from shore to its geographical ocean location; once at the service location, they help maintain platform stability.

A thruster’s base construction is reminiscent of a gigantic stern drive. Today’s smaller-size thrusters are used to propel ships; they afford excellent maneuverability — which is why they are used in pilot boats and ice breakers, as well as in ships requiring nimble harbor maneuverability. Thrusters can also be attached to a vessel as a module; this eases or eliminates many of the existing restrictions in ship design that can be traced to the conventional “inboard” drivetrain and its location of the motors and propeller shafts.

Thrusters use two bevel gearsets (Fig. 14); depending on the application, the ring gear diameters can vary between 600 mm and 2,500 mm. Ninety percent of the bevel gears for the propulsion of ships are skived, while 10% are ground as a hard finishing operation.

Special Applications

Large bevel gears—not hard-finished after heat treatment—are found in equipment and machines for the surface mining of coal and ore (fracking), as well as for stone crushing and stone mills. In some cases these large bevel gears are assembled without any post-cutting heat treatment; in others, a flame or induction hardening is performed. Figure 15 shows an oil drilling platform; the rotation of a horizontally oriented, internal combustion engine is re-directed in the orientation of the drilling rod. This application requires the transmission of high torque with rotary impulses generated by the stone-drilling action and the elasticity of the long rod. The bevel gearset must have a high degree of toughness in order to avoid tooth fracture due to, for example, a locking drill. To fulfill the requirements above, the bevel gears are surface-hardened and, because there is a ring gear diameter of about 1,500 mm in this unit, the bevel gears are hard-finished by skiving, as grinding is usually only recommended for diameters of up to 800 mm. **PTE**

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Figure 14 Thruster for marine applications (Source: Rolls Royce Marine).

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bevel gears

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Dr. Hermann J. Stadtfeld received in 1978 his B.S. and in 1982 his M.S. in mechanical engineering at the Technical University in Aachen, Germany; upon receiving his Doctorate, he remained as a research scientist at the University's Machine Tool Laboratory. In 1987, he accepted the position of head of engineering and R&D of the Bevel Gear Machine Tool Division of Oerlikon Buehler AG in Zurich and, in 1992, returned to academia as visiting professor at the Rochester Institute of Technology. Dr. Stadtfeld returned to the commercial workplace in 1994—joining The Gleason Works—also in Rochester—first as director of R&D, and, in 1996, as vice president R&D. During a three-year hiatus (2002–2005) from Gleason, he established a gear research company in Germany while simultaneously accepting a professorship to teach gear technology courses at the University of Ilmenau. Stadtfeld subsequently returned to the Gleason Corporation in 2005, where he currently holds the position of vice president, bevel gear technology and R&D. A prolific author (and frequent contributor to *Gear Technology*), Dr. Stadtfeld has published more than 200 technical papers and 10 books on bevel gear technology; he also controls more than 50 international patents on gear design, gear process, tools and machinery.



Figure 15 Oil drilling tower.

The Latest Design Technologies For Gear Devices with Great Transmission Ratios

Shuting Li

Four types of gear devices with great transmission ratios (simply called great ratio gears or GRGs) are discussed in this paper. They are strain wave gearing devices (SWGs), trochoidal gear reducers (TGRs), hypocyclic gear reducers (HGRs) and James Ferguson-type planetary drives (JFDs). The structures, advantages and basic performances of these four devices are compared. The latest design and strength analysis methods are also introduced. To conclude, the future tendencies of GRGs are predicted.

Introduction

In the latter period of the 20th century, factory automation was developed very rapidly in order to satisfy the requirements of mass production and reduce product cost. Industrial robots were successfully developed—mainly in Japan, Germany and Switzerland—for the express purpose of factory automation. Then GRGs—such as the SWGs and the TGRs—found applications in industry as robot joints. This was the beginning of GRGs being widely used in industry. Today, countless SWGs and TGRs are made every day, and they are used not only in robots, but also in many other high-performance machines such as semiconductor devices, aircraft and space-exploring machines, as well as critical power transmission devices.

Yet, after much R&D in making high-performance SWGs and TGRs a reality, design and strength calculation problems of the GRG remain.

This paper introduces the latest results of an extended period of comprehensive research on the design and strength calculation methods of the SWGs, TGRs, HGRs and JFDs. First, the structures, advantages and basic performance of the four GRGs are compared. Next, design and strength analysis methods developed for these four GRGs are introduced. And last, future tendencies are predicted for GRGs.

Structures, Advantages and Basic Performances of the GRGs

An SWG is also known as a harmonic drive device; it was invented by Musser (Ref.1) in 1957. Figure 1 is a structural example of a cup-typed SWG. As shown there, the SWG mainly consists of a thin-rimmed flex-spline (FS) spur gear; an internal spur gear, also known as a circular spline (CS); an elliptical-shaped cam, or wave generator (WG); and a flexible ball bearing (FB) that can be deformed freely by the WG.

Transmission ratio of the SWG—when the CS is fixed and the FS is

used as output—can be calculated by (Z_1/N) . Here, Z_1 is the tooth number of the FS; N is lobes of the WG. Usually, the WG assumes the shape of an ellipsoid; therefore $N=2$ at this time. If Z_1 is substantial, great transmission ratio can be available. Now, the SWG with transmission ratios among 30 and 200 are made as mass production products by makers.

Beyond the great ratio, benefits such as light weight, small size, very slight backlash and extremely high transmission accuracy are other advantages of this device. Also, the SWG can be made

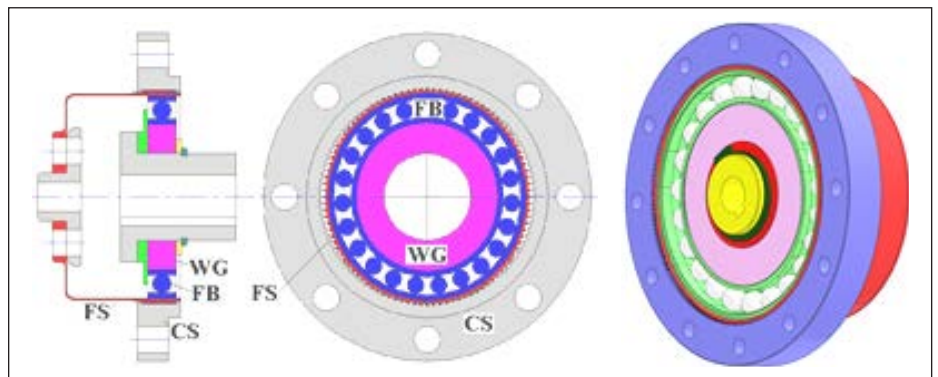


Figure 1 A structural example of the cup-type of SWG.

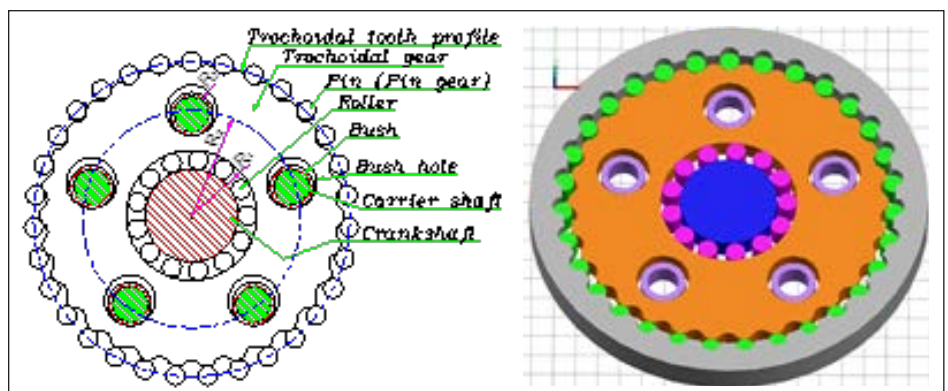


Figure 2 A structural example of the TGR.

very small—like a micro-machine. With these advantages, the SWG has found wide applications in industry, as well as in humanoid robots in recent years.

Trochoidal gear reducer (TGR). TGR is also known as a cycloidal gear reducer. It was invented by Lorenz Braren, a German engineer, in 1927 (Fig. 2). As shown there, an external spur gear with trochoidal profile—AKA *trochoidal gear*—is used. Many pins are used as teeth of an internal—or *pin*—gear. Like the SWG, an eccentric cam—or *crankshaft*—is used to drive the trochoidal gear to engage with the pin gear. Transmission ratio of the TGR can be calculated by $Z_2/(Z_2-Z_1)$ when the pin gear is used as output. Here, Z_1 and Z_2 are tooth numbers of the external and internal gears, respectively. Usually, $(Z_2-Z_1)=1$ and then the transmission ratio becomes Z_2 . So, if Z_2 is made very large, extreme transmission ratio can be made available.

In addition to great transmission ratio, the TGR is also characterized by great torsional rigidity, high load-carrying and overloading capacities. This

is because the number of contact teeth can be increased when larger torque occurs. The TGR also has high efficiency and strong tooth root strength because of the trochoidal profile. It is well known that only rolling contact (no sliding) exists between the contact teeth. But now the TGR can be made with very small backlash, lost motion and transmission errors.

Hypocycloidal gear reducer (HGR). HGR is a planetary drive with small tooth number difference. Figure 3 is a structural example of the HGR. In Figure 3 it is seen that the kinematics of the HGR is exactly the same as for the TGR, with only difference being the tooth profile curves. When involute curves are used as tooth profiles of the external and internal gears, the TGR becomes the HGR. The HGR can be made simpler than the TRG. This is because it is simpler to make the involute teeth than to make the trochoidal teeth. Transmission ratio of the HGR can be calculated in the same way as the TGR. The HGR has lower load-carrying capacity than the TGR. This is because the number of contact teeth of the HGR is less than

that of the TGR due to use of the involute profile. Of course, the torsional rigidity and overloading ability of the HGR are also lower than the TGR; perhaps this is the main reason why the HGR cannot be used widely in industry as is the TGR. It is presently a research subject of the author's as to how to increase the number of contact teeth of the HGR by way of a suitable involute tooth profile.

James Ferguson-type planetary drive (JFD). A James Ferguson mechanism (Ref. 2) is one in which one gear engages with the other two or three gears on the same tooth surface. This mechanism was also used in planetary drives for achieving great transmission ratio and compact size design (Ref. 3). The planetary drive that uses the James Ferguson mechanism is called the James Ferguson-type planetary drive (JFD) in this context (Fig. 4; Ref. 3). In Figure 4, Z_1 and Z_2 are tooth numbers of the sun gear and the planetary gear, respectively; Z_3 and Z_4 are tooth numbers of two internal gears. As shown in Figure 4, the planetary gear Z_2 engages with two internal gears (Z_3 and Z_4) on the same tooth surface. This is the main difference between a typical planetary drive and a JFD. In most cases a transmission ratio of a planetary drive cannot exceed 14; but the transmission ratio of the JFD can be greater than 100. The transmission ratio of the JFD can be calculated by $(1+Z_3/Z_1) / (1-Z_3/Z_4)$. Here, Z_4 is greater than Z_3 and (Z_4-Z_3) is equal to the number of the planetary gears used in the JFD.

Tooth interference must be checked twice, since two internal gears are used in the JFD. In order to avoid tooth interference, Z_1 , Z_2 , Z_3 and Z_4 cannot be given freely as desired. So, too, transmission ratio of the JFD cannot be obtained freely as desired. This is the first disadvantage of the JFD. The second disadvantage of the JFD is lower load-carrying capacity. It shall be introduced later that tooth side-heavier contact occurred in the JFD due to a face width discrepancy between the planetary gears and internal gears. It, too, is now a continuing research project of the author on how to reduce the tooth side-heavier contact through considering a new structure, or by performing tooth lead modifications.

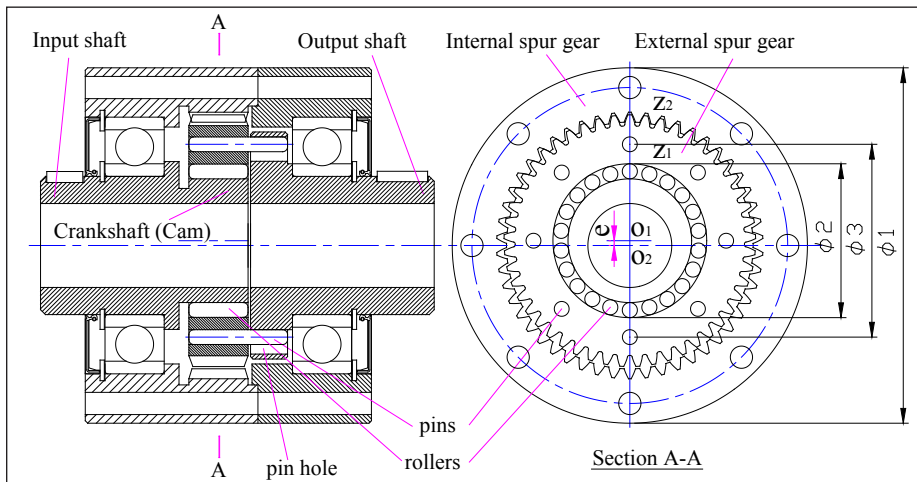


Figure 3 A structural example of the HGR.

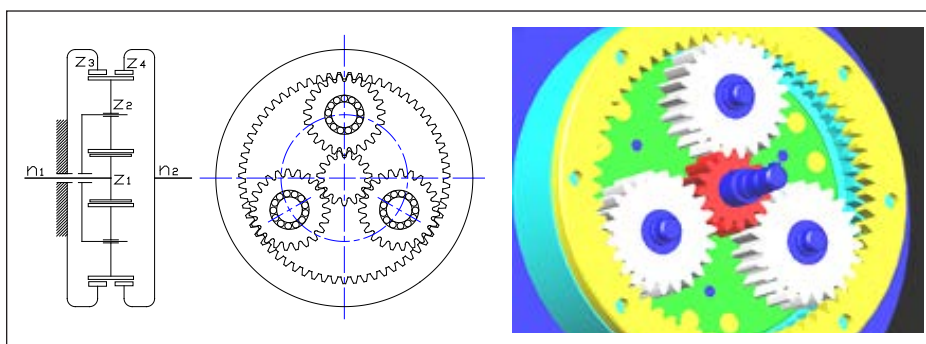


Figure 4 A structural example of the JFD.

The Latest Design and Strength Analysis Technologies for GRG

Design and strength analysis methods of the four GRGs differ from those of usual gears. For the latter, tooth contact and bending strength calculations are the main items in strength analyses, while for the GRG, tooth strength as well as bearing strength must be analyzed simultaneously. This is because contact fatigue failures of the bearings in the GRGs are also the *main* failures. In order to solve strength calculation problems of the GRG, special finite element methods have been developed to do contact analyses of these devices separately, based on long-term study by the author. Loads distributed on teeth, bearing balls and rollers are analyzed — initially through contact analysis with the developed FEM. Then tooth and bearing strength are evaluated using FEM and Hertz's formula once the loads on teeth, bearing balls and rollers become known. These main procedures are introduced in the following sections.

Strain wave gearing device (SWG).

In the mass production products of the SWG, three kinds of curves are now used as tooth profiles; i.e. — straight line, involute, and arc profiles, respectively. Tooth profile design of the SWG is a difficult thing for designers. This is because tooth profile design of the SWG must take the cam shape of the WG into account since cam shape has direct effects on tooth engagement. It requires very sophisticated technology in order to be able to design a suitable tooth

profile with high performances for the SWG. Special software has been developed to do tooth profile design and geometric dimension calculations of the SWG, based on more than 20 years' experience of the author with the SWG. Figure 5 is an example of applications of the developed software. This software was developed to run in the *AutoCAD* environment using *AutoCAD* VBA language. The straight line, involute, and arc curves are programmed in the software. When the gearing parameters are input in the software, tooth profile

design and geometric dimension calculations can be conducted automatically with the help of this software. The 2D drawings (Fig.5 (a)) can be drawn automatically on the drawing template of *AutoCAD* in a few seconds. 3D drawings (Fig.1(b)) can also be executed via 3D commands of the *AutoCAD* or *SolidWorks* software based on the 2D drawings.

Strength calculations of the SWG are another difficult hurdle for designers. This is because there is not yet available a simple method to do strength calcula-

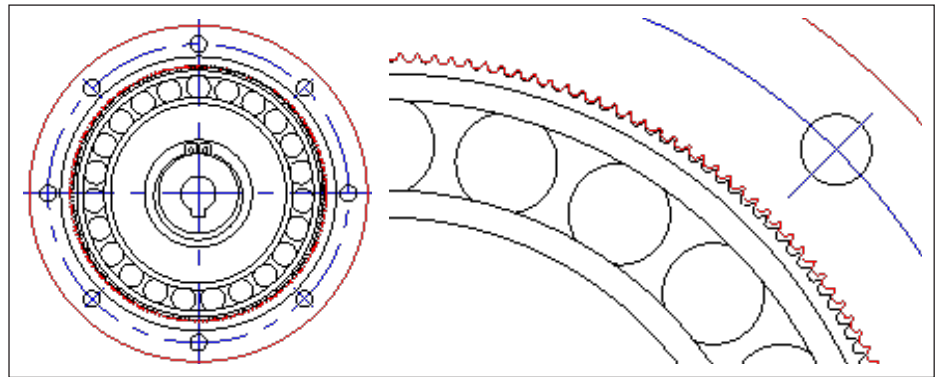


Figure 5 Geometric calculations and automatic drawing of the SWG.

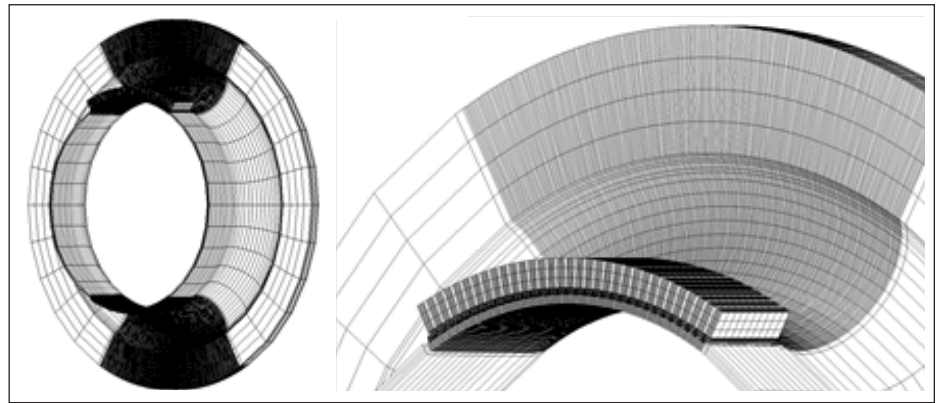


Figure 6 3D FEM model used for contact analysis of SWG.

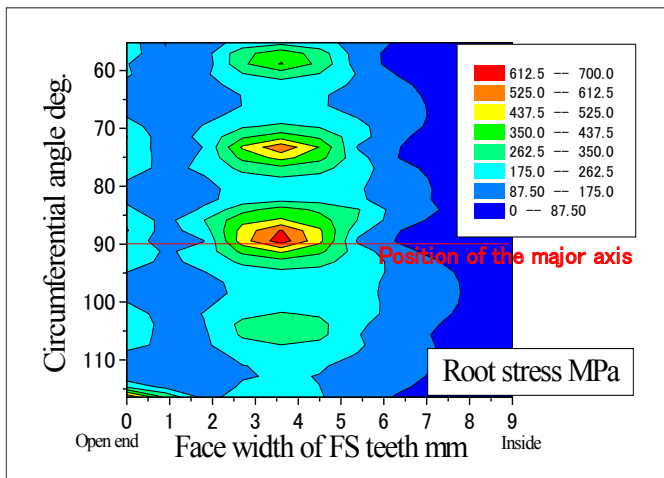


Figure 7 Tooth root stress distribution.

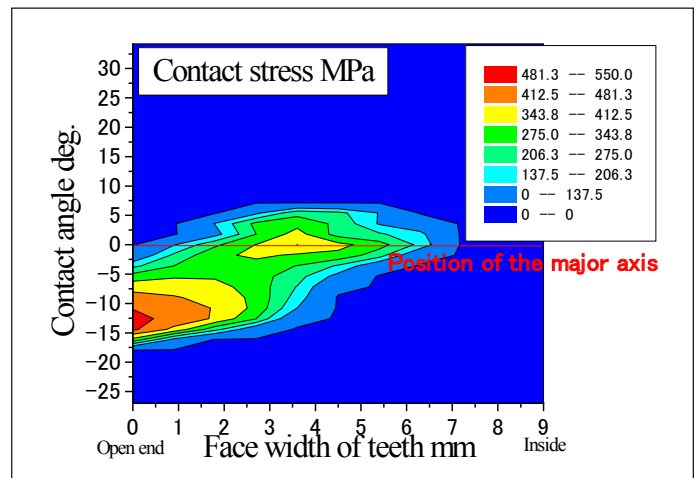


Figure 8 Tooth contact stress distribution.

tions of the SWG. To solve this problem the author in 1987 began seeking a suitable method for strength calculations of the SWG. A unique FEM for the SWG was eventually developed after a very long period of research. Today it is possible to calculate the following strength items of the SWG with the developed FEM software:

1. Contact strength of the contact teeth
2. Bending strength of FS tooth roots
3. Bending strength of FS structure (tube and diaphragm)
4. Contact strength of the FB.

(Except for these four items, buckling strength calculation of FS tube must also be included in the design procedures.)

Figure 6 is a 3D FEM model used for contact analysis of a silk-hat-type of the SWG (Ref. 4). Figure 7 is the root bending stresses of the FS teeth calculated by the developed FEM software. Figure

8 is the calculated maximum contact stresses on FS tooth surfaces. From Figure 7 it is found that the root bending stresses of the FS teeth are affected by the ball positions of the FB. Figure 8 indicates that the tooth contact pattern of the SWG is much more complex than that of usual gears.

Trochoidal gear reducer (TGR). Design software has been developed also for the TGR in an *AutoCAD* surrounding like the SWG (Fig. 9). With this software TGR can be designed very quickly and automatically. The 2D drawings of the designed TGR can be drawn automatically on the drawing template of *AutoCAD* (Fig. 2 (a)) and the 3D drawing can be made as shown (Fig. 2 (b)) using 3D commands of *AutoCAD* based on the 2D drawings.

Yet another difficulty is for designers to perform strength calculations of the TGR. This is because it is still an

unsolved problem to do three-dimensional contact analyses of the loads on teeth, bushes and rollers of the TGR (Fig. 2(a)), although many efforts have been made to solve this problem. It was started in 1994 by the author to develop a method and software that can do strength analyses of the TGR using 2D FEM. Now it is indeed possible to calculate the contact loads and stresses on teeth, bushes and rollers of the TGR with the developed 2D FEM software.

Figure 10 is the 2D FEM model used for contact analysis of the TGR with the parameters indicated in Figure 9. Figures 11-13 are calculated contact loads and stresses on teeth, bushes and rollers when a torque load is applied. Numbers of the teeth, bushes and rollers used in Figures 11-13 are also indicated in Figure 10. With the calculated contact stresses, the contact strength of the teeth, bushes and rollers can be

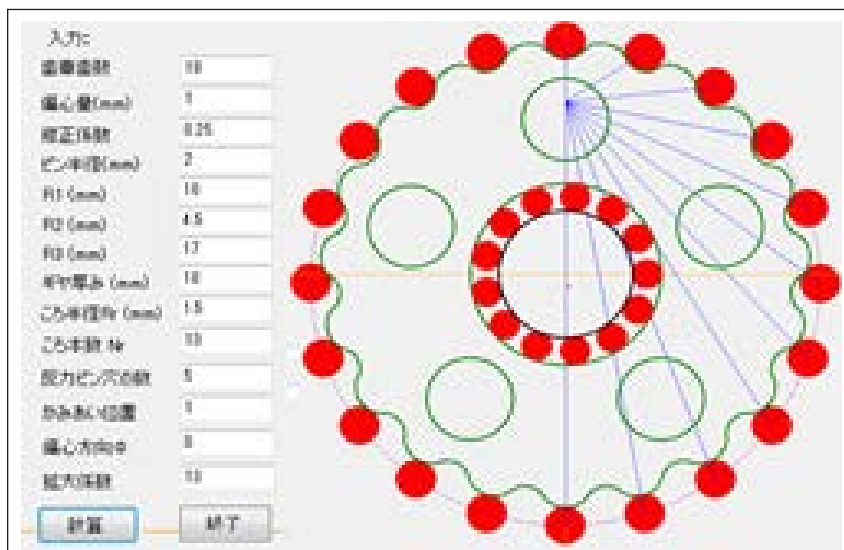


Figure 9 Automatic design program for TGR.

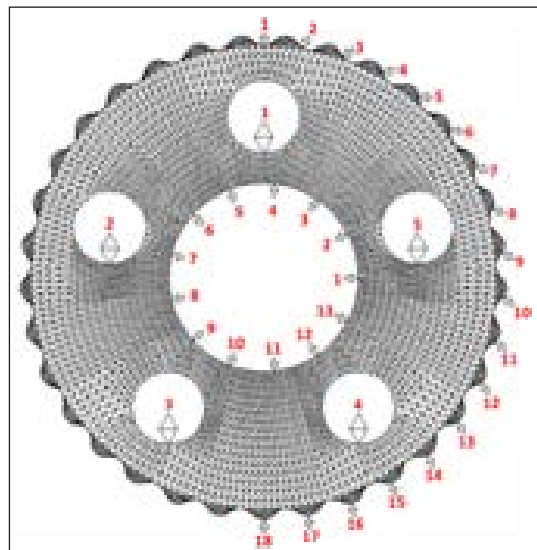


Figure 10 FEM model for contact analysis.

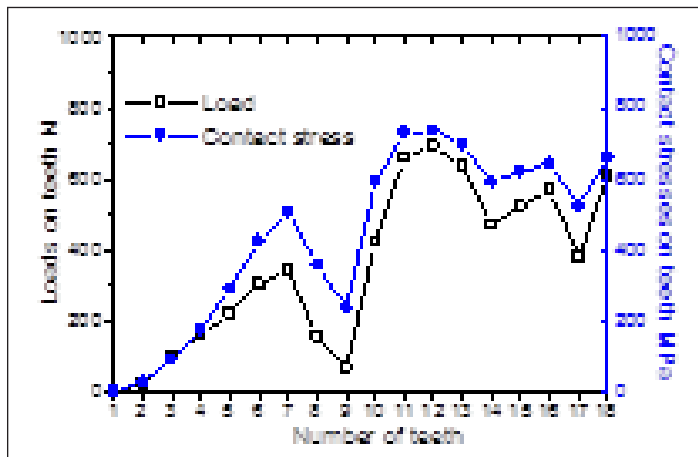


Figure 11 Loads and stresses on teeth.

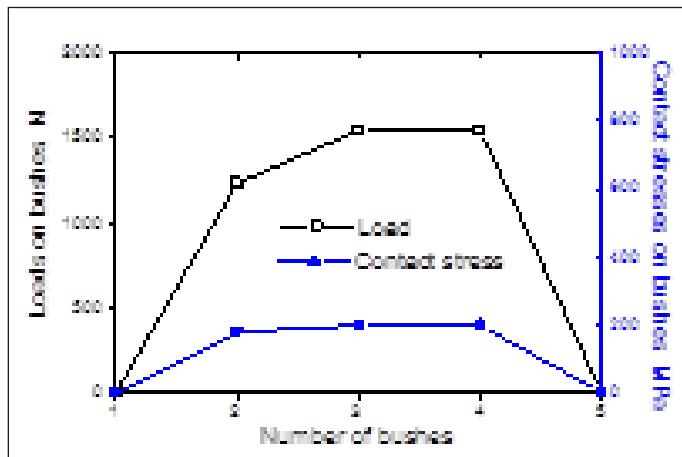


Figure 12 Loads and stresses on bushes.

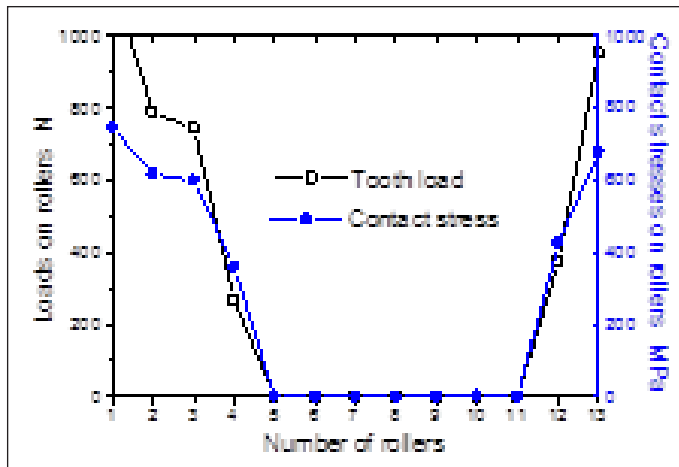


Figure 13 Loads and stresses on rollers.

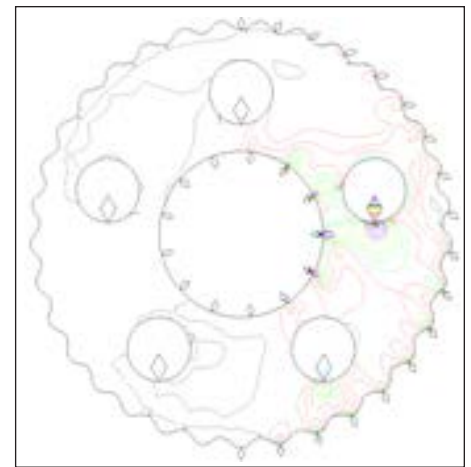


Figure 14 Von Mises stresses.

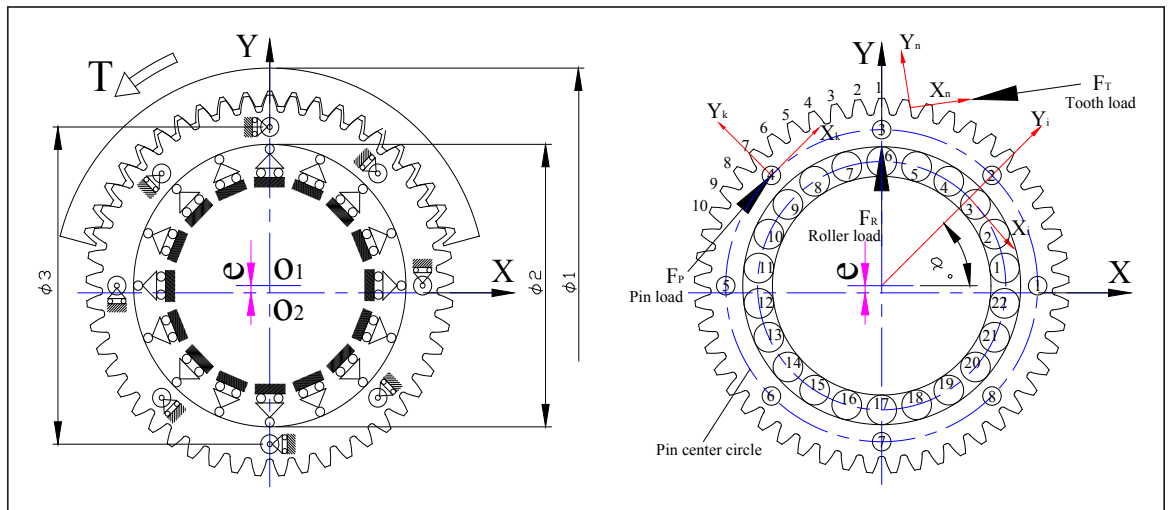


Figure 15 Mechanics model used for contact analysis of the HGR.

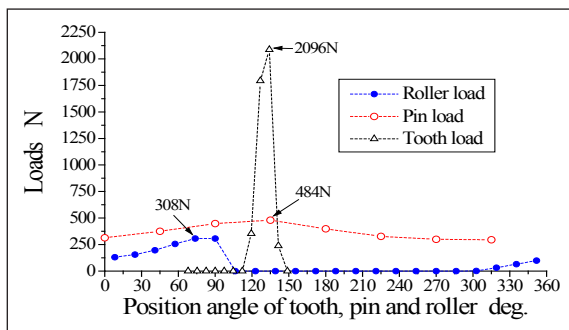


Figure 16 Loads on rollers, pins and teeth.

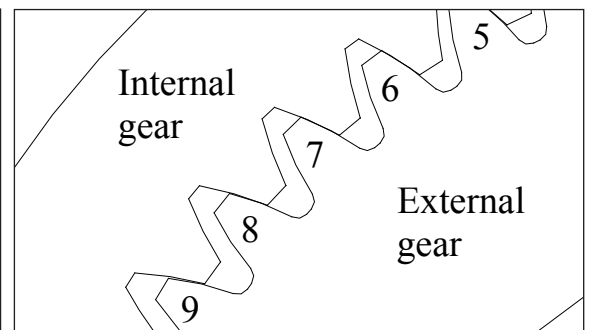


Figure 17 Enlarged view of engaged teeth.

evaluated two-dimensionally. Figure 14 is the calculated Von Mises stresses on the trochoidal gear; it can be used to evaluate the bending strength of the trochoidal gear—but it is rarely used for the TGR.

Hypocyclic gear reducer (HGR). Geometric design and strength calculation of the HGR also differ from usual gear devices. In order to be able to conduct strength calculations of the HGR, a special method used for contact analy-

sis of the HGR has been developed using FEM (Ref.5). Figure 15 is the mechanics model used for contact analysis of the HGR (Fig.3). With this model and the developed FEM, loads on contact teeth, pins and center rollers were analyzed (Ref.5) and are given in Figure 16, where it is found that only four pairs of teeth (tooth pairs 5, 6, 7 and 8 as shown in Figs. 17 and 15) are in contact. This means that the contact tooth number of the HGR is much less than that of the

TGR. As shown in Figure 11 there are 17 teeth in contact—from No. 2 to 18—for the TGR. It also means that tooth profile has a significant effect on contact tooth number. Though the HGR can be made easily because of using the involute profile, since contact teeth are much less than that of the TGR, the load-carrying capacity of the HGR becomes much lower than that of the TGR. This may be why the HGR cannot find wider applications in industry. For now, it is a research sub-

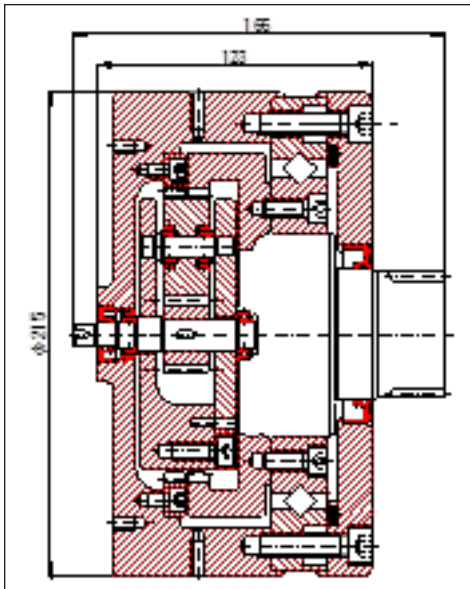


Figure 18 An example of JFD.

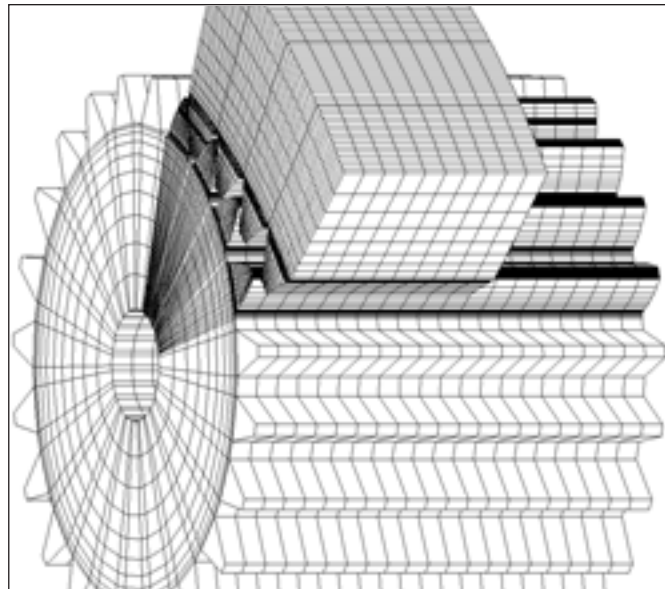


Figure 19 FEM model (different face widths).

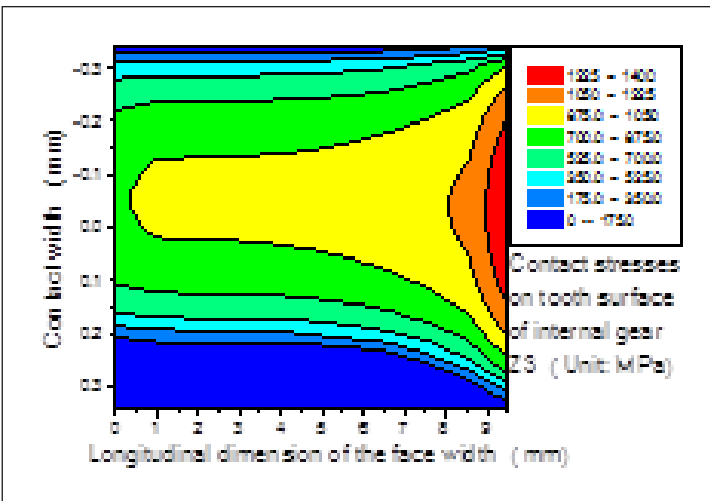


Figure 20 Tooth contact stresses on Z_3 .

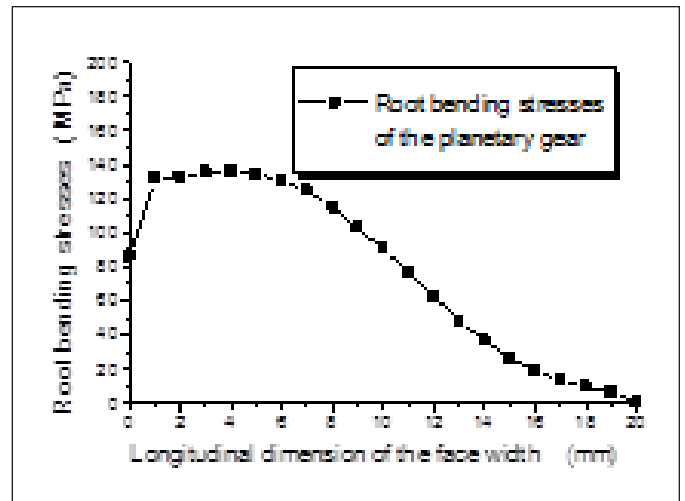


Figure 21 Tooth root stress of Z_2 .

ject for the author on how to increase the contact tooth number of the HGR; a new tooth profile is under study.

James Ferguson-type planetary drive (JFD). One of structural differences between the JFD and a usual planetary drive is the face width difference of the contact teeth between the planetary gears and the internal gears. In the case of JFD, face width of the planetary gears is about twice that of the internal gears (Fig. 4). This means that only half-a-length of the face width of the planetary gears is used to contact with the entire length of the face width of the internal gears (Z_3 or Z_4). This tooth contact on different face widths makes it difficult to do bending and contact strength calculations of the contact teeth using the methods

available for usual gears. So, a 3D FEM is developed to do loaded tooth contact analysis of the contact teeth with different face widths.

Figure 18 is a structural example of the JFD designed by the author based on the basic structure shown in Figure 4. In Figure 18, Z_1 , Z_2 , Z_3 and Z_4 are tooth numbers of the sun gear, planetary gear, and internal gears (left-side and right-side), as indicated in Figure 4. Figure 19 is an FEM model used for loaded tooth contact analysis of the planetary gear Z_2 with the internal gear Z_3 . As we see in Figure 19, the internal gear teeth are in contact with the right half-length of the planetary gear teeth.

Figure 20 shows the calculated contact stresses distributed on the tooth surface of the internal gear Z_3 . Figure 21

is the calculated root bending stresses of the planetary gear Z_2 distributed along the longitude. From Figure 20 it is determined that contact stresses are not uniformly distributed along the longitude of the internal gear teeth; i.e. — the side-heavier contact occurred on the right side of the contact teeth. In Figure 21 it is also seen that tooth root bending stresses are not uniformly distributed along the longitude of the planetary gear tooth; the left half-length of the planetary gear tooth has larger root stress distribution than the right half-length of the teeth. Although the right half-length of the face width is not used to contact with the internal gear teeth, the right half-length of the tooth also has smaller root stresses. Figures 20 and 21 indicate that the contact and

bending stresses of a pair of gears with different face widths are different from that of a pair of normal use gears with equal face widths. It is now another research project for the author on how to reduce the side-heavier contact of a pair of gears with different face widths through lead modification on the internal gear Z_3 .

Future Tendencies

A common gearing theory. In the future it will become necessary to build a common gearing theory for the SWGs, TGRs and HGRs, since there is a common point existing in all three devices that use eccentric movement to realize the great transmission ratios, as well as having very similar tooth engagement movements.

To date, gearing principles for a pair of conventional gears without eccentric movements (for example: a pair of spur gears or helical gears) have been well studied, but the same cannot be said for the gearing principles of the GRG with eccentric movements. The gearing theories of the SWG and TGR were built separately, while the gearing theory of the HGR has yet to be built. Plainly, it remains a difficult task to design a new type of tooth profile for the HGR. A most worthwhile future goal is to build a common gearing theory for these three GRGs. It may yet be proven that basic performances and load-carrying capacities of the three GRGs can be greatly improved when a new type of tooth profile is developed with the help of common gearing theory.

Lightweight, small size and high-torque transmission. In the last century, much effort was exerted in making the GRG as lightweight, small-sized and high in load-carrying capacity as possible, primarily because these items were required by users as product specifications and these items reflect the competitiveness of the makers' products. In order to create lightweight, small-size, high-torque transmission, many studies were conducted on gear design, materials, machining accuracy and heat

treatment methods. No doubt, these studies markedly improved performance of the GRG and also increased strength and competitiveness of the makers' products. Some makers were very successful in their business and able to compete in very large markets through these efforts. Per the industry experiences of the author, lightweight, small-size and high-torque transmission design are also important for the GRG in the future, as market demand will ensure their importance for quite a long time.

High transmission ratios. Prior to 2000, it was well-accepted to use high-speed, small-size motors in combination with the GRG to transmit great torque in industry robots and other machines. This idea is also successful in humanoid robots (for an example, Honda's ASIMO), NASA's Mars Rover and many other new machines. Now this idea is accepted by many engineers as a general design thought and used widely in new machine development. A familiar nickname — "Gearhead" — is also given to this idea by engineers, and is used very often in factories. Today's "Gearheads" often have transmission ratios among 30 – 200. In the future, much higher transmission ratios — among 200 – 400, for example — may well be needed in the marketplace. This would create new business opportunities in the future to design and make the much higher transmission ratio "Gearheads."

High performances. Also prior to 2000 much effort was expended in improving the performance of the GRG in order to satisfy market requirements. Today it is possible to make very high-performance GRGs with low transmission errors, low vibration, low noise, high transmission efficiency, and high strength with the help of gear technology advances in design, FEM analysis, materials, heat treatment and machining accuracy. Per the author's industry experience, it can be predicted that even much higher GRG performance will be pursued by users in the future.



Conclusions

- Structures, advantages and basic performance of four types of great transmission ratio gear devices — the strain wave gearing device; trochoidal gear reducer; hypocyclic gear reducer; and James Ferguson-type of planetary drive are introduced and compared.
- The latest design and strength analysis methods of the four great transmission ratio gear devices are introduced.
- Future tendencies of the great transmission ratio gear devices are predicted, based upon the extensive industry experience of the author with great ratio gear devices. **PTE**

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Finite Element Evaluation of Bearing Instrumentation Method

J. Austin, Dr. David Talbot, Dr. Donald Houser and Dr. Sandeep M. Vijayakar

This paper presents an evaluation of measurements being taken on a 750 kW wind turbine gearbox being tested by the National Renewable Energy Laboratory (NREL). High-speed stage gears and bearings have been identified as critical components of the gearbox; during gearbox testing, these components were instrumented and tests were developed to evaluate loads on high-speed tapered roller bearings (TRBs). In this paper an advanced finite element-based contact modeling procedure has been applied to model the high-speed stage with the bearings fully modeled in order to evaluate strain levels. A major conclusion is that the strains of the slotted grooves are at such a level that they have acceptable signal-to-noise levels. This was verified by the results of the initial experiments presented here.

Introduction

Motivation and gearbox configuration. The National Renewable Energy Laboratory (NREL) has made a commitment to address wind turbine gearbox reliability as part of its research agenda. A gearbox reliability collaborative (GRC) was developed to address major gearbox issues with the goal of increasing the overall reliability of wind turbines. Many gearbox problems may be a result of poor communication and feedback during the design, operation, and maintenance of turbines (Ref.1). The GRC is aimed at uniting these equally critical elements of the design process and encouraging collaboration and information sharing. A 750 kW turbine design, representative of many turbines currently in service, was selected by a committee of experts and gearbox consultants hired by NREL under the GRC.

The majority of observed failures appears to initiate at bearing locations, and are not a result of gear failures or gear-tooth design deficiencies. The failures appear to initiate at bearing locations and then propagate into other components of the gearbox. During the first iteration of testing there were a number of component failures seen in the gearbox, many of which were attributed to lubricant starvation. Components damaged in this gearbox included the high-speed gearset, sun spline, and planet bearings (Ref.2). The gearbox underwent a redesign and so began a new iteration of testing.

The GRC gearbox is shown in Figure 1; its design is a speed increaser that includes a planetary stage followed by two parallel shaft stages. The gearbox has a power capacity of 750 kW, with an

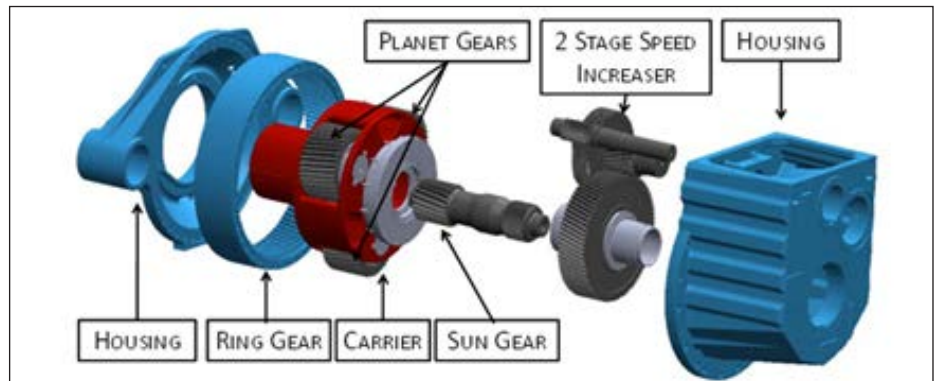


Figure 1 Exploded view of example gearbox (Ref. 3).

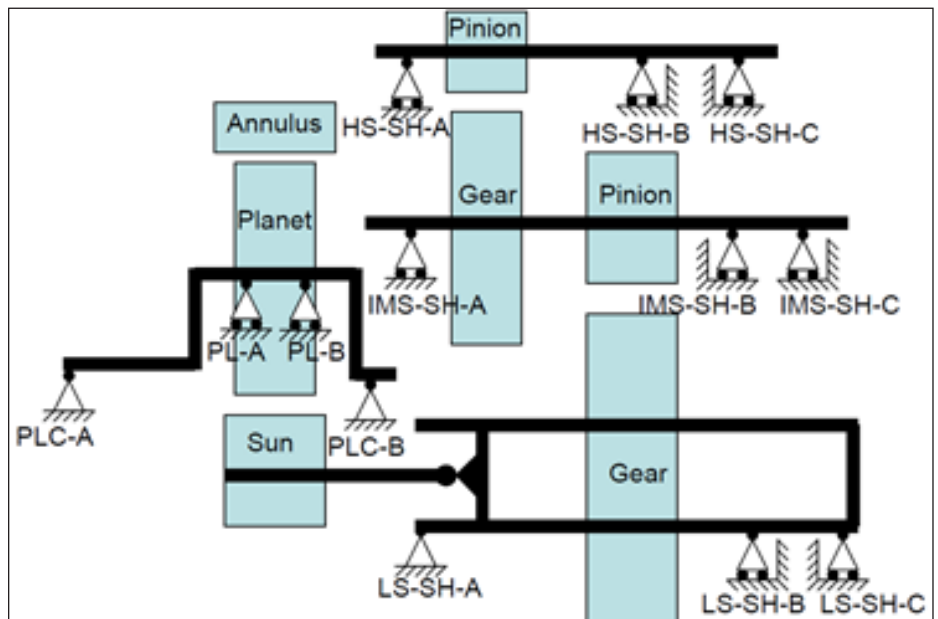


Figure 2 Gearbox bearing locations and nomenclature (Ref. 3).

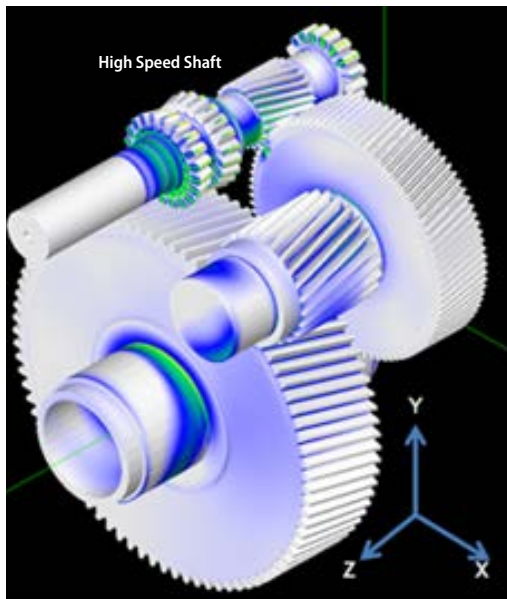


Figure 3 *Transmission3D* model showing high-speed, intermediate speed, and low-speed shaft stages.

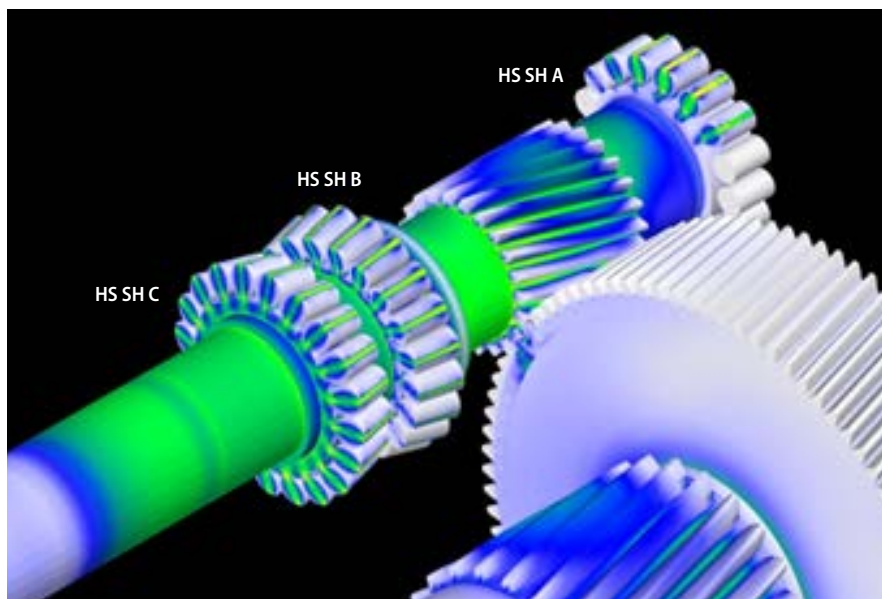


Figure 4 *Transmission3D* high-speed shaft stage with bearings fully modeled.

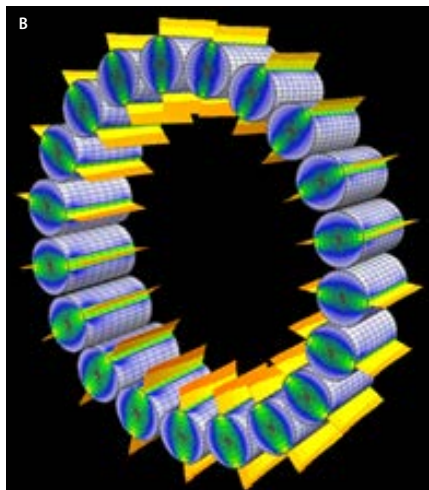
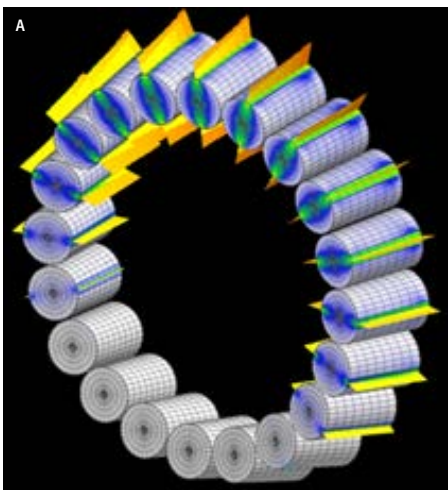


Figure 5 A) HS SH B and B) HS SH C roller contact pressure distribution.

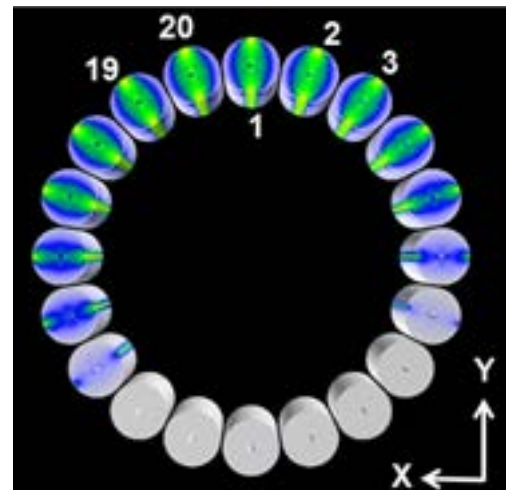


Figure 6 HS SH B TRB rollers with numbering convention.

overall speed increase ratio of 1:81,491. The nominal input speed is 22 rpm, with the output speed at 1,800 rpm. A 323 kN-m input torque is required on the rotor blades to operate the generator at full-rated power.

The following nomenclature will be used throughout the rest of this document when referencing internal components of the gearbox:

“*Upwind components*” are those located on the entrance side of the stage before power has passed through the gear.

These may also be termed “*rotor side*,” as they are located closer to the rotor.

“*Downwind components*” are those located on the aft end of the shaft.

Parallel shaft stages are comprised of three separate shafts—each supported

by three bearings. The bearing configuration of each shaft consists of a cylindrical roller bearing on the upwind portion of the shaft: (LS-SH-A, IMS-SH-A, HS-SH-A); and a pair of tapered roller bearings (TRBs): (LS-SH-B, IMS-SH-B, HS-SH-B, LS-SH-C, IMS-SH-C, HS-SH-C) on the downwind portion of the shaft. Bearing locations and naming convention are shown (Fig. 2). The subject of this paper will be the high-speed pinion shaft bearings (HS-SH-B, HS-SH-C) that support the upper shaft of Figure 2.

Transmission3D and Calyx. *Transmission3D* is a linear, finite element (FE) contact analysis program developed by Advanced Numerical Solutions LLC (Ref. 4), specifically designed for the analysis of multi-mesh-gear

drivetrains. The program empowers the user to model the housing, bearings, shafts, planet carrier, and gears as deformable bodies. Gear microgeometries can be included, as well as assembly and manufacturing errors. Bearings are generated similar to gears, and can include crowning on the rollers and races, as well as clearance and preload.

The greatest benefit of *Transmission3D* is in the contact algorithm. Gear, bearing, and spline stresses are localized and influenced by microgeometries on the micron scale. *Transmission3D* uses a unique contact analysis solver—*Calyx*—that utilizes a hybrid algorithm of finite elements to predict far field displacements, and an elastic half-space model to predict relative displacements local to the contact region

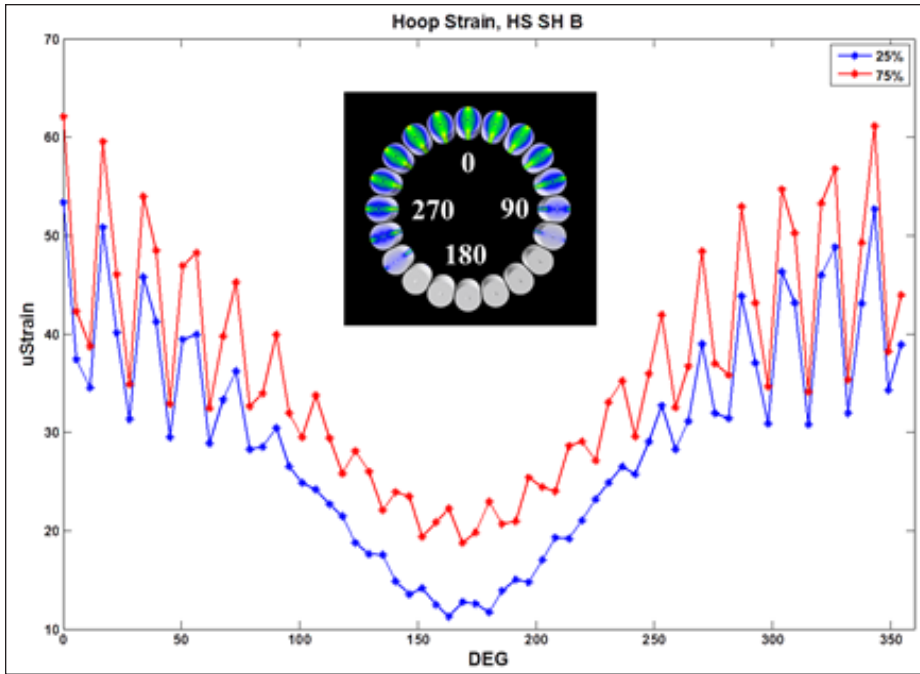


Figure 7 Unmodified outer raceway hoop strain of HS SH B for one-time step.

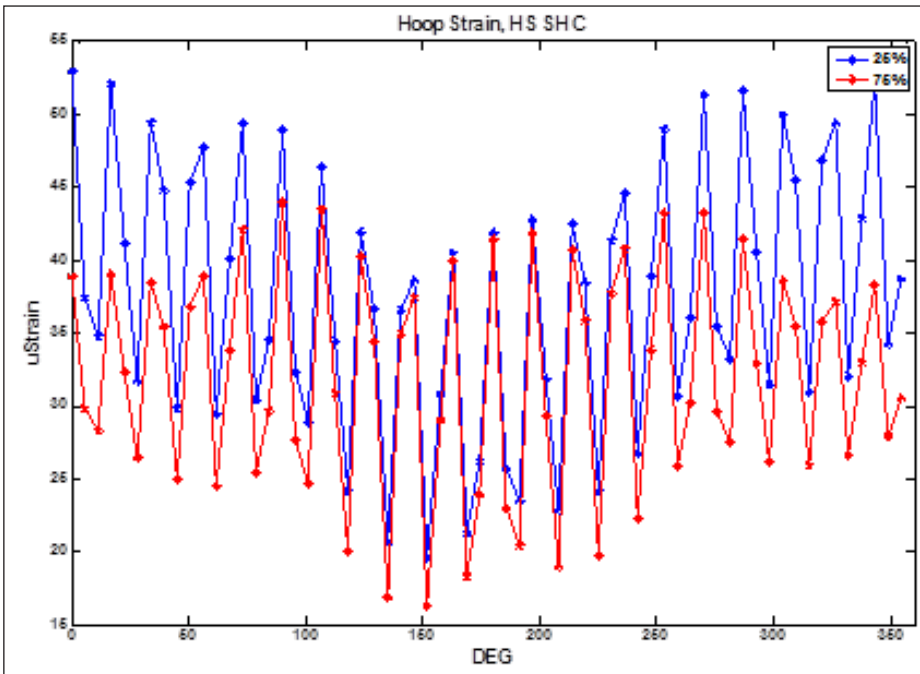


Figure 8 Unmodified outer raceway hoop strain of HS SH C for one-time step.

Location	Simulated peak-to-peak strains at groove locations with and without the modified bearing race.							
	HS SH B (micro-strain)				HS SH C (micro-strain)			
	No Groove		With Groove		No Groove		With Groove	
	25%	75%	25%	75%	25%	75%	25%	75%
A	19	23	133	150	18	11	103	81
B	3	10	47	5	21	19	134	163
C	2	4	-14	17	19	21	153	107
D	7	13	107	100	19	15	154	135

(Ref. 5). But in doing so, *Calyx* does not require a highly refined FE mesh.

High-Speed Shaft Analysis

The high-speed stage gears and bearings are acknowledged to be critical components of the gearbox (Refs. 1-2); there previously had been very little instrumentation of the high-speed shaft, gears, and bearings. During the next phase of testing, this portion of the gearbox was to be instrumented. In this next phase, tests were developed to evaluate the loads on the TRBs (Ref. 6). Gauges were placed in axial grooves machined into the outer race of the TRBs. Each bearing has four axial grooves, with two-gages-per-groove.

There was initial concern as to whether the strain levels would be high enough in the bearing raceways to provide an adequate signal-to-noise ratio. The outer race of the bearing is tapered; the groove geometry was tapered as well, with the intent of maintaining a constant radial thickness of the raceway along the groove.

In this analysis, contact was included in the model at all gear mesh locations and at the high-speed bearings; all other bearings were included as stiffness matrices. The high-speed, intermediate-speed, and low-speed stages are shown in Figure 3. The fully modeled bearings can also be seen, and are shown in detail in Figure 4, which also displays the naming convention.

Model parameters. An analysis was completed with and without the modified race under 100% torque loading conditions. The TRBs were preloaded with 70 micron of negative clearance to accommodate mounting preload and loads due to thermal expansion of the bearing components. The cylindrical roller bearing HS SH A includes 18 micron of diametric clearance. In this opposing TRB configuration, bearing HS SH C will carry the thrust load generated at the high-speed gear mesh, adding to the initial preload of that bearing and relieving the preload from HS SH B. Figure 5 shows the contact pressure distributions on a) HS SH B and b) HS SH C. It can be seen that all of the rollers in HS SH C are in contact; as mentioned previously, this bearing carries the thrust force generated at the gear mesh,

which keeps all rollers under load. HS SH B however, has approximately 30% of the rollers out of contact.

Bearing strain results. Figure 6 displays the numbering convention used for both TRBs. The first roller in each bearing is located at zero degrees—or top-dead-center (TDC) of the bearing—and increases clockwise while looking downwind (from the left, Fig. 2). The hoop strain was extracted around the circumference of the outer raceway (Figs. 7– 8). The strain was sampled at two axial locations, i.e.—at 25% and 75% of the axial length of the raceway. The results of this analysis are from one time step and can be viewed as if the race was unwrapped and laid flat on the page. Roller 1 is at TDC (0 degrees). The peaks correspond to roller positions; a peak indicates that a roller was directly under that location and a valley indicates that two rollers are straddling that point. The race with grooves has locations at 0° (Groove A); 90° (Groove B); 180° (Groove C); and 270° (Groove D). Differences in load distribution along the rollers themselves should result in shifts in strain values between the two axial locations, and could be used as an indication of roller load distribution. Figures 9 and 10 illustrate the strains extracted around the circumference of the outer race with the machined grooves; the groove locations are labeled. Table 1 shows the peak-to-peak, predicted strain indicating the strain caused by direct application of load by a passing roller.

Discussion

The grooves, as indicated in Figures 7-10, increased the simulated bearing race strains by as much as 300%. HS SH B had two groove locations that were either very lightly loaded or were outside the load zone completely—i.e., locations b and c—respectively. These locations did not see the same amplification as those located directly in the bearing load zone. In general the groove geometry increased strains by a considerable amount. One detriment to modifying the bearing outer race may be that the roller-to-roller load distribution could be affected by the modification. Figures 11 and 12 show the predicted roller loads of HS SH B and

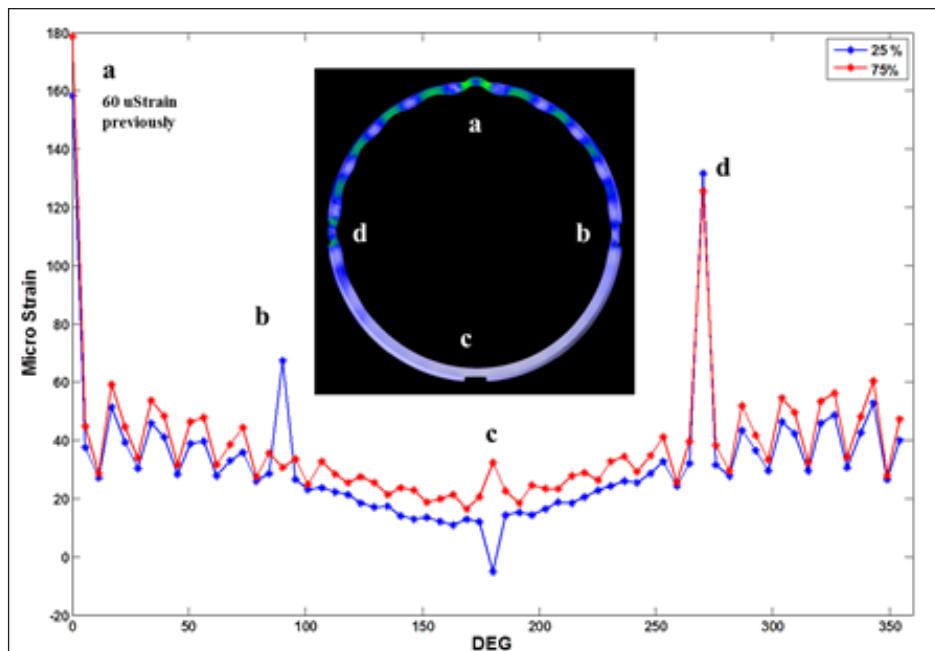


Figure 9 Modified outer raceway hoop strain of HS SH B for one-time step.

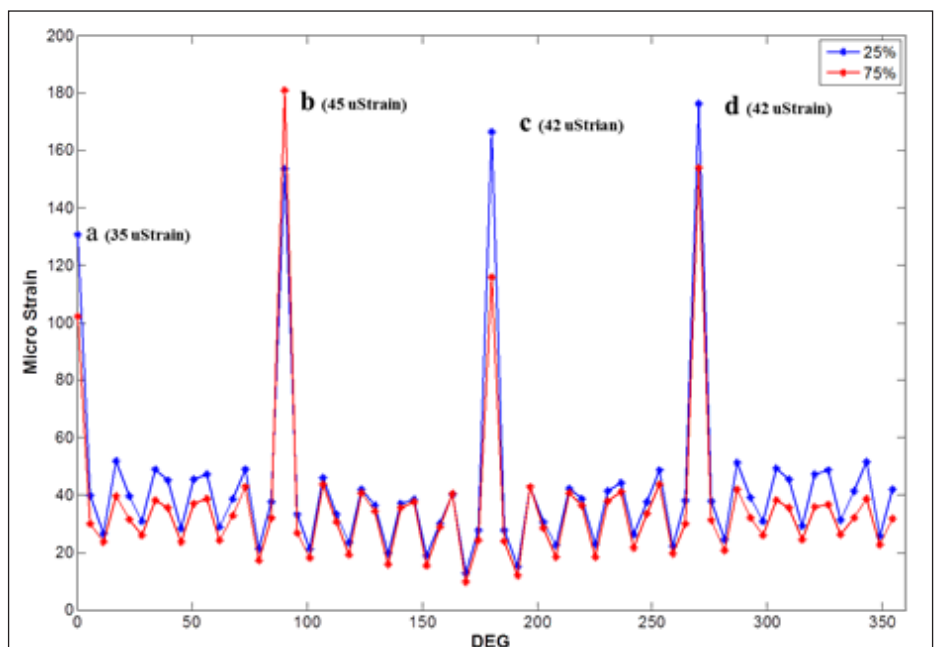


Figure 10 Modified outer raceway hoop strain of HS SH C for one-time step.

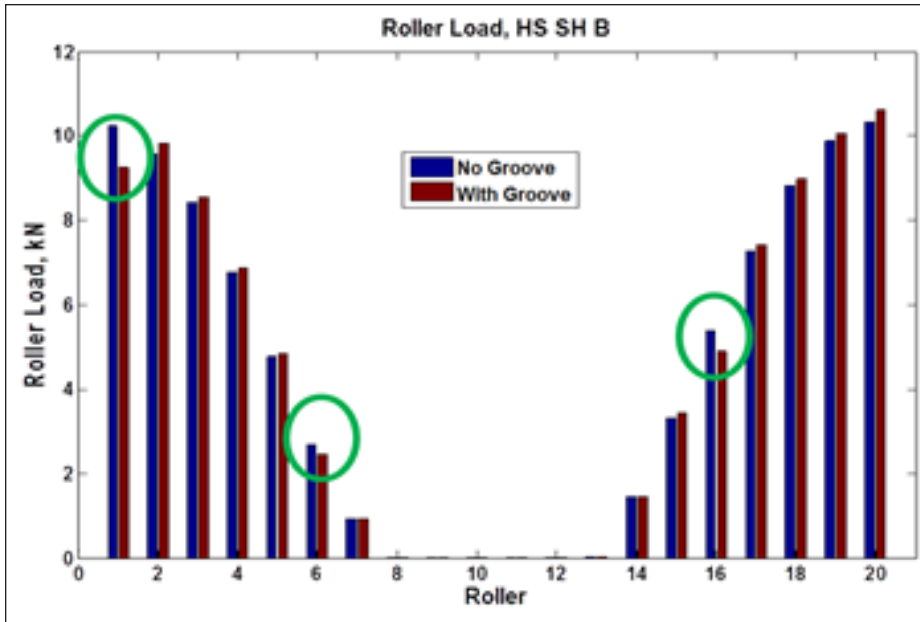


Figure 11 HS SH B roller loads — with and without modified raceway.

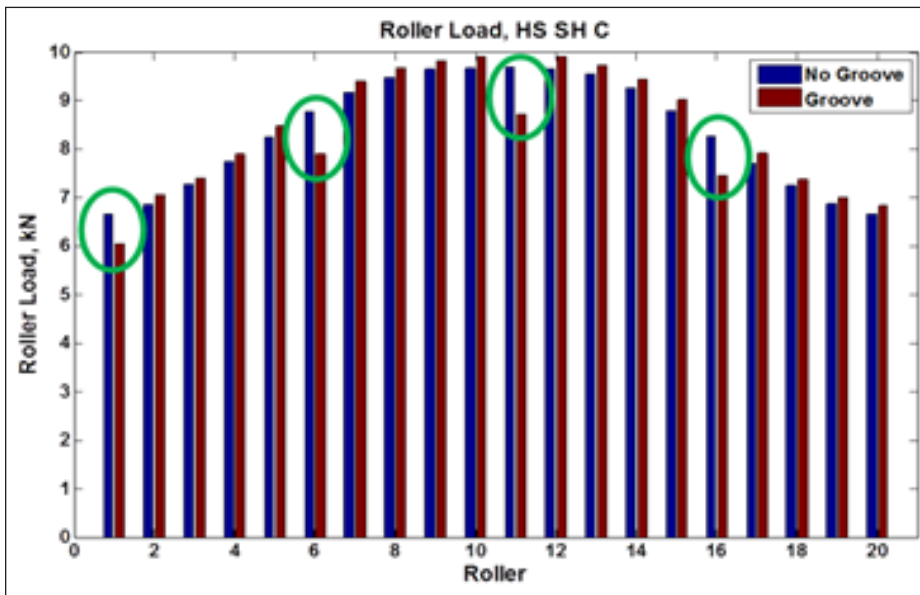


Figure 12 HS SH C roller loads — with and without modified raceway.

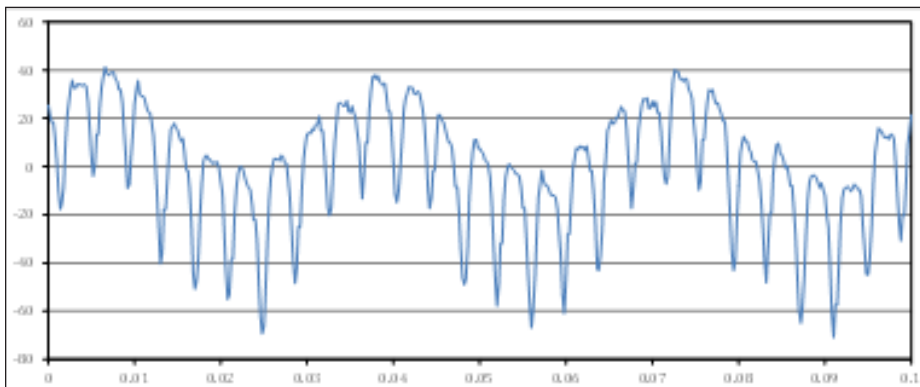


Figure 13 Measured modified outer raceway hoop strain in time for HS SH B, location "A" (0 deg), and axial position 75%.

HS SH C, respectively. Green-circled data points represent the locations of the outer raceway modifications; these figures show the total load carried by individual rollers for both the modified and unmodified outer raceway cases. Here the roller-to-roller load sharing is predicted to be minimally affected by the addition of compliance through the introduction of outer raceway grooves.

Implementation of Bearing Race Groove

The scheme discussed in this Section 2 has been implemented by the NREL Wind Energy group (Ref.6) and successfully tested. Its final implementation has an adjusted groove geometry that was applied to accommodate manufacturing considerations. Also, the bearing preload that was achieved is unknown, but was most certainly considerably lower than that used in the example for this paper. To demonstrate the fidelity of the signals, Figures 13 and 14 show 0-degree slot strains for HS SH B and HS SH C at 75% axial location, respectively.

Strain caused by the direct application of load by a roller on the outer raceway is represented in Table 2 as the average peak-to-peak-measured strain. As seen in Figure 13, there is quite a bit of variability in strain levels for each different roller passing. This variability is quite repeatable, with roughly every ninth roller passing corresponding to one shaft revolution.

It should be noted here that a torque trace taken from the shaft showed a significant once-per-revolution torque variation that seems to correlate well with the strain variations.

Table 2 shows that HS SH B carries a small amount of load in comparison to HS SH C. As noted earlier—and predicted in Section 2—this is due to the fact that the axial gear mesh load is supported by HS SH C, while the preload of HS SH B is reduced by this loading. In fact, for the 75% axial position of bearing HS SH B, it appears that virtually no load is carried by this end of the roller at positions C and D (Table 2). Because the analysis presented in Section 2 was performed assuming preload on this set of bearings, the simulations indicate more load carried by each of the bearings.

Conclusion

Here a full transmission model of a 750kW wind turbine gearbox was modified in order to assess bearing raceway modifications for measurement of strain in order to predict bearing load sharing and load distribution.

It is clearly apparent that the modification of the tapered roller bearing outer raceways — through the introduction of a groove — greatly increased the predicted strain in the raceway.

Simulations predicted that appreciable strain signals could be produced by introducing such grooves, and measurements show that to be true.

Improved strain predictions to be directly compared to the experiments may be attained by using exact groove geometries manufactured, as well as the known, bearing preload levels used in the experiments.

Acknowledgments. *This work was partially funded by a grant (GRT0023734/60030753) from the National Renewable Energy Laboratory (NREL). We would like to thank Jon Keller and Yi Guo of NREL for providing us with the test data, as well as the sponsors of the Gear and Power Transmission Research Laboratory for providing funding for this research. PTE*

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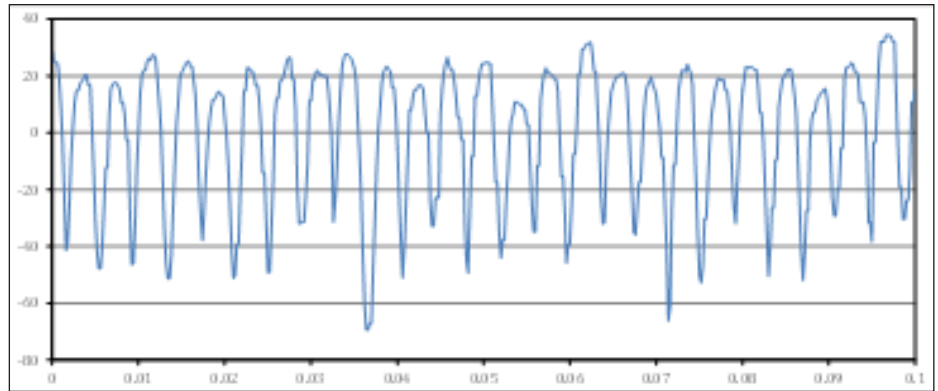


Figure 14 Measured modified outer raceway hoop strain in time for HS SH C, location "A" (0 deg), and axial position 75%.

Location	HS SH B (micro-strain)		HS SH C (micro-strain)	
	With Groove		With Groove	
	25%	75%	25%	75%
A	47	36	74	73
B	11	15	62	43
C	12	1	74	98
D	6	1	74	65

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Jason Austin graduated from the GearLab at Ohio State University in June, 2013, with an M.S in mechanical engineering. While there he authored a doctoral thesis on the FEA of a wind turbine gearbox via collaboration with the National Renewable Energy Laboratory and the Gearbox Reliability Collaborative. Austin is currently employed by DNV GL as a pipeline integrity engineer, tasked with providing technical consultation to the oil and gas industry.



David Talbot is a research scientist — mechanical and aerospace engineering — at The Ohio State University, specializing in gear system efficiency, manufacturing and geometry, and load distribution simulation.



Dr. Sandeep Vijayakar is founder and president of Advanced Numerical Solutions (ANSOL). He received his PhD from The Ohio State University, where he now serves as an adjunct faculty member. His company — ANSOL — specializes in the finite element contact analysis of gears. Vijayakar is credited with authoring the Calyx computer program, designed for the static and dynamic analysis of geared systems.

Dr. Donald Houser is Professor Emeritus of Mechanical Engineering and founder of the Gear Dynamics and Gear Noise Research Laboratory (GearLab) at Ohio State University. Dedicating his efforts and knowledge to gear dynamics research for over 45 years, he has also consulted for numerous companies. Dr. Houser is a past chairman of ASME's Power Transmission & Gearing, and Gear Noise Committees; is an active member of the AGMA Noise Committee; and has contributed gear noise-related chapters to *The Gear Handbook* (D. Townsend, editor) and *Handbook of Noise and Vibration Control* (M. Crocker, editor). Dr. Houser is also a prolific author of technical papers — presented at conferences and other proceedings worldwide — of which many have appeared in this publication.



Global Industrial Outlook: Houston, We Have a Problem

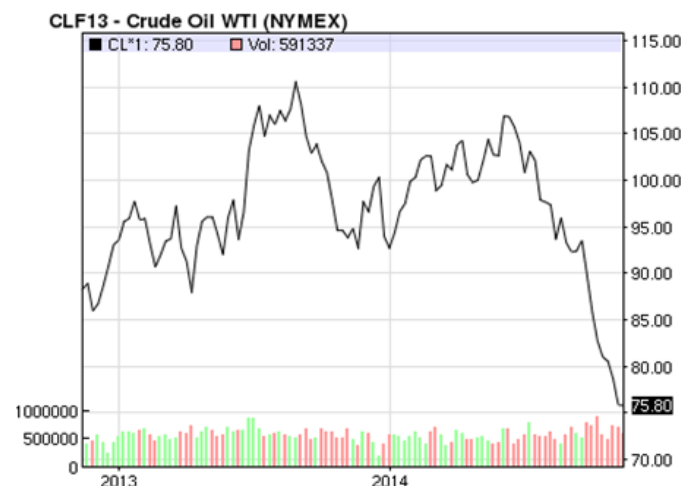
By Brian Langenberg, CFA

With two armed conflicts underway impacting economic performance in Eastern Europe and the Middle East, we continue our investment stance of “Buy on the Sound of Cannons—Selectively”—but readers of *Power Transmission Engineering* should not be sanguine.

Geopolitics is beginning to exert significant pressure on several end markets: I specifically refer to oil price. West Texas Intermediate or WTI has dropped from its \$95-105 trading range in late spring to about \$75—about a (25%) drop despite two ongoing conflicts because of excess supply.

In our view this is not an accident. We call it “the Putin’s Zipper Trade” because Vladimir has pretenses of greater Russian (Soviet?) glory, and at \$110-oil, his budget balances and he struts around just the way the above “label” implies. In my view the Saudis are opting to attack him the best way possible—by cutting his government’s revenue by over 20%. About 85% of Russian government revenues are driven by natural resources. Lower commodity price correlates to a stronger dollar and is very, very bad for his government and position. The counterargument is that Saudi Arabia is seeking to defend market share in the face of rising—but higher-cost—U.S. production, where higher-cost basins become less attractive, particularly oil sands, when oil drops below \$80. We disagree.

WEST TEXAS INTERMEDIATE – LAST 2 YEARS
\$ Per barrel



We will return shortly to how this hurts you.

WHAT MATTERS:

U.S. best growth spot. Non-residential construction, consumer durables (auto, housing) and gradually improving employment will offset weaker commodity-based demand.

Europe. Marginal hit (Nordics, resource-related parts of German economy) by conflict in Eastern Europe. Rest of

continent still struggling with weak banking system, but that is nothing new.

Middle East. Buying weapons is in vogue (UTX), old construction projects (Otis) are getting finished, but new ones? Oil & Gas activity should remain strong even with production cuts because mature fields require more capital and the region is seeking to capture more of the value stream.

Brazil. Continues to get whacked. Exports are down (40%) the last two years already (weak China) on lower iron ore prices and volume. Petrobras story (oil) being hurt by lower oil price and emerging criminal charges/graft between Petrobras and people close to President Dilma Rouseff. If that isn’t enough pain for you, weakening Japanese Yen will further hurt construction equipment pricing in the region.

War matters, Ebola does not. Warfare in Eastern Europe and Iraq caused further order and revenue push-outs in 3Q (Flowserve, others). Improving defense after-market revenue likely continues.

Oil & Gas: U.S. midstream and downstream are bullet-proof but *upstream spending will get tweaked downward*. Petrobras scandal may create further incremental uncertainty with your OE customers but the offset is Mexico is finally serious about investing in offshore exploration and production. Netting it all out though—oil price down (25%) = (25%) lower industry revenue = bad for you. Most of your customer base is claiming it will have little impact. They are wrong.

The challenge isn’t 2014—its 2015! Upstream represents, by far, the biggest chunk of capital spending and while at least half will be aftermarket/production driven, a significant piece includes incremental exploration and, with oil below \$80, marginal production. When wells lose money they get capped.

Potential second derivative weakness could occur in a broad range of end markets including construction equipment, land based power generation (small p not BIG P), and ancillary products and services. To be clear, we do not anticipate a steep decline, but would be amazed if energy sector capital spending does not decline in 2015. Other end markets....

Mining: Still awful—but hard to get worse; aftermarket is now stabilized.

Power Generation: U.S. power generation remains weak, owing to efficiency gains throughout the economy and lack of regulatory support for new (Wind) construction. Recent election results should have marginal impact on ability of administration to pressure coal sector (generation and the commodity itself), but there are bigger fights looming. Globally the industry looks good—including coal and gas.

Transportation Infrastructure: More pothole filling; no major infrastructure upgrade anytime soon. Immigration

COMPANY	TICKER	CAPEX (M)		% CHG
		2013 A	2014 E	
EQUIPMENT & SERVICES				
Schlumberger	SLB	3,943	3,800	(4%)
Halliburton	HAL	2,934	3,000	2%
Baker Hughes	BHI	2,100	2,000	(5%)
National Oilwell Varco, Inc.	NOV	669	600	(10%)
Weatherford Int'l Ltd.	WFT	1,575	1,275	(19%)
Transocean	RIG	2,238	2,600	16%
Seadrill	SDRL	4,699	4,500	(4%)
		18,158	17,775	(2%)

fight poisons well — not to mention ObamaCare — for everything that was pragmatically possible, including the corporate tax reform that could have brought funds back to reinvest.

Machinery: Capital is scared, translating into project push outs at E&C firms even as current production is up year over year. Agriculture is rolling over in the U.S. and Latin America. The Russia growth story is dead in the near term. U.S. truck build rolls along on replacement demand. Construction equipment orders have weakened, though utilization remains high in the U.S. while Europe is flattish and China declines. Non-residential activity and utilization supports a constructive view.

Consumer (auto, appliances): Old cars = continued U.S. strength. Auto-related end-markets will remain solid. U.S. residential recovery is on-track and will further support construction equipment demand.

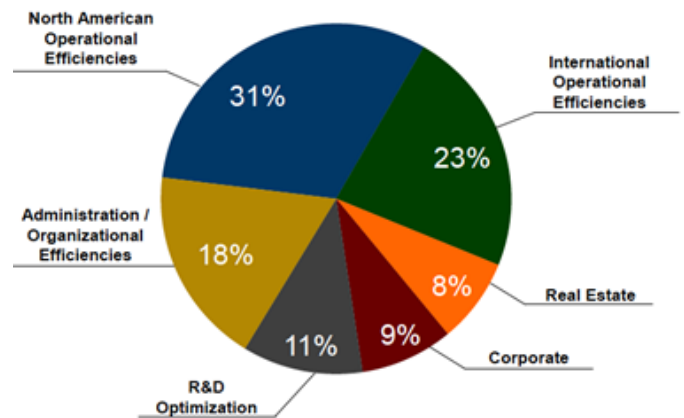
Aerospace/Defense: Strong commercial build rates — coupled with two shooting wars and depleted U.S. inventories — argue for a continued recovery in aftermarket activity. Long-term we expect a U.S. defense recapitalization, but not before 2017 authorization, given the current Administration. We do think it happens no matter which party captures the White House in 2016, because anybody except the total infantile have woken up to realize you need to have both a) a foreign policy, and b) a big stick to back it up.

FOCUS COMPANIES: HALLIBURTON (HAL), BAKER HUGHES (BHI)

Precipitous drops in oil price often lead to M&A activity in an effort to drive out costs and protect or increase margin. To that end Halliburton recently announced an offer for industry rival Baker Hughes that would combine the #2 and #3 U.S.-based players. Diving into the capital spending data earlier we note that combined expected capex is about \$5 billion in 2014.

The merger plan calls for \$2 billion in annual cost synergies. Experience tells us that large deals hurt capital spending in the near-term (uncertainty, distraction of people worrying about their jobs), and post deal (paying for the merger through greater efficiencies and elimination of overlapping functions, people and assets).

Nearly \$2 billion of annual cost synergies



Using their charts, about \$600M (31%) relates to U.S. operational efficiencies, but also \$220 million of R&D optimization.

Baker Hughes related projects carry higher risk. In reality there are no mergers — only acquisitions. Post-deal BHI shareholders will own 36% of the company. If two projects are marginal, the Halliburton project is more likely to win. You will want to think about this down to the **Basin** level.

Given both lower oil price and this merger, this is a good time to really focus on which Basins, OEMs and equipment service organizations your revenue stream is tied to in the Energy sector. **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.



Maxon Motor

HELPS POWER ROSETTA MISSION

On Nov. 12, the European Space Agency (ESA) successfully landed a small laboratory on Comet 67P/Churyumov-Gerasimenko (Chury).

The lander featured ten instruments which may provide important clues to the origin of life. Two DC motors made by Maxon Motor were on board the mission.

For the first time in the history of space exploration, scientists have access to data from a comet's surface. The Philae lander has a mass of 100 kilograms and features ten instruments. Maxon Motor, a Swiss-based drive specialist, provided two DC motors with a diameter of 13 millimeters each. These motors were used to lower the APXS instrument to the ground.



The APXS is an alpha x-ray spectrometer that is used to record the chemical composition of Chury and provide information on the presence of key elements such as carbon and oxygen. The instrument was developed at the Johannes Gutenberg University Mainz.

The individual instruments will now be activated automatically in sequence. The drives were then evaluated to determine if they survived the 10-year journey unscathed.

Oerlikon Drive Systems

PRESENTS 'SHIFTING SOLUTIONS' AT ITALIAN CONFERENCE

"Shifting Solutions" and the new fast track prototyping and small batch manufacturing facility from Oerlikon Drive Systems were presented at the EIMA International Agricultural and Garden Machinery Exhibition, in Bologna, Italy, from Nov. 12-16.

Oerlikon Drive Systems showed synchronizers and clutch packs that help to deliver increased efficiency, improved vehicle performance and reduced cost. A special area was dedicated to the new fast track prototyping and small batch manufacturing facility for cylindrical gears, synchronizers and drive subassemblies.

Oerlikon Graziano, a brand of Oerlikon Drive Systems Segment, produces around a million syn-



chronizers per year for agricultural tractors, construction equipment, passenger cars and trucks. The company exhibited products from a range that runs from 62 to 170 millimeters in diameter and includes single, double and triple cone solutions, and its range of carbon synchronizers that help to increase the reliability and longevity of construction and agricultural transmissions.

David Brown Gear Systems

OPENS FACILITY IN PHILIPPINES

David Brown Gear Systems, a supplier of industrial gearboxes and aftermarket services for applications in the world's core industrial sectors, announced the opening of its new industrial gearbox service and repair facility in Subic Bay Freeport Zone, Philippines.

David Brown Gear Systems (Philippines), Inc. is located in the heart of the region's growing industrial sectors and is fully equipped with state-of-the-art gearbox strip, condition assessment, repair, rebuild, assembly and test facilities.

Utilizing more than 150 years of gear engineering and service experience, David Brown's new service center will repair and upgrade gearboxes in industrial applications including mines, power stations, cement and sugar processing plants as well as oil and gas facilities and marine vessels.

"David Brown works in industries where maximum process availability is critical and we are proud to be the only industrial gearbox OEM operating a dedicated service center in the Philippines," said Scott Gilmour, general manager of David Brown Asia. "Our new service center in Subic Bay brings us even closer to our valued customers and is a major milestone in the company's plan to deliver premium gear engineering expertise throughout Asia."

British Ambassador to the Philippines, Asif Ahmad, welcomed David Brown's investment in Subic Bay.

"It is good to see another world-leading British company choosing the Philippines for its operations in this fast growing region," said Ahmad. "Filipino businesses in industries such as mining, energy and construction will benefit from David Brown's experience and expertise. With more than 150 years in the business, David Brown offers top-notch specialist transmission engineering and repair services and adheres to the highest global quality assurance standards. I am also impressed by David Brown's commitment to transfer technology for the Philippines; particularly to new employees the company will be recruiting."

Oerlikon Graziano

SLOTTED AS 'SUPPLIER OF THE YEAR' BY CLUB CAR

Oerlikon Graziano was recently awarded "Supplier of the Year" by Club Car, a brand of Ingersoll Rand. The award was announced during a ceremony that took place in Augusta, Georgia during Ingersoll Rand's annual Supplier Day.



"This is the second consecutive year that we received an award from Club Car," said Paolo Mantelli, Oerlikon Graziano's Head of Performance Automotive.

The relationship between Club Car and Oerlikon Graziano started in 1994 with the development of electric axles.

In 2013, Oerlikon Graziano was awarded in the program "Supply Chain Partners Performance Excellence," in recognition of contributions in several Value Management Program activities during 2012. This year, Oerlikon Graziano was chosen as "Supplier Executive of the year," with Eric Powell, director of strategic sourcing at Club Car and Sheila Tierney, vice president of procurement at Ingersoll Rand, handing over the plaque directly to representatives of Oerlikon Drive Systems.

PTDA

HOLDS 2014 INDUSTRY SUMMIT, ELECTS AJAY BAJAJ PRESIDENT FOR 2015

Nearly 600 power transmission and motion control industry representatives from over 250 Power Transmission Distributors Association member companies attended the PTDA 2014 Industry Summit. Along with an additional 230 spouses, companions and guests, the top executives convened from Oct. 22-25 at the Hilton Orlando Bonnet Creek in Orlando, FL.

At the summit, the PTDA elected its 2015 Board of Directors and Manufacturer Council. **Ajay Bajaj**, president of Rotator Products Limited in Woodbridge, Ontario, Canada will become the PTDA's president in 2015. **Cliff Bannon**, Eastern sales manager for Isostatic Industries Inc., in Chicago, IL will assume the duties of the PTDA Manufacturer Council chair in 2015, succeeding Brian Kolman, president of Brewer Machine & Gear Co. in St. Louis, Mo.



NES

RECEIVES WESTERN NEW YORK MANUFACTURING AWARD

Napoleon Engineering Services (NES) was honored by Business First of Buffalo with a Western New York Manufacturing Award for Operational Excellence at a ceremony held on May 13. NES was one of 21 manufacturers honored.

Founded in 1997 by lifelong Western New York resident Chris Napoleon, the privately held NES is an independent, single-point resource for bearing inspection, bearing testing and custom bearing manufacturing. With core competencies in high-precision custom ball and roller bearings using super elastic Ni-Ti alloys, wear-resistant, high-life materials and coatings, and advanced design technologies, the company has grown into a key resource for bearing manufacturers, distributors and OEMs across a diverse array of markets.

"It is beyond humbling to see the growth of NES over the years, since its beginnings in a spare bedroom and a half garage bay of my home in 1997," Napoleon said. "We would not be where we are today without the support of our loyal customers, employees and the Western New York community. This is our home. And we look forward to continuing to build and strengthen our presence here in the years to come."



www.nesbearings.com

Pat Wheeler

RECEIVES INAUGURAL WENDY B. MCDONALD AWARD

To honor the memory of Wendy B. McDonald, one of the power transmission/motion control industry's pioneers, the PTDA Foundation has established the Wendy B. McDonald Award.

The award acknowledges a woman who established herself as a critical contributor to her company's success and affected positive change within the power transmission/motion control industry. The first recipient of the Wendy B. McDonald Award was Pat Wheeler of Motion Industries (Canada).

Wheeler joined BC Bearing (now Motion Industries Canada) in 1980 as a shipper/receiver. She moved into inside sales



and then to office manager in 1990. In February 2003, she was appointed branch manager—the only female branch manager in the company at that time. In 2008, she was recognized by McDonald at the annual sales meetings for almost single-handedly managing her territory.

In her acceptance speech during the PTDA Industry Summit in Orlando, FL, Wheeler credited McDonald with being her idol and mentor because she paved the way for her to feel confident enough to accomplish all that she has in her 34 year career.

McDonald's daughter, Penny Omnes, and son, Scott MacPherson, were on hand to present Wheeler with the award.

QA1

HONORED WITH TWO SEMA GLOBAL MEDIA AWARDS

QA1, a manufacturer of high-performance suspension components, has been honored with two Specialty Equipment Market Association (SEMA) Global Media Awards for its carbon fiber driveshafts and Mopar Rear Suspension Conversion System.

SEMA introduced the Global Media Award program in 2004 to highlight the wide appeal of specialty-equipment products to enthusiasts on every continent. Products are reviewed by a panel of 35 top automotive journalists from more than 20 countries around the world and recipients were recognized in an evening program during the 2014 SEMA Show in Las Vegas, Nevada.



QA1's carbon fiber driveshafts, which are currently offered for street performance vehicles as well as dirt late models, are a major new offering from QA1's Advanced Materials Division. These driveshafts are lighter, stiffer, stronger and safer than aluminum and steel driveshafts and are filament wound in-house using 3MTM Matrix Resin that is exclusive to QA1 performance driveshafts.

"QA1 is redefining industry standards by performing the filament winding in-house, which allows us to make carbon fiber driveshafts specific to each application," said Travis Gorsuch, QA1's Director of Advanced Materials. "We're very excited for them to be recognized as a high-quality product that is relevant in multiple markets."

The second Global Media Award for QA1 was for the Mopar Rear Suspension Conversion System, a revolutionary bolt-in conversion from leaf springs to coil-overs for Mopar A-Body vehicles. The system utilizes a 6-link suspension that builds upon the traditional 4-link system and replicates its geometry while still mounting to the existing chassis mount locations.

"It's an honor to be recognized for this rear system," said Karl Hacken, vice president of engineering at QA1. "We've put a lot of time into development so that it would be a practical bolt-in system, allowing it to be available to a wider audience that may not be comfortable cutting or welding on their vehicles. The awards are a testament to QA1's emphasis on creating and producing performance-based products that have wide appeal."

Timken

ACQUIRES ASSETS OF REVOLVO LTD.

The Timken Company announced it has reached agreement with Eriks NV to acquire the assets of Revolvo Ltd., a specialty bearing company based in Dudley, U.K.

Revolvo makes and markets ball and roller bearings for industrial applications in process and heavy industries. The company's split roller bearing housed units are used by mining, power generation, food and beverage, pulp and paper, metals, cement, marine and waste-water end users. In 2013, Revolvo posted sales of approximately \$8.3 million.

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“We’re pleased to have Revolve become part of Timken,” said Hans Landin, product line executive, power transmission and engineering systems for Timken. “The Revolve team brings a wealth of experience and well-established customer relationships, and their split roller bearing housed unit line will strengthen the Timken portfolio of bearing and power transmission products.

“These split bearing housed units bring additional breadth to our industrial product solutions while addressing specific customer needs,” Landin added. “Revolve’s expertise and quality product line, coupled with Timken’s global reach and market access, will allow us to leverage resources to improve competitiveness and accelerate the growth of housed unit products, particularly in Europe and Asia.”



Revolve’s line of split-to-the-shaft roller bearing housed units enables the bearing to be fitted without requiring access to the shaft ends. Instead, it can be built around the shaft, which reduces downtime because no other drive components must be removed during installation or for maintenance. The product design accommodates misalignment, helps extend up-time, reduces maintenance costs and increases plant efficiency for end users.

The acquisition is subject to certain customary closing conditions, including employee consultation. Terms were not disclosed.

Kevin McCloskey

RECEIVES WARREN PIKE LIFETIME ACHIEVEMENT AWARD

The Power Transmission Distributors Association (PTDA) has named Kevin McCloskey, Category Manager at Kaman Industrial Technologies Corporation, the 24th recipient of its Warren Pike Award for lifetime achievement in the power transmission/motion control (PT/MC) industry.

McCloskey received the award at the association’s Industry Summit in Orlando, FL. The award was established in 1984 to honor individuals who have demonstrated outstanding, continuous, long-term support of PTDA and the PT/MC industry.

McCloskey has served on numerous PTDA committees and task forces and is currently a member of the Research & Innovation Committee. McCloskey also served on the Board of Directors from 1996-2002 and as the board president in 2001.

“Kevin has been a great partner through the years for Dodge,” said Jeff Moore, vice president of marketing and mechanical power transmission for Baldor Electric Company. “He collaborates well with our whole organization and works to achieve not only the best solution for Kaman, but also for the manufacturer as well. The thing I appreciate about Kevin is his transparency. If he doesn’t like something he will tell you. It’s easy to have a trusting relationship when you can have frank conversations with a channel partner and Kevin has always been one of a handful of people who will roll up his sleeves and work to achieve a mutually beneficial result.”

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Energy Efficiency, Configurable Solutions Highlight Pack Expo

Randy Stott, Managing Editor

A wide variety of companies displayed mechanical power transmission and motion control technologies at Pack Expo, held in November in Chicago. The event, which is the largest packaging and processing trade show in North America, attracted more than 48,000 attendees, according to show owner and producer PMMI. The four-day event included 2,352 exhibiting companies, an increase of more than 19 percent from the previous show in 2012.

“Pack Expo International 2014 was definitely a success,” said Jim Pittas, senior vice president of PMMI. “Exhibitors sold machines right off the show floor and collected high quality leads from the steady flow of attendees.”

Mechanical components and motion control were definitely a big part of that mix. Following are some of the highlights from power transmission and motion control exhibitors.

Bosch Rexroth

INCREASES THROUGHPUT WITH ADAPTIVE SYSTEMS

Adaptive Systems technology minimizes unwanted movements like oscillations and vibrations, increasing process throughput by up to 50 percent.

Bosch Rexroth offers Adaptive Systems motion control technology directly at the drive level to reduce unwanted movements in industrial machinery. The technology alleviates movements including oscillations, vibrations, sloshing and sway.

Vibrations and oscillations are simple, repetitive motions, but they're governed by complex factors of wave physics. The complex nature of waves often makes traditional vibration control methods ineffective. Because implementing vibration damping and avoidance techniques requires a control system that can quickly adapt to varying process, material and application changes, Rexroth offers Adaptive System technology directly at the drive level, rather than at the higher control level.

Rexroth Adaptive System motion control can handle high-speed inputs and deterministic events with closed-loop response times. Current closure can be accomplished in 62.5 microseconds, speed loop closure in 125 microseconds, and position closure in 250 microseconds.



Rexroth Adaptive Systems technology is implemented from the company's IndraMotion MLD drive-based motion logic controller. Rexroth IndraDrive intelligent servo drives with sensors monitor the status of axis mechanics. Additionally, Rexroth Productivity Agent software uses the drive as an intelligent sensor to monitor, analyze and reduce vibrations in real time.

For more information:

Bosch Rexroth Corporation
www.boschrexrothusa.com

Emerson Power Transmission

INTRODUCES UPGRADED CONVEYOR CHAIN

Emerson's Power Transmission Solutions business introduced its new System Plast NG Evo conveyor chain, featuring a proprietary, low-friction FDA-approved material for dry conveying in food packaging applications.

“NG Evo builds on the success of original NG chain, which is widely used for dry conveying in the bottling industry,” said Jeff Himes, System Plast Senior Product Manager. “The new chain provides a higher breaking load, greater elasticity, lower coefficient of friction and much greater abrasion

resistance than the original. NG *Evo* significantly expands options for dry conveying to meet sustainability and water conservation goals, which will grow in importance for food packaging as the U.S. already grapples with regional water shortages.

“All of the physical properties of the original NG chain have been enhanced to meet specific challenges in food processing applications,” Himes added. “In addition, beverage handling conveyors are typically lubricated with soap and water

Brother Gearmotors

EXPANDS RANGE FOR NORTH AMERICAN CUSTOMERS

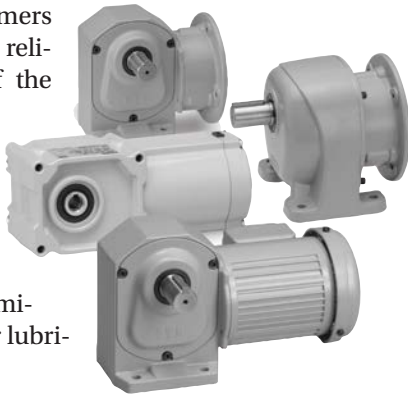
Brother Gearmotors, a manufacturer of sub-fractional AC gearmotors and reducers for the packaging, food & beverage and unit handling industries showcased several new benefits for customers in North America.

Gearmotors from Brother are compact in size, energy efficient and sealed for life, says Matthew G. Roberson, senior director for OEM and gearmotor business. Each model comes with a long-lasting protective paint coating whose electrostatic application assures a consistently tough, chemically-resistant coating designed to withstand especially harsh production environments.

According to Roberson, Brother customers who have installed Brother gearmotors often become customers for life. Durability and reliability are hallmarks of the Brother product line, he says. All gearmotors carry a high-grade grease standard, which means they are lubricated for the life of the product, helping to eliminate costly downtime for lubrication changes.

At its booth, Brother announced new bore sizes that open up a broader potential customer base for the company's gearmotors.

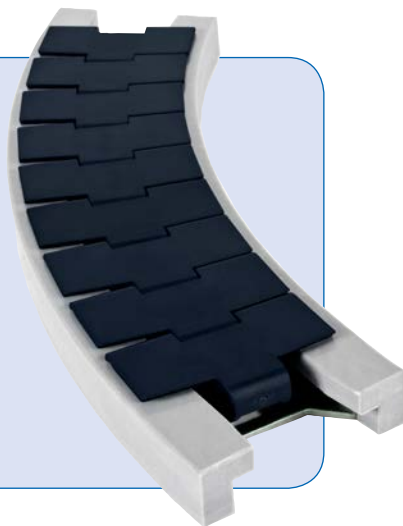
In addition, this summer Brother Gearmotors moved into a new world-class manufacturing facility, based in Bartlett, Tennessee. The modernized assembling facility - both ISO 9001:2008 and ISO 14001:2001 certified - allows Brother Gearmotors to shrink lead times for customer orders to an estimated three days. On-site technology also makes available a broader product mix to North American customers, including 16 different gear ratios and six voltage options. The facility will be a North American complement to the primary gearmotor factory, which has produced more than 10 million units over its 40-year history.



that uses two to three times more water than goes into the finished product.”

For more information:

Emerson Power Transmission Solutions
Phone: (859) 727-5263
jeff.himes@emerson.com
www.emerson-ept.com



Igus Energy Chains

SIGNIFICANTLY REDUCE DRIVE POWER

Recent tests and sample calculations performed at igus' test laboratory prove energy consumption can be drastically reduced by using the right cable

carrier material with a sophisticated design, especially in long-distance, high-load applications. If Rol E-Chain—a specially designed cable carrier with

built-in wheels that roll instead of glides to facilitate travel over long distances—is used, the friction factor is drastically reduced from 0.3 to less than 0.1. This correlates to a 37 percent reduction in drive power with Rol E-Chain when compared to a traditional gliding application, as well as a significant decrease in overall costs.

Metal cable carriers are being replaced more and more by plastic Energy Chains because they are lightweight, require no lubrication and can withstand even the toughest applications.

For more information:

Igus Inc.
PO Box 14349, East Providence, RI 02914
Phone: (800) 521-2747
Fax: (401) 438-2200
sales@igus.com
www.igus.com



Ringfeder Power Transmission

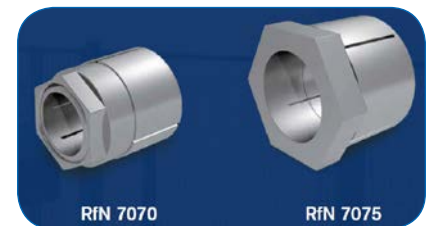
ANNOUNCES NEW LOCKING ASSEMBLIES

New locking assemblies from Ringfeder include a central lock nut for safe and backlash-free clamping in a matter of seconds. Labeled the RfN 7070, RfN 7075, RfN 7085, and RfN 7090 series, these locking assemblies are designed for easy mounting, compact dimensions and a safe connection between the shaft and hub.

Shaft-hub connections in modern transmission systems require smaller, faster and more powerful technology. Examples include applications with backlash-free synchronous transmissions powered by compact servo or multiphase motors, where positioning is critical. Conventional joints with keyways, grub screws and simple bushings do not guarantee zero backlash in such precision applications.

For more information:

Ringfeder Power Transmission
Phone: (201) 666-3320
sales.usa@ringfeder.com
www.ringfeder.com



Motors and Motion Meet in St. Louis

SMMA 2014 Fall Technical Conference Held

Jack McGuinn, Senior Editor

The motors might be small, but the big-brain technology driving these electrical wonders was on full display at the 2014 Small Motor & Motion Association Fall Technical Conference, convened November 4-6 in St. Louis, MO.

SMMA, the manufacturing trade association (120 members strong) that tends to the best interests of the electric motor and motion control industries — including manufacturers, suppliers, users, consultants and universities — played gracious host to a wide array of presenters from an equally diverse range of sources — from academia to the federal government. Like gears, motors are most everywhere, as evidenced by SMMA's membership (consumer-, public interest-, national defense- and commercial-oriented) demographic which includes: appliance; transportation; medical equipment; office automation and computers; aerospace; and industrial automation. The association's mission: To "serve as the principal voice of the electric motors and drives industry" and to provide a forum to "develop, collect and disseminate technical and management knowledge."

"Collect" and "disseminate" indeed; check out this sampling of Abstracts of Conference presentations. They reflect the findings of many hours, days, months — maybe years in some cases — of pre-competitive R&D conducted in conjunction with — and on behalf of — SMMA's members. Even a cursory glance confirms that many of these presentations — some works-in-progress — conjure and explicate new motor-and-motion technologies attending numerous applications/industries of intrinsic value and importance of some kind to various sectors of the U.S. economy and security. Such as:

The Use of Thin Lamination Materials in Motors. Kamran Ramezani, President, Ramezani and Associates.

Fluorinated Greases for Extended Bearing Life in Motors. Carl Walther, Senior Technical Service Engineer, Dupont.

Designing Small Brushless Servo Motors. Daniel B. Jones, President, Incremotion Associates Inc.

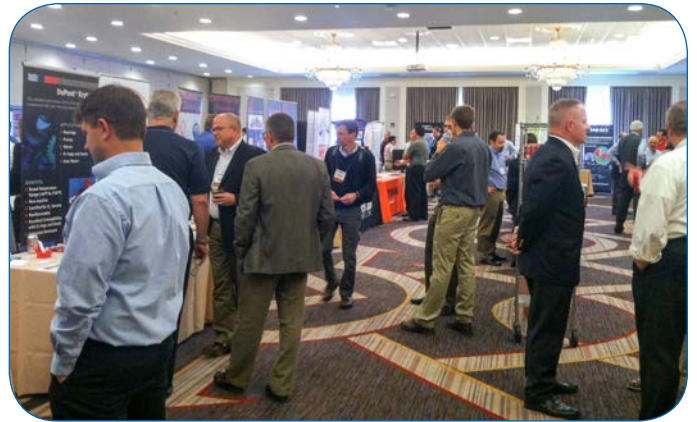
Permanent Magnet Motors for Industrial Applications. Emmanuel B. Agamloh, PhD, Senior Motors and Drives Consultant, Advanced Energy.

Challenges in the Design of Very High RPM Motors. George Holling, Technical Director, Rocky Mountain Technologies, Inc.

Mosolver: Robust Feedback for Harsh Environments. Don Labriola, PE, President, QuickSilver Controls Inc.

Smaller - Faster - Hotter: Market Direction and Material Advancements. Aaron Williams, Project Manager-Machine Applications, Arnold Magnetic Technologies.

Magnetic-Mechanical Co-Simulation for Electric Machines. Adrian Perregaux, Consulting Representative, Infolytica.



EMERF PCEMRC Update: Design of Ferrite Assisted Synchronous Motor (Fa-SrnRM) with Aluminum Conductors in Stator. Research project of the EMERF Pre-Competitive Electric Motor Research Consortium (PCEMRC) with Texas A&M University John Calico, Senior Research Engineer, Moog Components Group, and EMERF President.

Control Aspects of Various Electric Motors. Dal Y. Ohm, PhD, President, Drivetech Inc.

Effects of Magnetic Laminate Processing on Core Losses and Permeability. Aleta Wilder, PhD, Wilder Innovations LLC and The University of Texas; and Tapan Shah, Tanjore Jayaraman and Stephen Marr, Carpenter Technology Corp., Specialty Alloys Operations.

Meanwhile, as all of this was going on, a handful of short-but-informative motor courses was being presented on-site by industry luminaries. They included:

Evaluating Motor Power Efficiency in Small and Large Electric Motors. Instructor: Daniel B. Jones, President, Incremotion Associates Inc., and winner of the 2014 EMERF Award for "Outstanding Contributions (54 years) to the Electric Machines Industry."

Fundamentals of Brushless DC Motor Design. Instructor: William H. Yeadon, PE, president of Yeadon Energy Systems Inc. He is the author of many motor-related short courses and editor of the *Handbook of Small Electric Motors*.

Fundamentals of Materials for Electric Motors. Instructor: Aleta T. Wilders. Wilder has over 30 years of experience in process development and performance improvement based on materials science & engineering.

For more information:

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January 5-9 – SciTech 2015 Kissimmee, FL. SciTech 2015 will draw more than 3,000 participants from 40 countries and feature more than 2,500 technical papers, including the best papers from students around the world. Bringing together 11 individual technical events at a single location, this forum is the place to engage with colleagues within each discipline and to interact with experts in those fields. Discuss the science, technologies, policies and regulations that are shaping the future of aerospace. Walk away with innovative solutions that will create new opportunities and overcome challenges. For more information, visit www.aiaa-scitech.org.

January 26-28 – 2015 AHR Expo McCormick Place, Chicago, IL. The show brings together over 2,000 exhibiting companies and 40,000 visitors, representing the entire spectrum of the industry, HVACR manufacturers, engineers, contractors, OEMs, facility managers and other professionals. In addition, attendees will find over 100 educational seminars, workshops (presented by ASHRAE and others) and new product presentations. Those looking to keep up with the latest technology and trends, get face to face with the experts, and stay connected will enjoy this event. For more information, visit www.ahrexpo.com.

February 4-6 – SEMICON Korea 2015 COEX, Seoul, Korea. SEMICON Korea 2015 is the leading semiconductor technology event to explore the latest market trends and future developments for technology, featuring extensive technical forums, business programs and standards programs. For more information, visit www.semiconkorea.org.

February 10-12 – MD&M West Conference Anaheim Convention Center, Anaheim, CA. Delve into the latest challenges and opportunities that are impacting medical device design and manufacturing with the 2015 MD&M West Conference. Attendees can hear from the industry's brightest and gain valuable insights that will help them overcome the most crucial challenges from concept to market. Build knowledge and networks at this annual industry gathering. For more information, visit <http://mdmwest.mddionline.com>.

February 15-18 - 2015 SME/CMA Annual Conference Colorado Convention Center, Denver, CO. Taken as a whole the international mining industry is softening as the global economy expands at a more moderate pace and mine capacity may have outstripped demand in the short term. However, in the individual mining sectors of coal, metal, industrial minerals and aggregates, opportunities await for smarter companies that are meeting their own domestic and international challenges by opening new markets, creating new products, cutting costs and improving efficiencies. This multi-industry sector panel will address both the opportunities and challenges that lie ahead for each mining sector. Badges are required for admittance. All food and beverage functions held each day in the Expo Hall will be located in the SME Conference Café, lounge and two restaurants. For more information, visit www.smeannualconference.com.

February 15-18 - Middle East Turbomachinery Symposium Sheraton Doha Resort & Conference Hotel, Doha, Qatar. The 3rd Middle East Turbomachinery Symposium, held 17-20 March 2013 in Doha, is the premier turbomachinery event in the Middle East, combining a world-class technical conference and international exhibition. Technical sessions offer delegates continuing education credits while the exhibit hall featured over 65 industry-leading companies. For more information, visit <http://mets.tamu.edu>.

March 4-7 – The MFG Meeting Orlando World Center Marriott, Orlando, FL. The MFG Meeting brings together the entire manufacturing industry for a unique conference experience that provides unparalleled educational and networking opportunities. Engage with the industry's thought leaders and discuss business solutions with peers – all in one place. One of the highlights of this year's conference will be a training session with Michael Hoffman, President of Igniting Performance, a company that specializes in sales, leadership and building customer loyalty. His innovative program, "Secrets of the 1%ers," taps into the methods and the motivations of the best of the best – showing how they became influential – and how to replicate their success. For more information, visit www.themfgmeeting.com.

March 9-11 – SIAF Guangzhou 2015 China Import and Export Fair Complex, Guangzhou, China. The 2015 edition of SPS – Industrial Automation Fair Guangzhou is gearing up to be a must-attend industrial automation event in China. The event will cover over 40,000 square miles of exhibition space across four halls. Recognizing the importance and future growth prospects of the South China market, exhibitors are ready to present their latest collection of innovative solutions and products to international and domestic visitors. To date, over 300 exhibitors are confirmed to introduce the latest industrial automation technologies, including control systems, sensor technologies, software development, drive systems, components and much more for manufacturing-based industries. For more information, visit www.spsinchina.com.

March 23-26 – Automate 2015 McCormick Place North, Chicago, IL. Automate is the largest solutions-based showcase of automation technologies in North America. Automate demonstrates the full spectrum of automation technologies and solutions for a broad array of industries. Companies that provide integration of automation, robotics and machine vision will show actual demonstrations of systems that will allow attendees to see live demos solving challenges they face in their industry, and also to learn from solutions used in other industries that may be beneficial to them. The rest of the show features the latest automation, robotic, vision and motion control technologies and systems on display from leading global suppliers. A comprehensive educational conference accompanies the Automate show. Keynote speakers include Steve Wozniak, cofounder of Apple. For more information, visit www.automateshow.com.

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The Model T Ford: One Mean Machine

Some of us are old enough to have had say, great-grand-parents, for example, who when the occasion arose would casually refer to cars as “machines.” It sounded funny and arcane, and we would snicker under our breath. But of course the laugh was on us; back in the day—1910s through the 1930s—automobiles were commonly referred to as machines.

And the “machine” that ruled the streets in those days—and claimed what then was only the beginning of the greatest “middle class” demographic in the history of the world—was the Ford Model T—AKA Tin Lizzie, T-Model Ford and Model T. To be clear, however—Ford did not invent the automobile; cars had been around for many years.

What Ford did “invent” was *affordability*—at least in terms of car-buying. His then-state-of-the-art manufacturing processes allowed him to sell his cars to the working man—including his own assembly line workers—for around 300 bucks and still make him a millionaire many times over. At the time, it was a win-win of truly historic proportions on several levels—social, economic, etc.

“I will build a car for the great multitude,” said Ford. “It will be constructed of the best materials, by the best men to be hired, after the simplest designs that modern engineering can devise. But it will be so low in price that no man making a good salary will be unable to own one.”

Supporting the fact that the best ideas are often someone else’s, credit for the “assembly line” goes not (as it often does) to Ford but to another car guy—Ransom E. Olds—who mass-produced his Oldsmobile Curved Dash in 1901. But the invaluable, priceless refinements and sophisticated system advances during the production run of the Model T are attributed primarily to Ford and his fellow visionaries—who happened to be engineers.

But having one of these machines wasn’t much use if the thing didn’t work; not-a-problem. The Ford Model T (FMT) was a workhorse of the road, powered by an engine that was designed to be manufactured providing the horsepower. Let’s take a closer, under-the-hood look at the heart of the machine that moved America—the Ford Model T engine.

The Ford Model T Engine

The engine was an inline-four—all four cylinders cast into one engine block. This would prove to be BIG. The FMT’s “monobloc” design was known, but not particularly popular when production started in 1908; but it lent itself to mass production, showing Ford’s pioneering appreciation of focus on design for manufacturability. Of equal brilliance, the head was detachable. This not only further streamlined Ford’s plant process, but also made his future customers’ valve jobs easier and, therefore—cheaper.

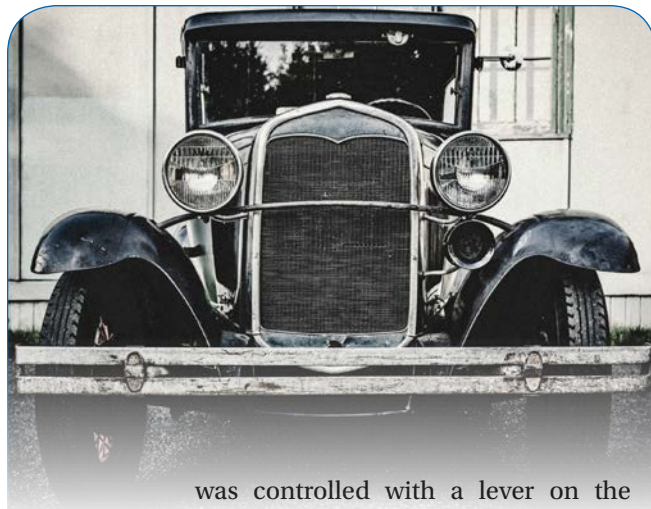
By The Numbers

- Bore: 3¾" (95.25 mm)
- Stroke: 4" (101.6 mm) even
- Total displacement: 177 cu in (2,900 cc)
- Valve train: side-valve (flat-head) design
- Crankshaft: Three main bearings

The compression ratio was low by modern standards, but typical for the era, making the engine forgiving of poor fuel quality and minimizing cranking effort at starting.

Model T Transmission

The rear-wheel-drive FMT was designed with a three-speed, planetary gear-oriented transmission. It was controlled with three foot pedals and a lever that was mounted to the road side of the driver’s seat. The throttle



was controlled with a lever on the steering wheel. The left pedal was used to engage the gear.

- With the floor lever in either the mid position or fully forward, and the pedal pressed and held forward, the car entered **low gear**.
- When held in an intermediate position the car was in **neutral**.
- If the driver took his foot off the left pedal, the FMT entered **high gear**—but only when the lever was fully forward.

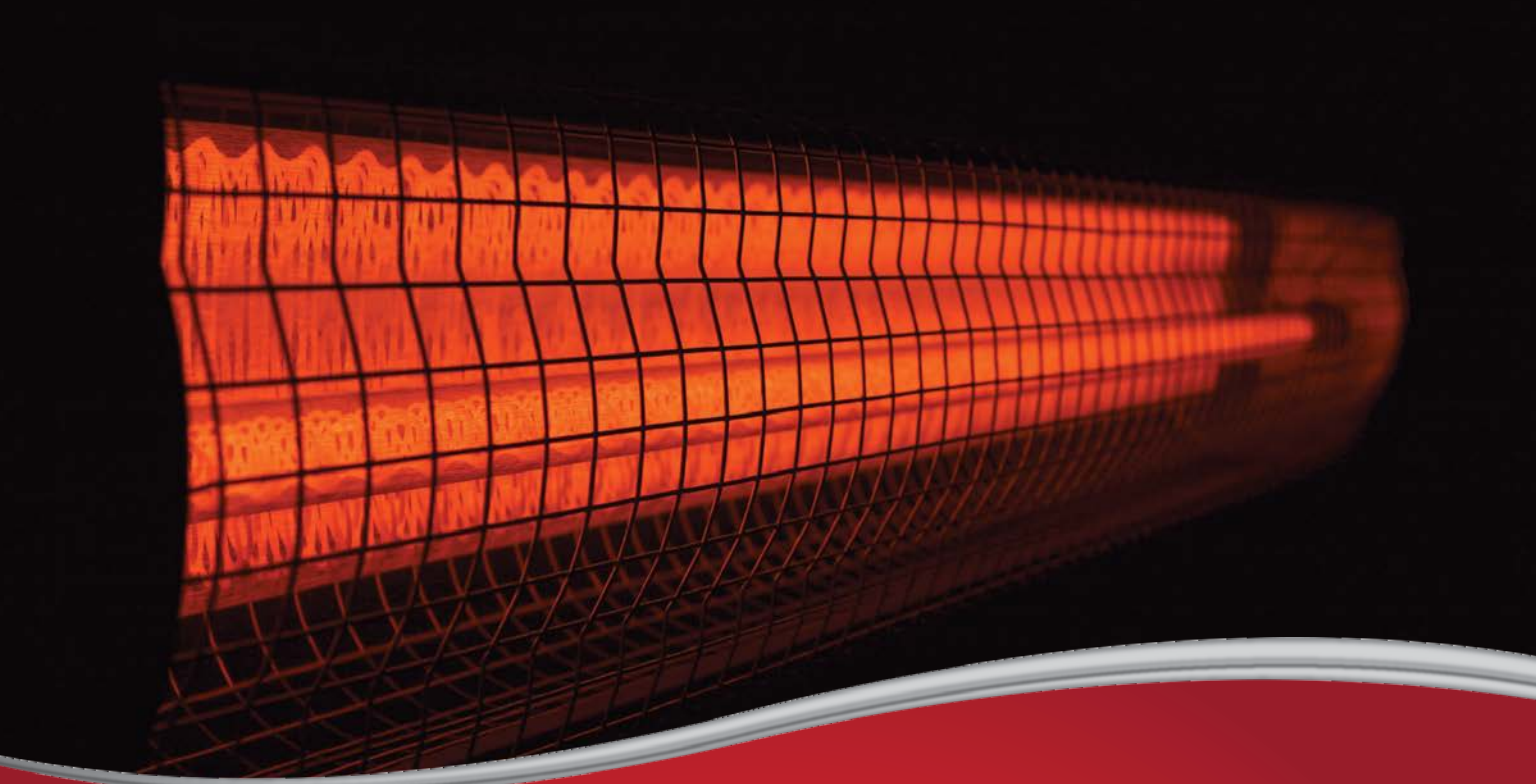
Oh, and by the way—no separate clutch pedal. And yet it sure seems like some very fancy footwork was required to drive one of these babies. And some nerves of steel.

When the car was in neutral, the middle pedal was used to engage **reverse gear**, and the right pedal operated the transmission brake.

There were no separate brakes on the wheels.

The floor lever also controlled the parking brake (no separate brakes on the wheels, but it had a friggig *parking* brake), which was activated by pulling the lever all the way back. Power was delivered to the differential via the single universal joint attached to a torque tube that drove the rear axle.

Appreciated for its simplicity, reliability, and economy, Ford’s Model T engine remained in production for many years; millions of units were produced. As for the engine *design*—it lived on beyond the vehicle itself, with industrial, marine, and military applications extending its production run. And one more thing: the Model T engine is on the Ward’s 10 Best Engines of the 20th Century list. (*Wikipedia.org was the primary source of information for this article.*) **PTE**



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