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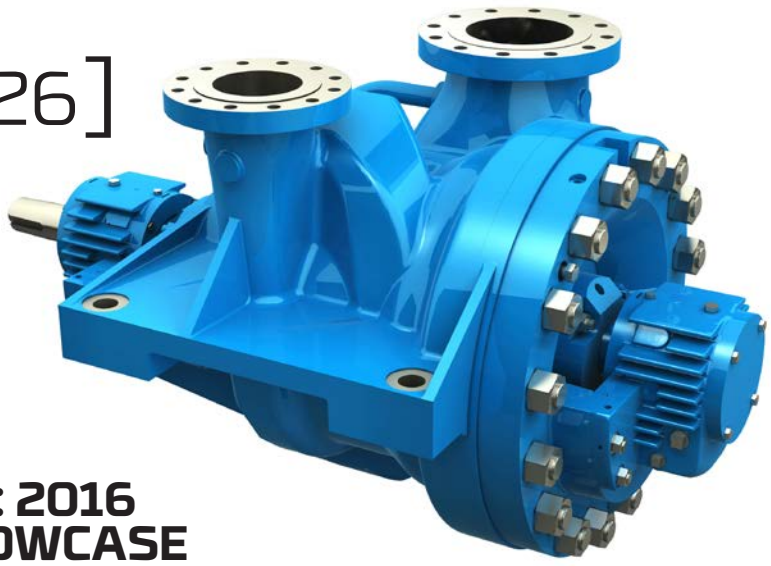

30 SPECIAL SECTION: 2016 ENGINEERING SHOWCASE

FEATURE ARTICLES

TECHNICAL ARTICLES

[24]

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Power Transmission Engineering

VOL. 10, NO. 2

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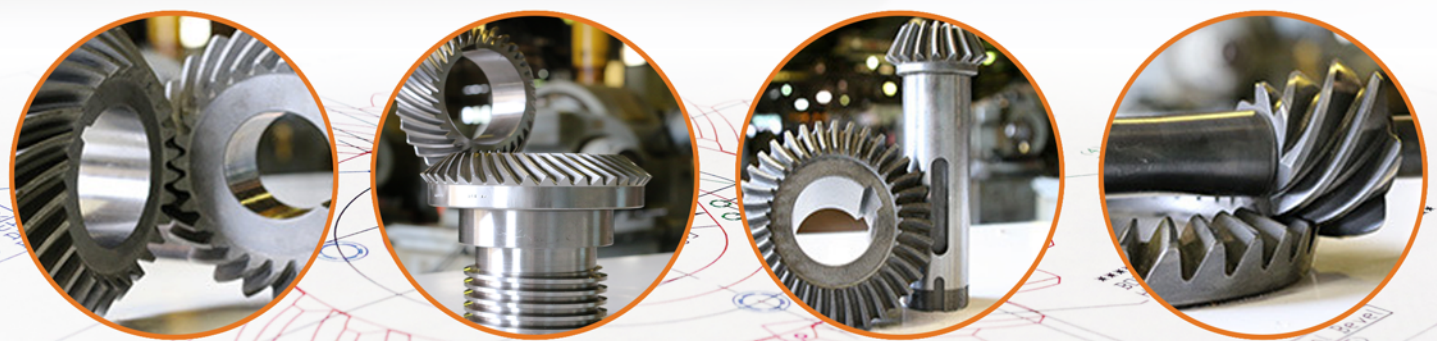

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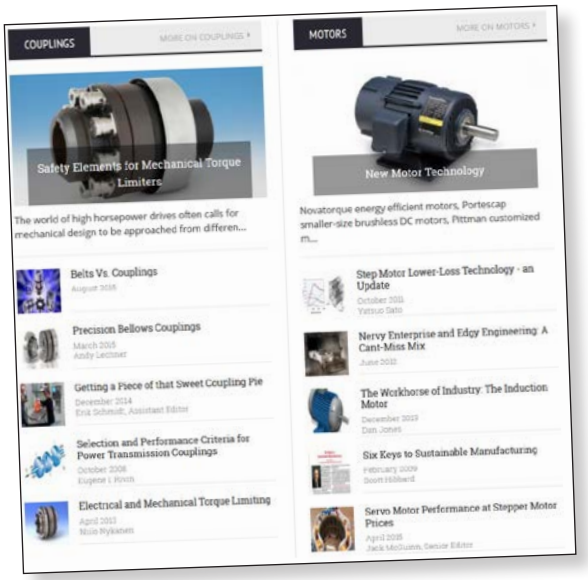
PTE Featured Topics

The PTE homepage (*www.powertransmission.com*) features an in-depth collection of mechanical component and motion control content. Articles are indexed by subject, so all you have to do is type what you're looking for in the search bar.

This Month's Highlighted Topics:
Couplings
Motors



Social Media

Have you browsed our Twitter page recently? We've added the latest PT news and product information from companies like Iwis, Brother Gearmotors, Kollmorgen and ABB. Check out these and other PT manufacturing topics here: *www.twitter.com/PowerTransMag*

Facebook is another resource that features updates on the Bearing Blog, additional Ask the Expert resources and a quick and convenient way to renew your PTE magazine subscriptions: *www.facebook.com/Power-Transmission-Engineering-524202381060172*

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Randy Stott, Managing Editor

Don't Believe the "R" Word

For several months, many economists have been using the "R" word when it comes to manufacturing. They say we've been in a global manufacturing recession since some time in the fourth quarter of last year.

There's no doubt that much of manufacturing has been in a funk. If your business relies heavily on Chinese manufacturing, you probably have some reason for concern. According to a Bloomberg report, China's manufacturing purchasing managers index (PMI) dropped to 49.4 in January — both a three-year low and a level below 50, which indicates contraction. And if your business is tied to energy — particularly oil and gas exploration and extraction — then you're probably even worse off, as the price of oil looks to remain low for some time, and investment in capital equipment has dried up. For more information on that, just read Brian Langenberg's *Global Industrial Outlook* column on page 52.

Oh, and if you're exporting from the USA, don't expect the dollar to suddenly weaken and help you out much, either.

Speaking of the USA, the Institute for Supply Management keeps track of manufacturing statistics. According to the ISM, economic activity in the manufacturing sector contracted for the fourth straight month in January, with the PMI at 48.2%.

NEMA's Electroindustry Business Conditions Index (EBCI) dropped to 44.4 in February from a January reading of 50, as more survey respondents reported that conditions had eroded, rather than improved. The EBCI has been at or above 50 only twice since September 2015.

According to the Motion Control & Motor Association, global shipments for motion control products declined by 3.9% to $2.9 billion in 2015, with the fourth quarter decreasing by 7.3%.

But lately, there have been a few positive signs.

For example, although the February ISM report indicated manufacturing contraction in January, the report also stated that numbers for new orders and production are growing. These are positive signs that, examined independently, sound an awful lot like growth.

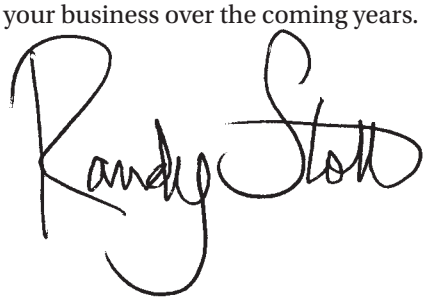
The U.S. Commerce Department also released figures in February stating that orders for durable goods rose by 4.9% in January. Also, manufacturing output rose in January, and factory payrolls increased in January by the largest amount since August 2013.

So which numbers are we supposed to believe? I have nothing against economists, but if you put 10 of them in a room and asked them what color the sky is, you'd probably get 10 different answers, ranging from "cerulean" to "sky blue" to "it depends upon the weather."

I don't have the answers, either, but I can offer this observation: Many of the negative numbers, the indices that point toward gloom and doom, and the signals that say we're in a manufacturing recession are based on the opinions and perceptions of survey respondents. Everyone's cautious right now — and for a lot of good reasons. And that caution is exacerbated by the fact that we're in a presidential election year. Nobody wants to make big investments until they have a better idea what they're in for over the next four years.

But at some point, negative opinions and perceptions become a self-fulfilling prophecy. Caution leads to even greater caution, despite the evidence that not everything is as bad as it appears, and in fact, many manufacturing industries are doing just fine.

So my advice to you? Listen to the news if you want to, but expect that over the next several months, you'll continue to receive mixed signals from the economists. We're probably still going to have a bumpy ride for some time. But if you want to know what's really going on, pay close attention to what your customers and suppliers are telling you. They're the ones who are truly closest to you, and they'll have the most direct impact on your business over the coming years.



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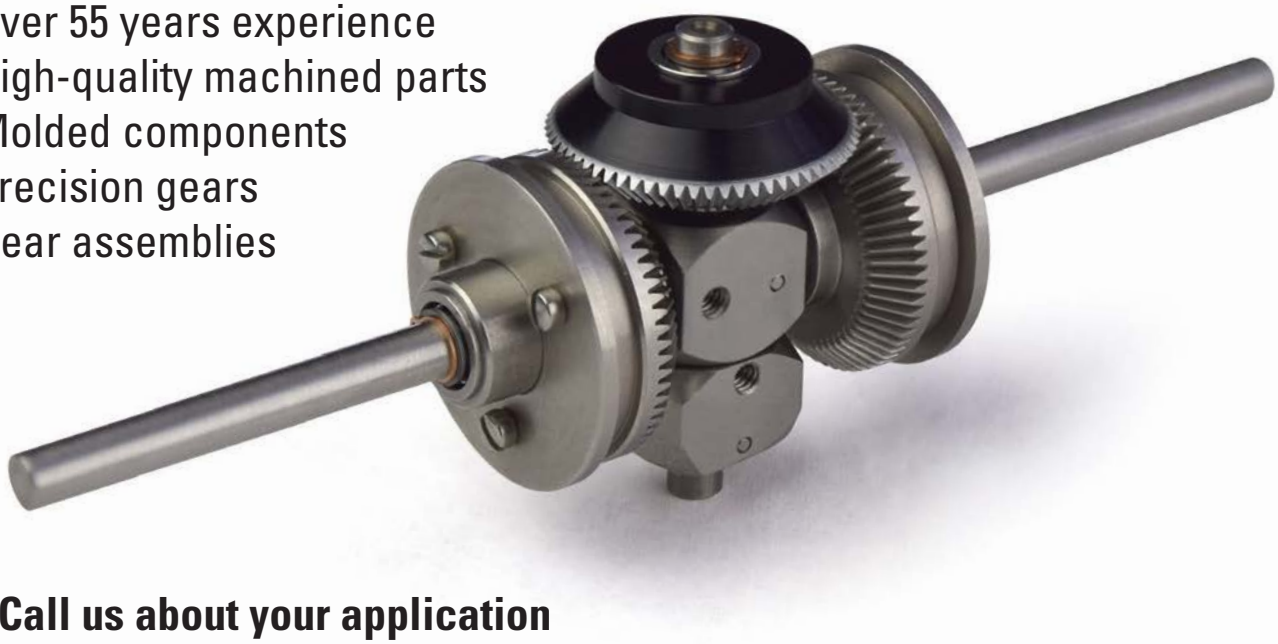

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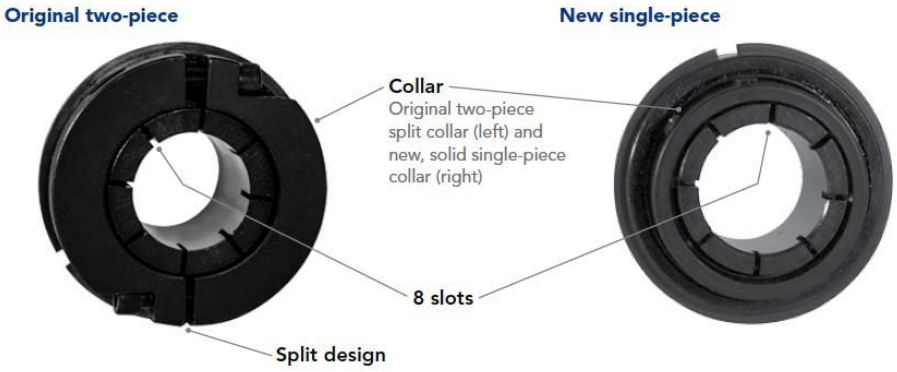
Rexnord Centrik-Lok Collar

ACCOMMODATES 32 BALL BEARING SIZES



Rexnord recently released a newly-designed, single-piece Centrik-Lok Collar (ER-K) for all 32 sizes of its Link-Belt ER Style Ball Bearings, which will now accommodate an even broader customer base and expand its use in hundreds of applications.

This smaller, versatile single-piece collar will fit into even more applications that utilize ER style bearings, allowing the product to be available to a larger market. With eight slots, it maintains the same clamping force from Rexnord Link-Belt Ball Bearings, while fitting more easily into additional processes and applications. Common applications requiring the Centrik-Lok Collar have included farming, road construction, lumber, printing, and general conveying applications.

"To our customers' delight, the new, single-piece collar is completely interchangeable with the original, two-piece collar design on all ER bearings," says Dan Gengler, ball bearing product specialist at Rexnord. "All ER bearings can be ordered with the single-piece design, and customers can simply replace the previous collar without a problem."

The new single-piece Centrik-Lok Collar allows the collar's outer diameter to be smaller by 0.55–0.85 inches and eliminate interference issues with installation. Except for the collar, the rest of the Rexnord ER-K bearing and its dimensions remain the same, including the unique eight-slot inner rings and the length through bore.

"Most importantly, we are not taking away or substituting something that Rexnord customers have been buying," says Gengler. "Rather, we are adding an additional option for a wider range of customers and applications. We can still accommodate the two-piece collar if customers would like to continue ordering them. Aside from the new Rexnord ER-K bearings, all other mounted Centrik-Lok Ball Bearings will feature the two-piece design and will remain unchanged."

Rexnord first introduced the original Centrik-Lok Collar in 2011, with a design that featured a unique eight-slot design and a two-piece locking collar. According to Gengler, this product not only allowed for easier installation, but with eight slots instead of six, ranks among the highest shaft clamping force in the industry. The positive reception this product received from the industry spurred the rollout of the Centrik-Lok Collar on all Rexnord Bearing products, including pillow block, flange ball blocks, and ER bearings.

For more information:
Rexnord Corporation
Phone: (414) 643-3000
www.rexnord.com

Siemens Sinamics Drives

OFFER HIGH POWER DENSITY IN SMALLER FOOTPRINT

Siemens recently announced the availability of its Sinamics G120C drive in AA size, which replaces the previous G120C frame size A in power ratings up to 2.2 kW(3 hp), including communication variants for USS, Profibus, Profinet and EtherNet/IP. Offering high power density in a smaller footprint, the new "tiny drive" offers fully compatible replacement for the equivalent power ratings on the previous version.

On new control cabinet designs, the G120C FSAA has significant size advantages, up to 32 percent less overall volume, for the OEM or integrator, but requires no re-engineering, when migrating from the G120C FSA on current jobs. Overall dimensions on the smaller unit, designed for use with Profibus and USS variants are only 173 mm high × 73 mm wide × 155 mm deep (6.8" × 2.8" × 6.1").

Other benefits of the new G120C FSAA include use with increased motor cable lengths, up to 50 m (165 ft) for shielded and 150 m (495 ft) for unshielded, plus identical voltage ratings, current ratings, load cycles and compatibility with all standard Siemens options such as operator panels, input and output chokes, as well as external Class B EMC filters.

The G120C FSAA offers UL open type, IP20 protection in the 0.55–2.2 kW (0.75–3 hp) range.

Through the introduction of this new tiny drive, Siemens can now offer machine builders another economical, space-saving and easy-to-operate standard AC drive with a wide range of functions, according to Robert Soré, product marketing manager for general purpose drives at Siemens. Typical applications for this product span a broad machine and equipment range,

Portescap Surgical Motors

OFFER THE ROBUSTNESS TO WITHSTAND STERILIZATION

Portescap has launched application specific motors for surgical powered hand tools, arthroscopic shavers, ENT microdebriders and large bone drills. Prototypes will be available to ship within three weeks of order placement. Based on 20 years of experience in surgical motor design, application specific motors are designed to the precise performance requirements of surgical hand tools. Products are designed using Portescap´s standard autoclavable motor design and have the robustness to withstand sterilization. Portescap motor technology has demonstrated autoclavability up to 1,000 cycles.

Arthroscopic shaver brushless DC mini motor solutions have been designed to drive powered surgical hand tools used in minimally invasive joint surgery; surgical procedures that are responsible for repairing joints such as hip, knee and shoulder joints. No-load speed of the arthroscopic shaver motors range from 4,000 to 7,000 rpm, while maximum continuous torque is 117 mNm and 119 mNm.

Portescap´s large bone drill brushless DC mini motor solutions offer a cannulated gearbox and motor combination to allow for in-line pin and k-wire driving and provide high torque at operating speed. These battery powered solutions can meet extreme torque demands without stalling during joint replacement surgeries such as those of the knee, hip, and shoulder.

including smaller test stands, mixers, conveyors, fans, pumps, compressors and basic production machinery.

For more information:
Siemens Industry, Inc.
Phone: (847) 640-1595
www.usa.siemens.com

The large bone drill motor offers a no-load speed of 950 rpm with maximum continuous torque of 818 mNm.

Ear, nose, and throat (ENT) brushless DC mini motor solutions provide the high speed and high torque required by powered surgical hand tools used in minimally invasive surgical procedures of the ear, nose, and throat as well as arthroscopic surgeries of small joints. With no-load speeds of 11,800 rpm and a maximum continuous torque of 39 mNm, these solutions are designed to perform precise cutting of tissue and clean burring of bone. For high-speed drilling in spine, cranial, maxillofacial and otologic (ear) surgery, Portescap´s spine drill motion solution will provide 90,500 rpm of no-load speed and 9.2 mNm maximum continuous torque.

For more information:
Portescap
Phone: (610) 235-5499
www.portescap.com

Brevini

EXPANDS GEARMOTOR CAPABILITIES WITHIN SMALL- TO MEDIUM-DUTY APPLICATIONS

Brevini has launched a new range of gearmotors, which will expand its capabilities within small- to medium-duty applications across a wide range of industries and sectors.

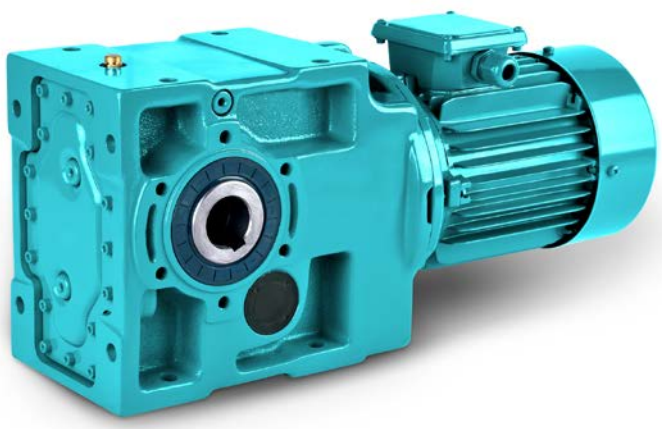
Brevini's heavy duty gear systems offer new products, available in the range of 50 Nm to 18 kNm output torque. The range includes parallel shaft helical gearboxes, foot and flange mounted inline helical gearboxes, bevel helical gearboxes and special gearboxes for hoisting applications. The gearmotors are suitable for use in material handling, lifting, winching, steel and metal fabrication, rubber and plastics, water and wastewater as well as food and beverage production.

"The introduction of the new gearmotors expands the breadth of our product range and enables our customers to single-source all their power transmission requirements from Brevini," said Gonzalo Salvatierra, Brevini's business development manager, who is based in Scunthorpe, North Lincolnshire, England. "The quality and support service for the new product range meets the same high standards delivered for our large scale gear systems."

As unpowered units, the new gearboxes can be specified with male or female input shafts with IEC or other mounting flange. Both the gearboxes and the gearmotors can be provided with a range of special output shafts such as shrink disc, flanged, extruder or agitator. Other options, including brakes and encoders are also available with the range.

"Brevini's excellence in engineering is meticulous, from materials selection, design and construction to installation, commissioning and ongoing service. The new range of gearmotors enables us to extend this philosophy across a wider spectrum of power transmission requirements," Salvatierra said.

For more information:
Brevini USA, Inc.
Phone: (888) 273-8464
www.breviniusa.com



Celera Motion Agility Series Motors

DELIVER SMOOTH VELOCITY CONTROL

Suited for scanning, pointing, measuring and cutting applications that require extremely smooth velocity control and highly accurate positioning, the Agility Series delivers suitable torque ripple and zero cogging. Engineered with ZeroCog slotless motor technology from Applimotion, the effects of cogging torque, magnetic forces, flux harmonics and phase balance and alignment are minimized to counteract the causes of torque ripple. Agility magnetic designs and construction techniques can achieve less than two percent torque ripple.

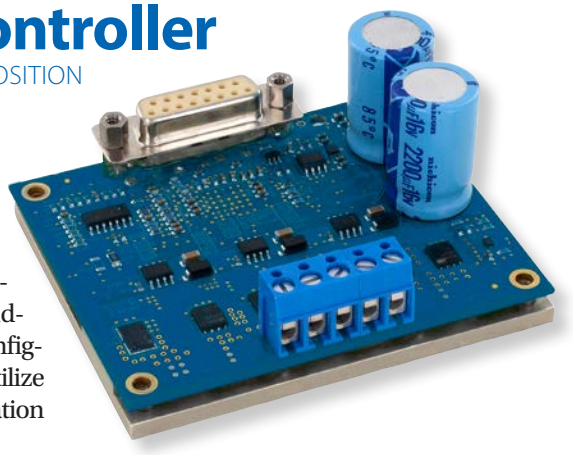
The Agility Series is offered in a wide range of low-profile form factors with a large through hole for convenient routing of cables, optics, sensing technologies and other system elements. Models are available in diameters from 12 mm to 300 mm, and with peak torques up to 41 Nm.

Frameless direct drive kit construction, high torque density and low mass enable the Agility Series to be tightly integrated into compact, lightweight precision assemblies. All models are compatible with a wide range of controllers and drives. Windings and form factors can be customized to meet application requirements.

For more information:
Celera Motion
Phone: (781) 266-5200
www.celeramotion.com

DDC Motor Controller

PROVIDES SPEED, TORQUE AND POSITION CONTROL



Data Device Corporation (DDC) has introduced a new, low-cost BLDC motor controller for speed, torque and position control. The MC-5000 series BLDC motor controller provides a turnkey, plug-and-play solution that is available in configurations to support motors that utilize Hall sensor or sensorless commutation

for torque and speed control, or encoder feedback for position control or commutation. The device can be programmed, via an easy-to-use Graphical User Interface (GUI), enabling it to deliver optimal motor performance with a wide variety of brushless DC motors and loads. Additionally, ease of programmability reduces time-to-market costs and in-house development efforts by enabling key system parameters to be tuned to optimize performance during development, and then, if needed, reprogrammed for use with additional applications and motors. Beyond these cost and time saving benefits, the MC-5000's compact, highly-efficient single-module design provides size, weight, power and cost savings, while ensuring precision motor control, making it a suitable solution for single axis, point-of-load industrial applications, including: pumps, fans, valve actuators, compressors, autonomous guided vehicles, industrial robotics and underwater ROV thrusters and fin controls.

For more information:
Data Device Corporation
Phone: (800) 332-5757
www.ddc-web.com

Timken

EXPANDS DRIVES LEAF CHAIN LINE

The Timken Company has introduced a new line of drives leaf chain to address global demand for heavy-duty large pitch leaf chain. The company now offers a complete series of drives large pitch leaf chain in sizes BL12 through BL20. Large pitch leaf chains are used in saddle cranes and front-end loaders found in rail yards and ports throughout the world. "The in-house, state-of-the-art designed tooling we use in manufacturing helps enhance our leaf chain performance, improving pitch tolerance and hole quality for better fatigue strength and pin retention," said Tom Young, director of the drives business at Timken. "We specifically designed our wide-waist link plates to resist bending for higher fatigue strength." Timken manufactures drives leaf chain using high quality steel at its drives chain facility in Fulton, Illinois.

For more information:
The Timken Company
Phone: (234) 262-3000
www.timken.com

Torotrak Drive Technologies

BOOST APPEAL OF VARIABLE-SPEED SUPERCHARGING AND AUXILIARY DRIVES

Torotrak Group recently introduced two new proprietary technologies called PitchSteer and DriveDisconnect. PitchSteer is a low-cost method of control that reduces the actuation power requirement of the Torotrak variable drive for devices such as superchargers; use of a 10 W actuator means that cost, weight and losses are minimized.

DriveDisconnect provides a zero output speed capability within the variator itself to provide the functionality of a disconnect clutch without the cost or weight penalty. Torotrak will continue to develop both technologies to further advance its V-Charge variable speed supercharger system.

"In a main-drive transmission application we typically control variator torque by modulating hydraulic pressure to give exceptional functionality and driveability. Most likely there are other devices requiring hydraulics in the transmission, such as clutches, and so this is no problem. However, for a small auxiliary drive this is not the case and we need to strip out all the cost we can" explained Chris Gaskell, design engineer at Torotrak. "PitchSteer enables the use of a single, low cost mechanical actuator with very low power consumption. The actuator draws only 10 W whilst changing ratio and negligible actuation power is required to maintain a constant ratio."

Torotrak has validated PitchSteer in one of its V-Charge supercharger units

Curtiss-Wright

OFFERS NON-CONTACT, ROTARY POSITION SENSOR

Curtiss-Wright's industrial division recently announced that it has launched a new non-contact, rotary position sensor from its brand family of Williams Controls.

The WM-830 is a cost-effective, non-contact rotary position sensor that uses proven Hall-effect technology to provide accurate and reliable measurement of angular position. Its mechanical, ruggedized design offers exceptional levels of performance against water, dust, shock, vibration and temperature.

Benefits of the WM-830 rotary position sensor include non-contact sensing technology, standard 48.5 degrees measurement angle—common for many electronic throttle pedal designs, interchangeable with the existing WM-810 rotary position sensor, available with optional PWM outputs and 15- to 360-degree measurement angle and connects via industry-standard Packard Electric 'Metri-Pack' 150 connectors.

The WM-830 operates from a 5 Vdc supply and has dual integrated circuits that are electrically isolated to provide two truly independent voltage signals, allowing the host electronics to detect output errors.

For more information:
Curtiss-Wright
Phone: +(44) 1425 271444
www.cw-industrialgroup.com

with a variator ratio range of 10, achieving a rapid rate of ratio change of just 300 ms for a full sweep. In addition to minimizing the actuation power, the wide ratio range capability allows the driven device to be reduced to a very low speed relative to the input whenever its function is not required, and therefore parasitic losses are greatly reduced.

The second new technology, DriveDisconnect, provides the function of a disconnect clutch, further reducing parasitic losses by disconnecting the variator output when the driven device is not required. As an integral function of the variator, DriveDisconnect does not add weight or cost, markedly differentiating it from a typical electromagnetic clutch, which can add 3 kg to the mass and around 30 euros to the cost of an auxiliary drive, even in high volume automotive production.

For more information:
Torotrak Group
Phone: +44 (0) 1772 900900
www.torotrak.com

Clutches: Declassified

Engineers Want Reliability, Consistency and Customization

Matthew Jaster, Senior Editor

The Mach III CBA4K-002 is a heavy duty, quadruple disc, high torque capacity clutch with female pilot.

In the world of PT components, the clutch gets absolutely no recognition whatsoever. There are entire magazines dedicated to gears, bearings and motors, but clutches get very little press outside of the automotive industry. If they do, it's limited to a case study or the occasional product news announcement. Part of the silence may come from the fact that the design and technology of clutches hasn't changed much through the years.

"It's a simple, precise and strong component," said Ron Ashbrook, applications and design director at Mach III. "The overall mechanical design of clutches has remained the same for many, many years. They're as reliable today as they were 40 to 50 years ago."

It's your basic "if it ain't broke, don't fix it," philosophy, according to Andrew Helander, vice president, Tiny-Clutch, Helander Products Inc. "We've been using the same technology on these things for decades. The size and scope may change, but fundamentally they all work the same and they work very well."

Clutches are used to transmit power from one rotating shaft to another. They can protect equipment from any kind of damage that may result from a mechanical overload. Applications vary, including roller coasters, satellites, bottling machines, conveyor systems and printing presses.

PTE recently caught up with Mach III, Tiny-Clutch and Nordex to discuss custom clutches, unique applications and the questions to ask when sizing and selecting these components.

Mach III Focuses on Custom Products

Mach III has shifted to an entirely inbound marketing strategy targeted to direct interaction with design engineers, according to Lesli Riehemann, president and CEO. "Inbound is a current marketing craze, but we started moving in that direction about 15 years ago. Today, a design engineer is more likely to open a web browser if she or he is seeking a clutch, brake or torque limiter solution than to reach out to a rep or distributor, so we know it was the right decision."

This strategy involves Mach III updating their website navigation to make exploring their products easier. "We have also added a new section that highlights our custom products, including access to PDF detail sheets and 3D models for dozens of our custom designs. While we have always publicized our abilities to generate customized products, I am confident that giving engineers the opportunity to see and work with 3D models will lead to more interest." (*Ed's Note: This section can be viewed at: www.machiii.com/Custom-Design-Solutions/).*

While Mach III offers catalog clutches, the majority of their work is customized to an extent. "There's nothing really 'off the shelf' in the classic sense," said Riehemann. "We build every single item to order even our catalog models are bored to whatever shaft size the customer specifies when the order is placed."

The Mach III C3A2R-STH is a through shaft pilot mount air clutch.

Mach III recently supplied a slip clutch (torque limiter) to Woods Hole Oceanographic Institution, an independent, non-profit organization dedicated to ocean research, exploration and education (*www.whoi.edu*). "The product we provided, T3C2H-010, is a special ultra-low torque version of our catalog model T3C2H-56L 56C NEMA Frame torque limiter. The two products look identical from the outside, but the T3C2H-010 has a torque rating of 80 pound inches versus the T3C2H-56L with a torque rating of 792 pound inches."

The slip clutch will be mounted between the motor and the gear reducer on an automated winch that lowers instrumentation in and out of salt water autonomously for several months. "The torque limiter would slip in case of a snag to prevent the winch wire from snapping and the instruments being dropped to the bottom of the bay where they are conducting research. The application has a torque requirement of only 8 lb.in. which was too low to be achieved with the catalog model, thus the need for the customized model," Riehemann added.

Ashbrook at Mach III said the company typically works within the 3–8-inch size range. "This is our bread and butter. We're tooled up for these sizes

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clutches
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and don't need to make any adjustments. Once we look at anything under 3-inches, it becomes a challenge to provide the tooling."

Ashbrook receives plenty of unique application requests from customers. He enjoys the day to day challenges of "putting out fires" for Mach III's customers. He's even had an epiphany in the middle of the night back in 2002 where he jumped up and started sketching out a new clutch design at one o'clock in the morning.

"I've been in a meeting on Friday and turned around and had the clutch on the customer's desk by Monday morning. I'm always looking for new ways to make our products more effective. It usually starts with a problem I have to solve and the solution somehow, someway always presents itself."

The Mach III T2B2F-012 is a friction torque limiter with integral pulley.

Tiny-Clutch Customizes Eco-Marathon Component

Tiny-Clutch, Helander Products Inc. provides miniature clutches in areas like aerospace, packaging, commercial cookers and HVAC equipment. As mentioned earlier, they've been utilizing the same technology for their roller clutches for decades. The company's magnetic clutches (M-Series) combine the high torque capacity of a spring clutch with the control of a conventional electric clutch.

"We tend to design miniature clutch systems that simply utilize a one-off piece from one of our standard catalog items. For example, we may take a standard M50 Series Magnetic Spring Clutch and provide the mating pulley and the belt for the customer," Helander said. "We've also built hand-operated tool assemblies that had three clutches in each unit for a hand tool that applies laminate. Some jobs are more common than others."

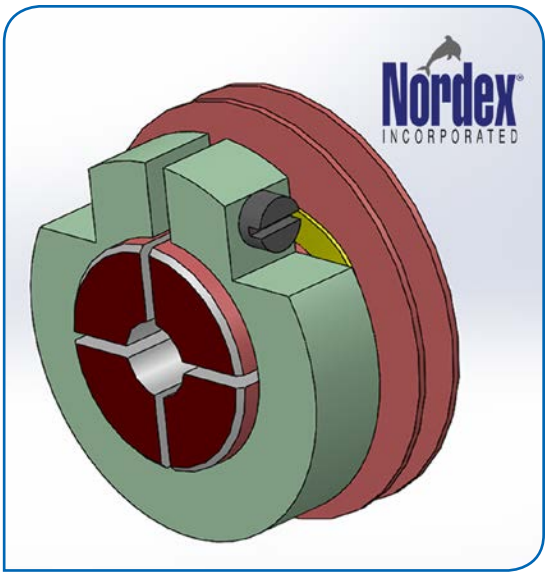
Recently, Tiny-Clutch was asked to provide an M-series clutch for a vehicle participating in the Shell Eco-Marathon. The Eco-Marathon features high school and university teams competing to get the most mileage per gallon in a fuel efficiency competition. This event challenges students around the world to design, build and drive the most energy efficient car. The competition dates back to 1939 when Shell Oil Company employees made a friendly wager over who could travel the farthest on the same amount of fuel.

Hector Perez, a sophomore at the University of Texas El Paso, is participating in this year's race which takes place in Detroit on April 22-24. "To turn on the motor in our vehicle, we needed a special clutch that could withstand huge amounts of torque but come in a very, very small size," Perez said. "The clutch we were using at first would overheat due to the torque involved, but we discussed the problems we were having with Helander and they customized a solution that fit perfectly."

After a couple of false starts, the vehicle is running well and ready to take on the competition in Detroit. For Perez it was great to work with a company that was so supportive during the entire vehicle design process. "Helander gave us the advice and equipment we needed to make the clutch work. We're excited to see how our vehicle holds up in the Eco-Marathon competition."

"These are time-proven components that are steady and reliable," Helander said. "Once you start getting down to the really small sizes the work gets more complicated because of the precision involved, but we're pleased that the clutch is working well for the University of Texas El Paso team."

Asking the Right Questions with Nordex



Nordex Inc. offers One Way and Slip Clutches with shaft sizes from ⅛ to ⅝.

Nordex Inc. offers One Way and Slip Clutches with shaft sizes from ⅛ to ⅝. These can be utilized for unidirectional stepping, automatic flywheel decoupling and backstopping. There are many manufacturing challenges involved in manufacturing miniature clutches like these, according to Nicholas Antonelli, mechanical engineer at Nordex, Inc.

"Miniature clutches tend to be low torque capacity and are used in precision applications where the torque range tolerance is very tight," said Antonelli. "Weight as well as the connecting assemblies may need to be factored into the design of the clutch and the component production needs to be consistent over many unit runs."

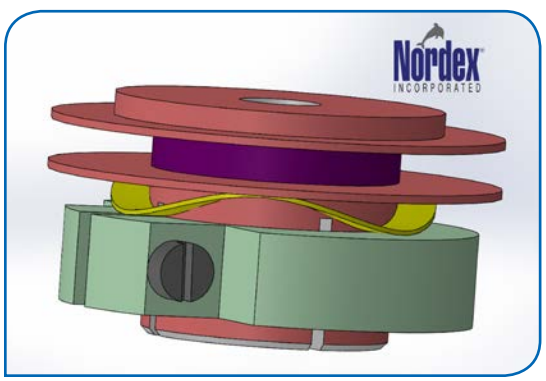
While the basic concepts are the same in friction clutches for larger models, the main differences in miniature clutches are the complexity and materials. "A miniature friction clutch may have a simple wave washer to apply the force while a large clutch may have several springs to apply forces to specially designed friction plates," Antonelli said. "Miniature clutches have used materials such as cork for a friction surface. Larger clutches may use woven or cast material with good heat transfer potentials to prevent "overheating" during high duty cycle use."

In order to find the right clutch for your application, Antonelli said it's important to ask the right questions. Is the clutch intended for intermittent or continuous duty? Does it need to be adjustable or can it be pre-set at the factory? Does it need to prevent overload one time and then be replaced? Is there a certain diameter or length it must fit between? Must it engage remotely?

"All these factors will help determine which clutch is best," Antonelli said. "There are numerous wrap-spring, friction, particle and clutch-brake combinations to suit any requirement, so there is no single clutch that would suit all applications."

Many times a non-engineering entity will let the wrong factor determine which clutch to select, according to Antonelli. "Do not let one factor decide what clutch to purchase, always remember that the clutch is an integral part of the entire drive system."

Today, new materials for friction surfaces that last longer are being developed for clucthes that are more environmentally sound. "This is the direction we're headed," Antonelli added. "Smaller sizes, lower costs and improved materials are being examined for the next generation of clutches." **PTE**



Today, new materials for friction surfaces that last longer are being developed that are more environmentally sound.

For more information:

Mach III Clutch, Inc.
Phone: (866) 291-0849
www.machiii.com

Nordex, Inc.
Phone: (800) 243-0986
Nordex.com

Tiny-Clutch
Helander Products, Inc.
Phone: (860) 669-7953
www.tinyclutch.com

The Other Side of the Spectrum

While this article examined smaller clutches and applications, there's plenty of room for larger components as well. Case in point: Eaton's Airflex 76VC2000 dual clutch system and Wichita Clutches Grinding Mill clutches.

Eaton's Airflex 76VC2000 (*www.eaton.com*) transmits rotary torque from high-speed electric motors that drive gearboxes or low-speed synchronous motors to high-performing mills up to 14,750 horsepower per pinion. The clutch's 76-inch-diameter friction drum enables it to transmit adequate torque for large grinding mill-drive applications. The clutch offers a motion-control solution for higher horsepower grinding mills, which were driven primarily by clutchless, low-speed motors in the past. This creates a slow startup rate that keeps component wear to a minimum and reduces power consumption.

High-speed motors using gearboxes or low-speed synchronous motors have been available for grinding mills, but mismatched clutches resulted in a startup rate that was too fast, causing increased stresses on mechanical systems. Eaton's VC clutch enables low-speed synchronous motors or high-speed motors driving through a gearbox to achieve full engagement at a slower rate not achievable with previous clutch solutions, thereby protecting the powertrain by slowing the acceleration of the entire drive system.

Wichita Grinding Mill clutches (*www.wichitaclutch.com*) are designed to provide smooth starts with limited current surge for heavy-duty grinding mills. The clutch is adaptable to remote control allowing centralized operation through simple air or electric circuits. These clutches do not need to be adjusted or lubricated, offer high heat dissipation and feature high energy absorbing friction material. The 72-in. version offers a maximum speed of 12,930 hp. **PTE**

For more information:

Eaton
Phone: (800) 386-1991
www.eaton.com

Wichita Clutch
Phone: (940) 767-2000
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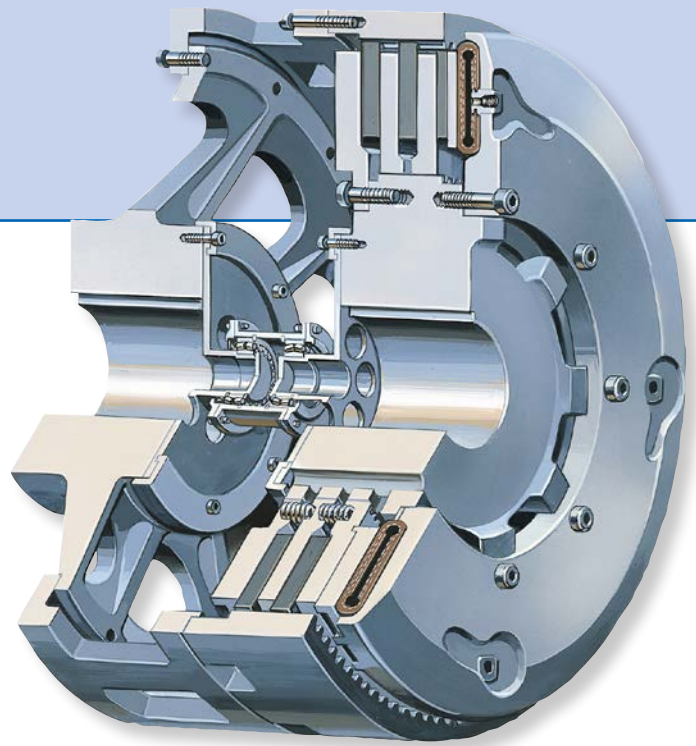

Wichita Grinding Mill clutches do not need to be adjusted or lubricated and offer high heat dissipation.

Troubleshooting Through Reverse Engineering

Certified Bearing Specialist (CBS) Takes on Hot Asphalt Conveyor Line

Michael Odom, certified bearing specialist and customer sales and service at Applied Industrial Technologies, explains how he used his bearing expertise to save a customer both money and downtime.

"An asphalt plant and new customer was having constant bearing failure on the hot asphalt conveyor line. They were going through one bearing every month. They had brought in the conveyor company to look at the situation, but they could not recommend anything at that time to determine why it was failing. One day I made a cold call to the plant and the plant manager happened to be onsite. I started introducing myself and handed him my business card. On the back of the card my Certified Bearing Specialist credentials were printed. His eyes lit up as soon as he saw that. He began telling me of the constant trouble they were having with this one application. We went out to look at the conveyor they were having problems with. I informed him to please save me one of the pillow blocks next time they had a failure and changed them out.

A couple of weeks later they had a bearing for me. I went to the customer and got help from one of the maintenance guys and we started disassembling the bearing. The shaft was $5^{15}/_{16}$" and they were using taper roller bearing household units. First thing that I saw was that the grease inside the bearings was completely "cooked out."

After fully disassembling the entire bearing, I was shocked at everything I was seeing. First thing I observed was the scoring and peeling of the roller elements and also the inner and outer races. After completely cleaning all pieces of the bearing, I also saw geometric stress concentration spalling and excessive preload. My first thought was that the lubrication was causing some of the problems, but the excessive preload wear had me baffled a little. I knew I was going to have to actually see about reverse engineering to try to get to the true root of the problem.

I went back and started doing a documentation of everything that I saw and also took detailed pictures. I knew that the material conveying was of some concern due to the high temperatures. I gathered everything I had and set up a meeting with the plant manager and all the maintenance guys in the facility. We looked over the situation and noted that it wasn't the normal nature of the beast, per say.

> **First thing I observed was the scoring and peeling of the roller elements and also the inner and outer races. After completely cleaning all pieces of the bearing, I also saw geometric stress concentration spalling and excessive preload.**

After looking over the application, running temperature readings, load readings, runout on the shaft and also looking at what I saw in the evaluation of the bearing, I determined they had heavy radial loads, expansion on the shafts from the high temperatures of the material being conveyed, and also really bad misalignment of the shafts.

I suggested, after weighing the options, to put in place SAF-style housings with spherical roller bearings, putting auto lubrication units, switching to high-temperature grease and also converting the conveyor over so that the bearings would be mounted externally and farther away from the material and high temperatures. He agreed to give it a try. We got everything together and I returned to the customer to help with the installation. I set the internal clearance to allow for the thermal expansion and also set the bearings up with expansion and also no expansion to allow for the thermal growth of the shaft. We mounted and installed the lubrication unit and also did the machine work that needed to be done to mount the bearings externally and finally got the alignment set right on the shaft.

After the first month the customer was amazed. Six months later, he is still in disbelief that the bearings are still running. I saved him over $100,000, not including downtime. I have made a customer for life with them. Being a Certified Bearing Specialist made all the difference in the world. It opened up so many doors that could have been closed without it. I would recommend it to anyone looking to broaden their horizon in the industrial world." **PTE**

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Certified Bearing Specialist

BSA's Certified Bearing Specialist (CBS) program is the only bearing industry-specific program that identifies and quantifies the specific skill sets to certify an industry professional as a bearing specialist. The CBS program is all about developing the expertise to help customers and end users make the best bearing decisions. Take advantage of this complimentary access to a Certified Bearing Specialist. Please email your question to *info@bsahome.org*. An expert CBS will respond to your inquiry and it may appear in this article.

Michael Odom has held multiple positions in the industrial sector for 18 years and has completed many achievements thrughout his career. He is currently in customer sales and service at Applied Industrial Technologies.

The Test Run

Dassault Systèmes Collaborates with FEops on software for heart patients

Edited by Matthew Jaster, Senior Editor

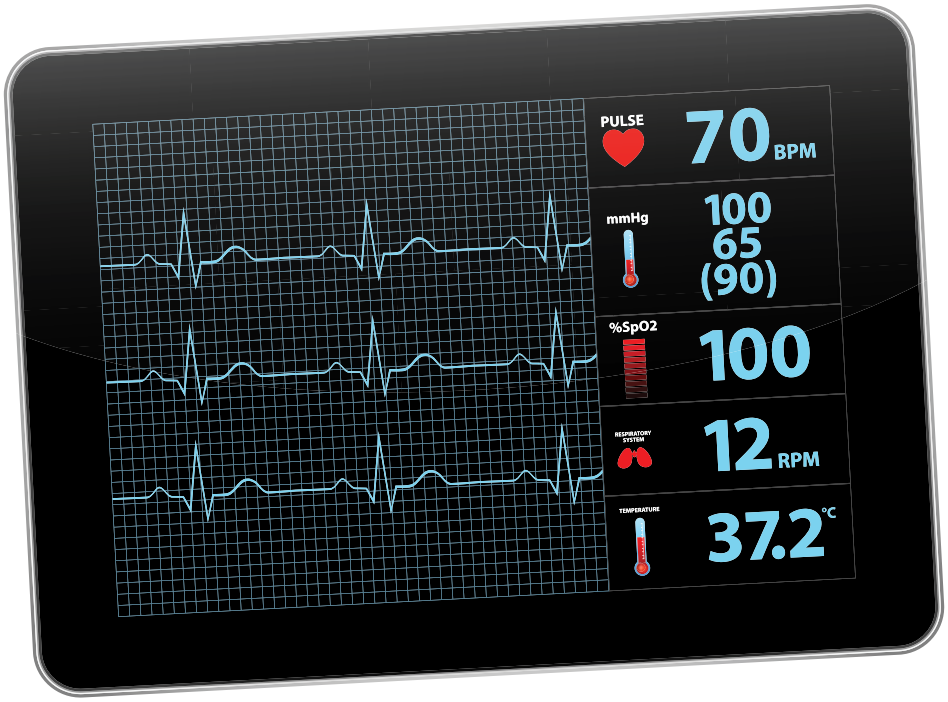
Modeling and simulation is a key driver of innovation. Whether it's general manufacturing, consumer goods or life sciences, the ability to realistically model and simulate the response of parts, sub-systems and complete assemblies to increase accuracy and repeatability is vital in today's analytical world. This can be done to evaluate design alternatives in aerospace applications, predict structural analysis for engineering concepts or predict the real world behavior of wind turbines.

The same kind of modeling and simulation software can be used to simulate the human body. Dassault's *Abaqus* software suite was used in conjunction with FEops, (a Belgian-based provider of physics-based simulations for minimally invasive cardiovascular devices), to provide a simulation tool that allows surgeons to pre-operatively visualize surgical procedures and predict the behavior of medical devices.

Transcatheter Aortic Valve Implantations

The heart is often compared to a pump, facilitating the flow of blood between its upper and lower chambers. The heart's valves, which open and close with each beat, regulate the pressure and course of blood throughout the body. Unfortunately, according to the American Heart Association, more than 5 million Americans are diagnosed with heart valve disease each year. It can occur in any single valve or a combination of all four, but disease of the aortic and mitral valves is most common.

According to the University of Maryland Medical Center, up to 1.5 million U.S. citizens suffer from aortic valve disease. The aortic valve controls the movement of oxygenated blood from the left ventricle into the aorta, the main artery leading to the rest of the body. Without an aortic valve replacement (AVR), 50 percent of aortic valve disease sufferers will not survive more than an average of two years after the onset of symptoms. An estimated 85,000 surgical AVR procedures are performed every year in the United States.



For patients deemed too old or too ill to undergo AVR through traditional open-heart surgery, transcatheter aortic valve implantation (TAVI) is a growing alternative approach. It is much less invasive, as it avoids cardiopulmonary bypass and requires less time and anesthesia than a major surgical procedure. TAVI involves inserting a catheter, usually through the femoral artery in the thigh, which is then threaded into the heart, where it inserts a replacement valve inside the native (original) one. This replacement valve is mounted upon a dedicated endovascular prosthesis or stent.

Even with the much less-invasive TAVI approach, complications can still arise. During the deployment of the device, particles of calcium can break away from the aortic wall, travel to the brain and cause stroke. Calcium deposits on the original valve may also shift toward the origins of the coronary artery and restrict blood flow to the heart muscle. Another potentially serious complication is regurgitation, which occurs when the new implant does not seal completely against the aorta walls. The resulting leakage allows blood flow along the sides of the device when the aortic valve is supposed to be closed. There can also occasionally be electrical conduction problems, requiring a pacemaker to manage the electrical current that travels over the heart and signals it to contract.

"It was clear that these complications could be mitigated by further improving the TAVI designs and procedure planning," said Matthieu De Beule, Ph.D., co-founder of Belgian-based FEops. "For this reason, FEops developed its unique *TAVIguide* technology which aims at improving the design, planning, safety, and efficacy

Figure 1 These images represent the progression of the *TAVIguide* process. On the far left is a patient's pre-operative CT image, which is then used to create 3D reconstruction (center). At right is a simulation of TAVI in this specific patient's anatomy.

of TAVI products and procedures."

FEops is a spinoff from the IBiTech-bioMMeda group at Ghent University. Their team of biomedical Ph.D.s has extensive experience with advanced cardio- and endovascular device-and-procedure modeling, in collaboration with academic researchers and clinicians worldwide.

TAVIguide uses pre-operative images, gathered from an individual's CT scans, to create digital 3D-anatomically correct finite element models (Figure 1) of patients' aortic roots by combining *Simulia Abaqus finite element analysis (FEA)* software from Dassault Systèmes, with proprietary software. "The technology allows the study of different virtual procedural alternatives, in order to be optimally informed before performing the real procedure," added De Beule.

Through a collaborative retrospective pilot study with Professor Peter de Jaegere from the Erasmus Medical Center in Rotterdam, Netherlands, FEops has compared the simulation

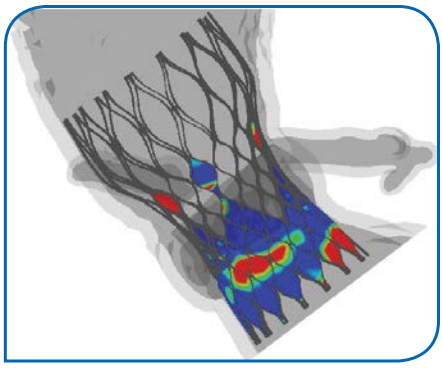


Figure 2 In this *Abaqus FEA* image, the blue shading represents good apposition, and the red incomplete apposition. *TAVIguide* simulations allow surgeons to compare how different stent-supported valves will act in their patient's anatomies.

results from TAVIguide with post-operative CT scans of patients who underwent a TAVI procedure. There was excellent agreement between the simulations and the post-operative data.

"I believe this technology will have an important clinical implication," says de Jaegere. "It will allow the selection of both the type and size of the valve for a particular patient. Such tailored medicine has the potential to significantly improve current TAVI planning and reduce complications.

"With simulation you can gather so much more accurate information than using strictly simplified bench tests," says De Beule. "Now you can gain greater insight in regard to what stresses and strains these devices can withstand once they are deployed into an individual's anatomy (Figure 2). The simulations can then predict the behavior of replacement valves during transcatheter delivery, implantation, and even after new-valve function begins in a patient's body."

Abaqus FEA has proven highly capable of replicating the complicated landscapes and methods of the TAVI procedure. "We have decades of experience using *Abaqus* specifically for minimally invasive cardiovascular and endovascular devices," De Beule says. "*Abaqus* can accurately simulate the complexities of the TAVI procedure and products, which allows us to be very confident in the results," (Figure 3). "We are convinced that this technology and personalized approach can not only be applied to additional cardiac devices, but our simulation framework can also help medical device designers consider a variety of new cardiovascular products in realistic and validated patient anatomies early on in the pre-clinical state of development, paving the way for virtual clinical trials."

Results from a retrospective validation study on 39 patients were recently published in *EuroIntervention* (a journal read by interventional cardiologist all over the world), according to Peter Mortier, CTO and co-founder of FEops. "The results show that with our technology, the interaction between a transcatheter aortic heart valve and a specific patient can be well predicted, which has the potential to improve clinical outcome."

In September 2015, FEops received CE approval (the European equivalent of the FDA) for TAVIguide. This advanced pre-operative planning tool will be available for individual patients in routine clinical practice in Europe and is expected to not only facilitate TAVI treatment planning for the clinician, but most importantly to aid in reducing the occurrence of life-threatening complications, such as paravalvular leakage and conduction abnormalities. "We also plan to offer similar pre-operative planning solutions for multiple cardiovascular treatments such as mitral valve interventions," Mortier said. **PTE**

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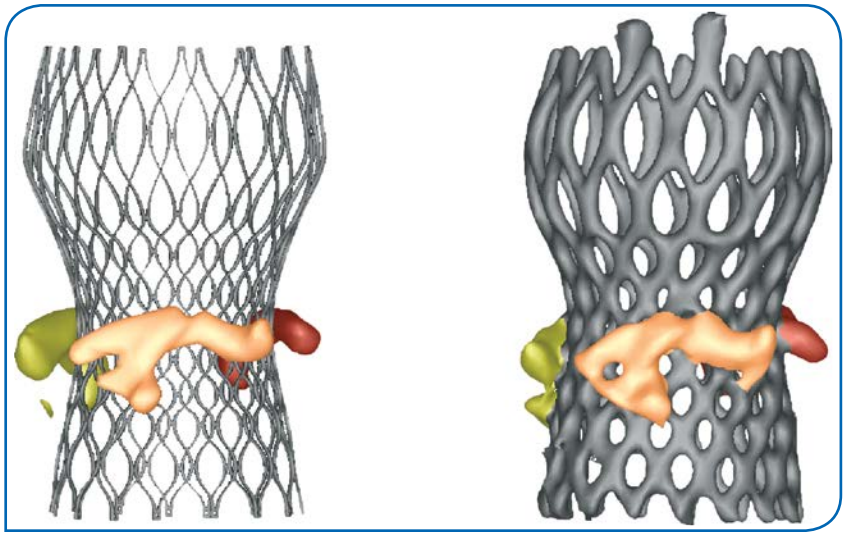
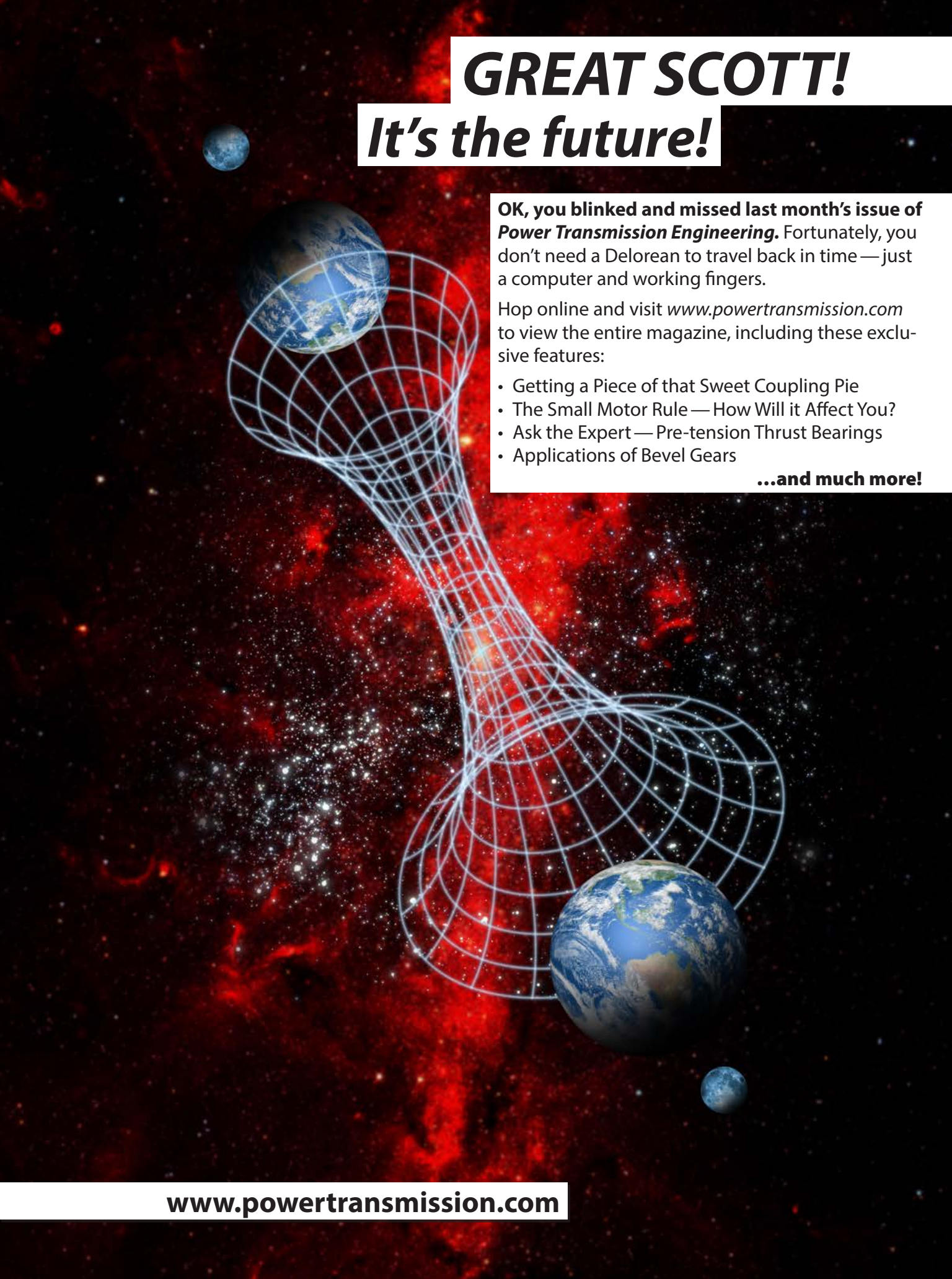


Figure 3 Comparison of predicted (left) and observed (CT, right) calcium movement illustrating the predictive power of the model.



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Slicing Downtime

Cheese packager utilizes oil shear technology to enhance productivity

Stan Porter, Force Control

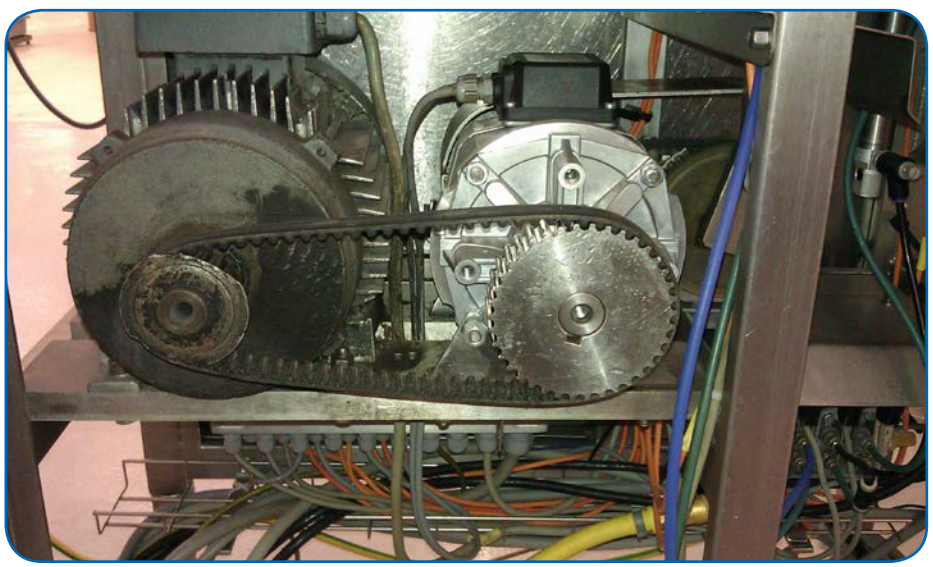
An independent cheese packager in central Wisconsin packages millions of pounds of cheese every year. Whether shredded, sliced, crumbled or waxed, each package is designed specifically for a customer's unique needs. As a "toll processor," production line speed is critical to productivity as well as profitability. In order to ensure productivity improvements, the company replaced a dry clutch brake with a Posidyne oil-shear clutch brake for a slicing line. This increased processing speed while maintaining accuracy — thus cutting downtime and boosting overall productivity.

The slicing line — where cheeses are sliced to specified thickness using a cutting arm attached to a clutch brake — is a critical area. Accuracy is vital. With approximately a four-inch stroke, positioning of the cutting arm — and consistent repeatability typically determines success. Using a dry type clutch brake, this line "had a maximum speed, with good accuracy, of about 45-47 cycles per minute," according to the plant manager.

With any dry type clutch brake, adjustments are required to maintain accuracy. That's because the sacrificial wear surface abrades away with each actuation of the brake. To maintain their desired accuracy required plant employees to "turn the wedges in on the friction plate" — a 15-minute ordeal each week, or over 12 hours annually. While 15 minutes may not seem like a lot of time, at 45 cycles per minute, that's at least 675 slices a week lost to maintenance downtime.

Despite a fastidious maintenance regimen, the dry clutch brakes had a short service life, lasting only six to eight months. Replacing them required an hour or more — or another 2,700 slices lost to maintenance downtime.

Additionally, maintenance or service on other components of the line would cause the clutch brake to run idle — and build heat, which created problems. "If it sat idle without running any cycles for more than 10-15 minutes, we'd have to cool it down for another five minutes before running any product," recalls the plant manager. The result was even more lost production.



The frustration with the maintenance and adjustment as well as replacement costs for the dry clutch brakes prompted management to look at alternatives.

Bob Rohde at Linder Electric Motors suggested the Posidyne oil shear clutch brake from Force Control Industries which requires no maintenance or adjustment and typically lasts much longer than dry-type models. A demonstration trailer was brought on site where the production and management teams could see firsthand the viability of oil shear technology.

Force Control built and shipped a clutch brake overnight to accommodate the packaging company. The new clutch brake has increased cycle times by 10 to 20 percent. "Since we've installed the Posidyne, we have not performed any ongoing maintenance on it, nor have we made any adjustments," the plant manager said. Maintenance crews change the oil annually but the brake requires no other maintenance, repair or adjustment.

Although they have had the clutch brake idled for an hour or so on several occasions, they have not had any additional downtime due to heat buildup with the oil shear product. That is because with this patented technology, there is a boundary layer of transmission fluid in shear between the friction discs and drive plates. As the parts come together the fluid under shear will transmit torque between the two parts, as well as absorb heat. This eliminates direct contact of the friction discs and drive plates during high speed slip. Heat from the friction surface is dissipated as the fluid circulates to the housing — whether the clutch brake is engaged, or idled.

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Judging from their initial experience and review of warranty claims in terms of cycles, company officials figured that the Posidyne clutch brake would last approximately four years — or six times as long as the dry clutch brake that it replaced. Four years later, the brake is still running smoothly, indexing precisely, and allowing this facility to maximize production. In that timeframe, at least six dry-brake replacements have been avoided, saving the company thousands of dollars in replacement costs. In addition, avoidance of maintenance costs and lost downtime has been significant. Converting the 12 hours per year that was devoted to dry brake maintenance into production time allows the company to produce more than 33,000 additional slices of cheese.

The frustration with the maintenance and adjustment as well as replacement costs for the dry clutch brakes prompted management to look at alternatives.

"The two clutch brakes were within a couple hundred dollars of each other — and the Force Control product requires no maintenance or adjustment, and lasts a lot longer," said the plant manager, "so it is well worth the additional investment." **PTE**

For more information:
Force Control Industries
Phone: (800) 829-3244
www.forcecontrol.com

How Oil Shear Technology Works

Normal dry clutch brakes and brakes employ a sacrificial surface — the brake disc or pad — to engage the load. Having no good way to remove the heat caused from engagement between the disk and plate, this material must absorb the heat. These extremely high temperatures will eventually degrade the friction material. As the friction surface wears away and begins to glaze, the ensuing torque fade causes positioning errors which require adjustment or replacement of the friction surface.

Oil-shear technology plays a major role in ensuring that the cheese slicer at this independent cheese packager operates at its peak efficiency — even at a much higher cycle rate. Since a fluid film flows between the friction surfaces, as the brake is engaged, the fluid is compressed. The automatic transmission fluid particles in shear transmit torque to the other side. This torque transmission causes the stationary surface to turn, bringing it up to the same relative speed as the moving surface. Since most of the work is done by the fluid particles in shear, by the time the surfaces actually meet or "lock up," wear is virtually eliminated.

In addition to transmitting torque, the ATF also helps to dissipate heat, due to a patented fluid recirculation system. Along with torque transmission and heat removal, the fluid also serves to continually lubricate all components — thus extending their service life. Oil shear technology also provides a "cushioned" stop that reduces shock to the drive system — further extending service life. Unlike dry clutch brakes, the totally enclosed oil shear system is impervious to external elements such as wet, dusty or dirty environments, as are found in virtually all shingle manufacturing plants. Since the layer of oil eliminates wear, the Posidyne clutch brake provides a long service life. With elimination of wear comes elimination of adjustment — and increased "uptime" for this cheese processor. **PTE**

Sum of the Parts

The Department of Energy is expanding its focus to full system efficiency and has released its first ever set of efficiency standards for pumps.

Alex Cannella, News Editor

In the Department of Energy's endless energy efficiency game of whack-a-mole, motors have historically always been one of the go-to moles. They've been in the spotlight since 1992. Over the past few decades, repeated efficiency laws have seen motor efficiency get whacked into tighter and tighter shape.

As far and away the biggest source of global electricity consumption, motors have been an obvious focal point for the DOE's energy efficiency efforts, but at this point, many motors now exceed 96 percent efficiency. Between the increasing cost of developing more efficient motors and the relatively low expenses of utilities, there's a growing argument that we've hit the ceiling on efficiency, or at least gone as far as is practical.

"We've stair-stepped efficiency up to a premium efficiency level and we've extended coverage over a very wide range of motor configurations," John Malinowski, senior manager for industrial affairs at Baldor, said. "So in a typical induction motor, there's not a whole lot more to go. If we raised efficiency higher, we would perhaps change away from squirrel-cage induction motors and go into some other technology. The cost of that technology might not jive with the payback. Payback would take too long in an industrial sense."

But despite all the effort that's been put into making motors more efficient, the International Electrotechnical Commission still reports that they consume 45 percent of all global electricity. How?

A part of the reason is just the sheer number of motors used around the world (and the fact that not all countries have efficiency laws), but even in parts of the world where motor efficiency is at a record high, they're still hampered by the systems—the pumps, air compressors and fans—that they run. While efficiency standards on motors have been repeatedly tightened, the systems themselves have mostly avoided scrutiny and fallen behind, effectively hamstringing the energy savings provided by a top-of-the-line motor.

The DOE, however, has started to address this. They recently released a final ruling on pumps, and they won't be stopping there. They're also planning on releasing a proposal for the fan industry, and the next step after that will be to look at air compressor efficiency.

In the Spotlight

The DOE's ruling on pumps is the first U.S. efficiency law to be imposed on them, and the department's opted for a uniform baseline across multiple pump categories and designations. The new ruling is based on a survey of over 3,000 pumps and is designed to eliminate the 25 percent least efficient pumps currently on the market.

While that may sound like a significant number, it's important to note that the DOE's first ruling targets a narrow section of the pump sector. The only pumps affected by the ruling are clean water pumps (pumps with a maximum non-absorbent free solid content of 0.016 pounds per cubic foot and a maximum dissolved solid content of 3.1 pounds per cubic foot) ranging from 1–200 hp. Of those pumps, only end suction close-coupled pumps, end suction frame mounted/own bearings, in-line pumps, radially split, multi-stage, vertical, in-line diffuser casing pumps and submersible turbine pumps will be affected. The DOE is further limiting the ruling to pumps with a flow greater than 25 gallons per minute, a head less than 459 feet and a design temperature between 14 and 248 degree Fahrenheit (–10 to 120 degree Celsius).

Non-clean water, mixed/axial flow, nuclear, mil spec, sealless, self-priming, prime assist, sanitary, circulator, pool and fire pumps are also exempt in the new standards. For more information on exactly what is and isn't included in the final ruling, the Hydraulic Institute has put together a handy diagram that you can find at *www.pumps.org/DOE_Pumps.aspx*.

For the affected pumps, the DOE has set up a new metric they're referring to as the Pump Energy Index (PEI), which lays out specific efficiency requirements for each target category, with additional distinctions made between 1800 rpm and 3600 rpm pumps and constant load and variable load pumps.

The DOE also laid out test procedures in a second ruling to ensure that affected pumps meet the new standards. They will require that all affected pumps be tested by the compliance date in 2020. The testing method is a modified version of the Hydraulic Institute's HI 40.6 test where the pump's pump energy rating will be matched against a "standard pump energy rating" that is meant to represent the performance of a bare pump of the same equipment class that shares the pump's characteristics, such as flow, hydraulic load and specific speed, and is minimally compliant with DOE's energy conservation standards.

The HI is currently developing a three-part training series on the testing method and calculations. Each part of the series will cover a different topic related to the ruling. The first will go through much of the background behind the rule, the second details the test procedure itself and the third will run through the calculations to check if your pump is up to snuff.

"The general outline is that we want to educate at a high level," Peter Gaydon, director of technical affairs at

the Hydraulics Institute, said. "What is this rule, what does it mean, what's in scope, what's out of scope, etc. Now that you have to test the products, what test procedure do I need? What's important? What do you have to worry about? And when I'm doing these calculations, what do all of these calculations mean?"

The DOE's strategy with pumps seems similar to how they dealt with motors. The current ruling has a narrow focus, but we can expect it to expand in scope in the future.

A Cooperative Strategy

The DOE's ruling sets a good first precedent for the pump industry, giving all involved a clearly established, concrete baseline to shoot for, including those who may not be affected. While the ruling currently has a narrow focus, the DOE seems to be taking a similar approach to what they did with motors, which means that the efficiency standards could be expanded to cover other sections of the industry at a later date.

The DOE's focus has shifted to include overall system efficiency, but technically, none of their rulings, published or under consideration, are guidelines for total system efficiency. Instead, the DOE is raising overall efficiency by targeting each individual major component of larger mechanical systems and regulating them one at a time.

One of the most interesting things about the DOE's process, however, has been how much it has involved outside input. The DOE has been in contact with groups such as the Hydraulics Institute for over five years leading up to the final ruling, gathering data and input from the affected industry every step of the way. The back and forth dialogue has not only led to a ruling that the pump industry can reasonably bear, but also kept the industry informed.

"The pump manufacturing community has been well-versed and well involved in the negotiation and the setting of minimum efficiency levels," Gaydon said. "So I think the overall reaction is that they got what they expected."

The Hydraulic Institute has been working with the DOE since they first showed an interest in improving pump efficiency. Since then, they've helped with the survey that formed the basis of the research behind the DOE's ruling, formed committees to help get further information to inform the DOE's decision, and developed HI 40.6, the testing procedure that became the basis for the DOE's ruling on official pump efficiency testing methods. Throughout the process, the HI has been a go-between for the industry and the DOE.

"Our members negotiated with advocates as far as 'what is an appropriate level that's not too burdensome to the industry, that isn't going to put people out of business, but will still achieve the goal of saving industry to make it a worthwhile standard?'" Gaydon said. Waiting in the Wings

So now that attention is shifting towards system efficiency, where does this leave motors? The DOE will take another look at motors in the future and could put out another ruling tightening efficiency further, but between the time it would take to draft up another ruling and the several years' grace period typically given afterwards to comply, a motor bought today could conceivably last you a long while down the road. At the same time, already mandated rulings are coming into effect (the latest will do so in June). Meanwhile, newer and better motors will likely continue to one-up each other as they're released. While the U.S. has shifted focus, many foreign motor manufacturers (including ABB, whose motors you can get through Baldor) have doubled down on motor efficiency. Not only do they produce IE3 motors (which are equivalent to our premium motors), but also IE4 (super premium) and even IE5 motors, and the race only seems to be gaining momentum. In some corners, people are already trying to define what an IE6, 7 or even 8 motor might look like.

That's all a lot to consider. While super premium and better motors may exist, whether or not you should buy one is a question that will have to be answered on a case-by-case basis after crunching some numbers. According to Malinowski, this is particularly true here in the United States.

"Compared to the rest of the world, we've fundamentally got very inexpensive electricity today and we don't have carbon taxes," Malinowski said. "In the middle part of the United States, electricity's still only about 6 cents a kW/hour. It might be higher on the coasts, certainly it's a lot higher in Hawaii and places where you don't have natural gas for fuel, but in the heartland of the country, energy's really cheap. Where you go to Europe, it might be two or three times that, plus you have a carbon cap on top of it. So what works here and what works in Europe… totally different deal."

Due to those cheaper electricity costs, the already diminished returns from each efficiency level become even slimmer, which makes the super premium efficiency wave that's taking over Europe a harder sell for American businesses. While super premium motors will inevitably save money in the long run, Malinowski believes that payback may be too long to be economical in some cases.

"Does [an IE4 motor] have payback?" Malinowski said. "Well, yeah, it does. Is it going to pay back in two years? Well, maybe, maybe not."

There are other factors to consider as well, such as how often the motor will be running and if it will be doing so at maximum output. A motor that isn't constantly running or doing so at half speed will change your calculations.

The Silver Lining

Whether you work with pumps or motors, or are even waiting for the hammer to fall on fans or compressors, there is a bright side to the new rulings. From their new expanded focus on system efficiency to their collaborative approach, some of the recent rulings from the DOE have marked shifts in both strategy and scope, and they seem to be well-received in the industries they've worked alongside.

"It acknowledges that you can save more energy by controlling a pump properly in specific applications," Gaydon said. "So I think it's a positive that they're looking at the system."

"We find that the proactive way, working together with [the DOE] to develop a standard, is more favorable," Malinowski said.

While rising efficiency standards can be a burden on the industry, the DOE does what it can to make that burden lighter, and that is something to be happy about. **PTE**

For more information:

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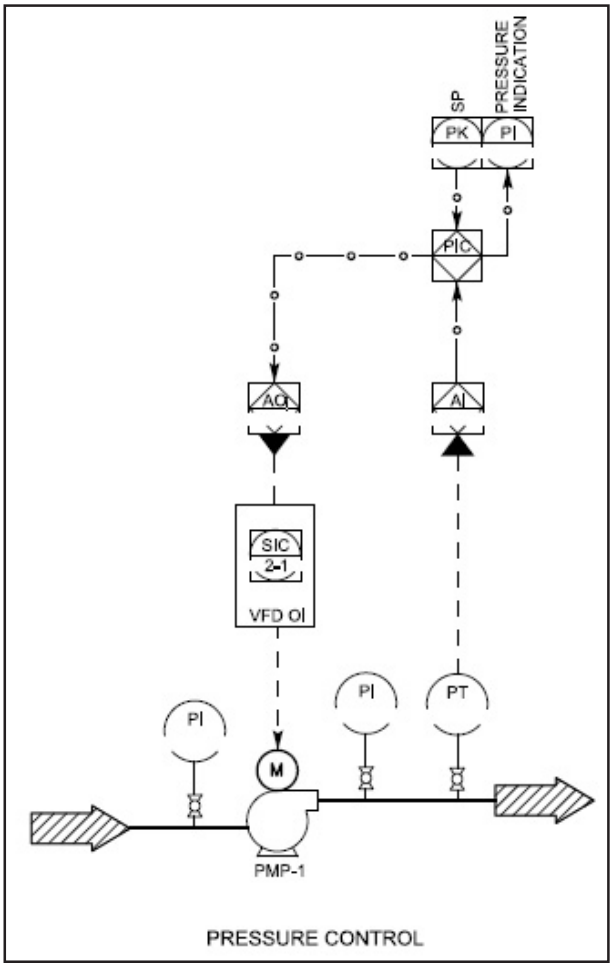

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Power Transmission Engineering

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

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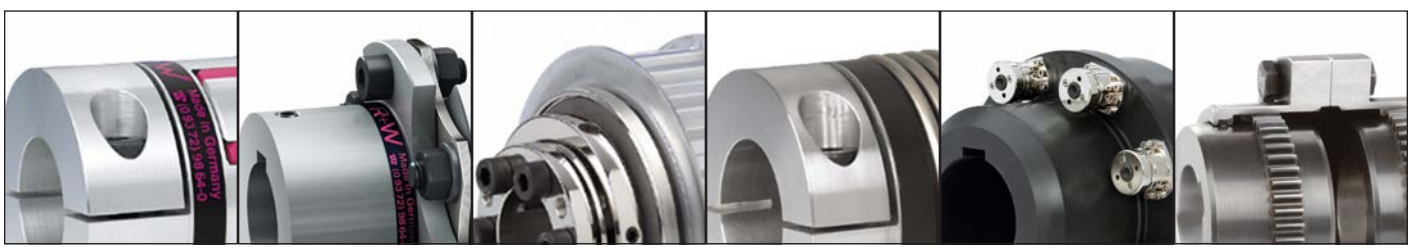

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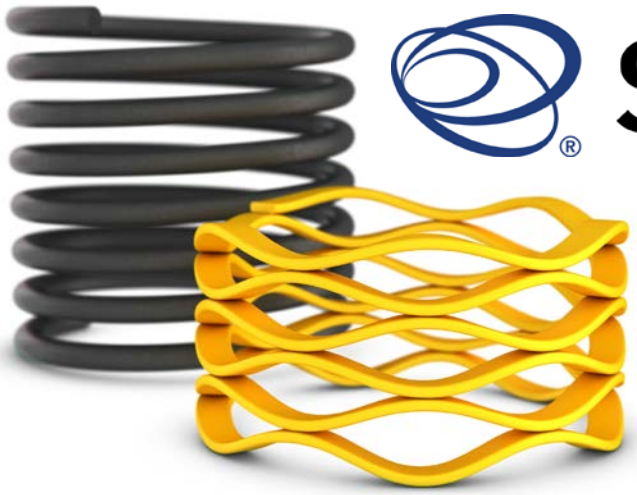

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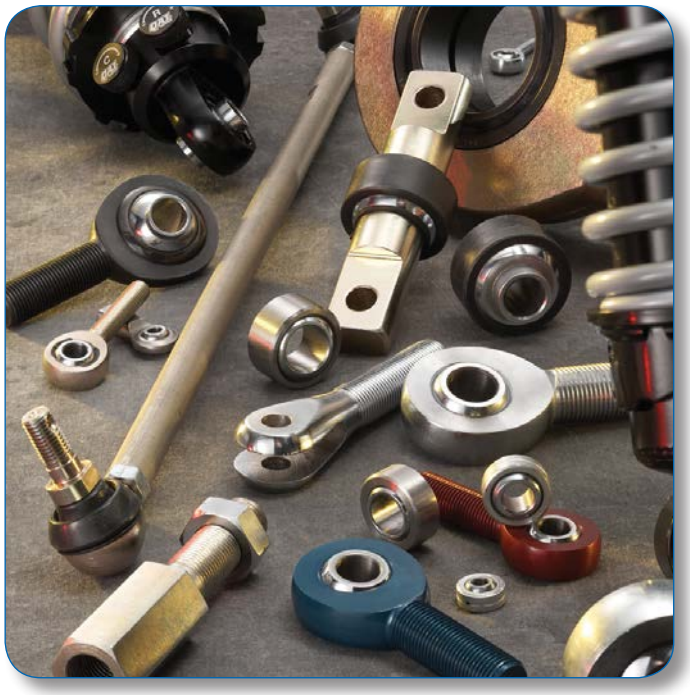

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Load Ratings & Bearing Life

Shedding Light on Bearing Standards and Performance Characteristics

Power Transmission Engineering is collaborating with the Bearing Specialists Association (BSA) on a special section within the magazine. *Bearing Briefs* will present updated reports on bearing topics for each issue in 2016. Complimentary access to all BSA Bearing and Industry Briefs is available on the BSA website at *www.bsahome.org/tools*.

Bearings are often regarded as a commodity product, however continuing advancements in materials, manufacturing, technology and design indicate that this is not the case. Unfortunately, the way these improvements are reflected in load ratings and life calculations has becoming increasingly complex and not always consistent between manufacturers. This paper aims to shed some light on this topic as a guide for those trying to make sense of the various claims and industry standards.

The current standards for load ratings and fatigue life for ball bearings and for roller bearings are defined by the International Organization for Standardization through standard ISO 281:2007. Additionally the joint American National Standards Institute (ANSI) and American Bearing Manufacturers Association (ABMA) Standard 9:1990 used for ball bearing load ratings remains in place and Standard 11:2014 used for roller bearing load ratings has been updated in 2014 to make it more consistent with ISO 281:2007. ISO/TS 16281:2008, an addendum to ISO 281:2007, recommends calculation methods to determine the modified reference rating life to include influencing parameters beyond those included in IS0 281:2007. The table (right) summarizes the principle differences between the various life calculation methods.

These standards provide the equations and factors needed to calculate the Basic Load Rating for rolling bearings of all types including various life adjustment factors, such as for reliability, for material, lubrication and for application conditions. The purpose of this report is to point out two important issues pertaining to these standards. The first is to remind distributors who have perceived themselves as "selling a commodity" that the bearing industry has made technological improvements in their product — improvements that should be emphasized with the user. You are selling a better product than you were ten years ago and should be able to explain why this is so and what it means to the user.

Content summary of standards for bearing life calculation.

	Standard				Factors Considered					
Life Method	IOS 281:2007	ANSI/ABMA 9	ANSI ABMA 11	ISO/TX 16281:2008	Dynamic Load Rating	Dynamic Equivalent Load	Lubrication	Contamination	Fatigue Limit	Internal Stress Distribution
Basic Rating Life	✔	ball brgs	roller brgs		✔	✔				
Adjusted Rating Life		ball brgs	roller brgs		✔	✔	*	*		
Modified Rating Life	✔				✔	✔	✔	✔	✔	
Modified Reference Rating Life				✔	✔	✔	✔	✔	✔	✔

The second point is that some recent improvements such as cleaner bearing steels and improved understanding/control of bearing geometry are not accurately reflected by the methods in the standards. As a result bearing manufacturers have used two different methods to show the improved performance of the bearings. The first was to keep the original load rating and apply life adjustment factors to indicate that life had improved, either in time or revolutions. The other method of showing the improvement in bearing performance was to increase the load rating of the bearings. With these two very different methods, it was difficult and sometimes impossible to determine if like bearings had similar performance characteristics.

Advances in bearing material, both standard and special, and application analysis, including effects of misalignment and lubricant quality and resulting life analysis, have been dramatic in the past few years. It is, therefore, always wise for a user to contact bearing manufacturers or their authorized distributor for current load rating and life analysis.

For more information:

Bearing Specialists Association (BSA)
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Powder Metal Gear Technology: A Review of the State of the Art

Anders Flodin

During the past 10 years, the PM industry has put a lot of focus on how to make powder metal gears for automotive transmissions a reality. To reach this goal, several hurdles had to be overcome, such as fatigue data generation on gears, verification of calculation methods, production technology, materials development, heat treatment recipes, design development, and cost studies.

All of these advancements will be discussed, and a number of vehicles with powder metal gears in their transmissions will be presented. How the transmissions have been redesigned in order to achieve the required stress levels while minimizing weight and inertia, thus increasing efficiency, will also be discussed.

Introduction

Automotive transmissions today are an important machine element for Powder Metal (PM) components. In manual transmissions, the PM synchronizer hubs have gradually replaced machined hubs over a 20-year period. Several other PM parts can be found in manual transmissions, such as synchronize sleeves and shift fingers. In epicyclical automatic transmissions, carriers have been made using PM for many years, in addition to oil pump gears. Recently, powder forged planet gears were introduced in a Ford automatic transmission (Ref. 1), thus opening up the market. Also, Getrag Ford in Cologne has taken PM gears to implementation readiness through an extensive validation program (special interest seminar Euro PM 2014, Salzburg).

Initially, the PM synchronizer hubs in manual transmissions were introduced for the higher gears that were not subjected to that many cycles, typically fourth gear, since there were concerns about durability for the highest gears. The hubs then gradually started to replace machined hubs in the higher and lower gears. Finally, within the last 5 years, PM synchronizer hubs have been introduced in first, second, and reverse gears where abuse is an issue. It took around 20 years for this to happen, and PM gears will likely experience the same cycle with respect to transmission gears. We are now in the introduction phase of PM gears for the least loaded gear stages in car transmissions, where the technology has to prove itself before replacing the more heavily loaded gears. Meanwhile, the PM industry advances their technology to be able to cope with abuse loads and severe driving conditions.

PM Gear Processing

There are several ways to manufacture a PM gear, and the route is dictated by the performance requirements since strength levels can be tailored through material and process changes. For a manual gearbox, some gears, typically fourth to fifth, could be made following this sequence:

- Compaction-Sinter-Case carburize, quench, temper (CQT)
- Hard finish (grinding/honing)

This is a four-step process and could be made even shorter by the introduction of a combined low pressure sintering and CQT process (LPC):

- Compaction-LPC-Hard finish

This three-step process provides strength levels equivalent to approximately 70% of a wrought 16MnCr5 gear, processed using conventional cutting, CQT, and grinding, with respect to tooth root bending fatigue and pitting fatigue. If more strength is required, another sinter and compaction step could be utilized to increase density to 7.4–7.5 g/cc or add a densification process that involves surface rolling of the gear flanks and sometimes in the root. This rolling process flattens out the pores in the surfaces and thus reduces porosity and the number of potential crack initiation points (Fig. 1). This rolling process has been used by Getrag Ford in their validation work; see below.

For gears, the densification takes place in the surface volume, where the highest stresses can also be found. Generally, the performance level of a good densification will give durability similar to solid steel (16MnCr5 for instance), provided all other process steps are done well.

Another method used to increase strength is to powder forge the gears, a technology that has been around since the mid-1970s but never gained popularity due to cost and difficulties with high helix angles. The process steps would be:

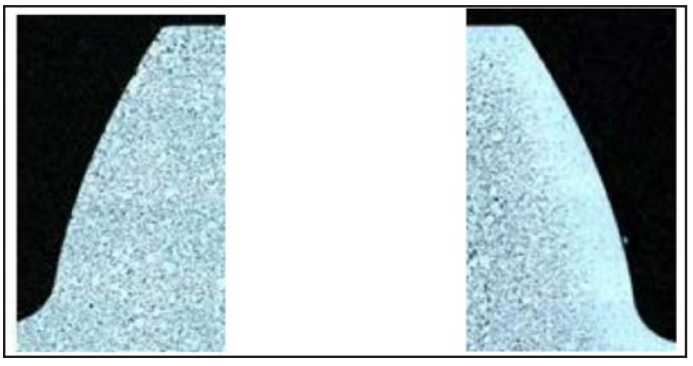


Figure 1 PM gear flanks, cut view, left: non-densified flank; right: densified flank with pore removal.

- Compaction-Sinter-Forge-CQT-Hard finish

This process would require multiple tools, and the tool wear when forging is normally quite high, making it difficult to maintain tight tolerances. Powder forging would, however, give very good strength in all parts of the gears, which is not the case, for instance, for a densified gear that lacks densification in the bore and has lower ability to redistribute stresses from impact loads. Powder forged gears were referenced in the beginning of the paper; one reason to go with powder forged gears for an epicyclical gear set is that it enables a bearing to be run directly on the powder forged bore surface since it is fully dense, in comparison to rolled gears that have a porous bore. For a manual gearbox, this is less of a problem since there is no load on the bearing while the gear is rotating relative to the shaft. There are even manual gearbox designs with no roller bearings; the gear bore itself is used as a journal bearing rotating directly on the shaft.

Another method of achieving high strength PM gears is by hot isostatic pressing (HIP) of the gear. This has not been done commercially yet, but lab-scale testing shows very good results. The process would be:

- Compaction-Sinter-HIP-CQT-Hard finish

There is also a pending patent on a process where Sinter, HIP, and CQT steps are used in sequence. This three-step processing sequence would produce a gear that is fully dense, with a microstructure qualified for nuclear power plants. So while market introduction for PM gears will be with a process giving lower but still good enough strength for certain gears, more refined processes are being developed that will open up PM for much more highly loaded gears.

Heat Treatment of PM Gears

Heat treatment of PM gears can be performed with the same type of equipment used for processing regular steel gears. Nitriding, CQT, induction hardening, etc. work well with PM, but the process parameters have to be specially tailored for these types of materials and gears. The reason is that the porosity in these gears permits much shorter processing times to be used. This also means that process control becomes much more important. A variance of 5 minutes for a 20-minute soak time for PM material is more significant than a 5-minute variance on a 2-hour soak time that is used for a solid steel gear. Material-wise, it is possible to tailor the alloying and carbon content with respect to cooling rates that can be achieved, or the desired case depth. Another important difference is the method used to measure hardness. For PM, the preferred method is Micro-Vickers (HV 0.1). Using Vickers with a 1 kg indentation weight will render low values, and the part will appear to be out of specification, even though that might not actually be the case.

PM Gear Design

Powder metal manufacturing technology offers and demands a different design approach. Conventionally cut gears are based on rack generation, but PM gears are not limited by that. Instead, the direct gear design method (Ref. 2) is better suited where the functionality of the gear dictates geometry without the influence of how a hob makes its cut.

Micro Design

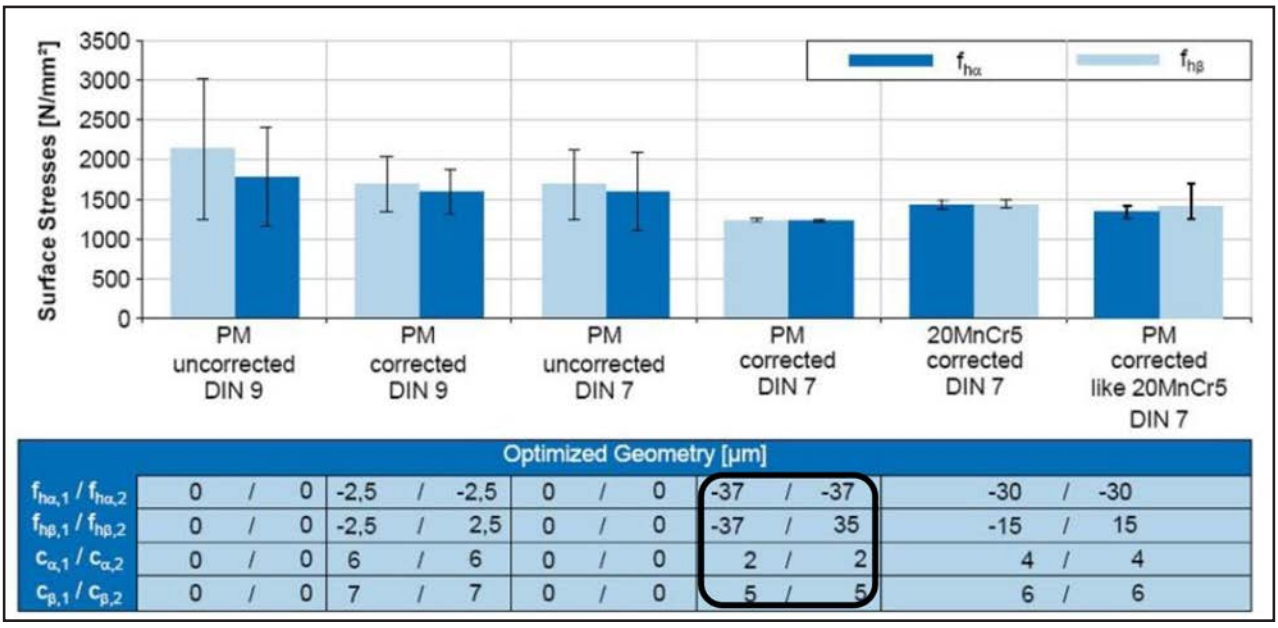
The Young's modulus is dependent on the density of the PM gear. This relationship can be described by Equation 1 (Refs. 3–4).

$$E = E_0\left(\frac{\rho}{\rho_0}\right)^{3.4} \quad (1)$$

where

E Young's modulus of PM part
E_0 Young's modulus of solid steel
ρ Density of PM part
ρ_0 Density for solid steel

This means that PM gears will deflect more than steel gears as long as they are not the same density as steel. The deflection will have to be accounted for in the micro design of the



Optimized Geometry [µm]						
$f_{h\alpha,1}$ / $f_{h\alpha,2}$	0 / 0	-2,5 / -2,5	0 / 0	-37 / -37	-30 / -30	
$f_{h\beta,1}$ / $f_{h\beta,2}$	0 / 0	-2,5 / 2,5	0 / 0	-37 / 35	-15 / 15	
$c_{\alpha,1}$ / $c_{\alpha,2}$	0 / 0	6 / 6	0 / 0	2 / 2	4 / 4	
$c_{\beta,1}$ / $c_{\beta,2}$	0 / 0	7 / 7	0 / 0	5 / 5	6 / 6	

Figure 2 Surface stress of PM with different modifications.

gears in order to maintain a good mesh and low transmission error (TE).

Figure 2 shows an example of how the micro design affects the stresses on the gears. The bars are the average value of the variation ((*Max*+*Min*)/2) when a gear pair is run within the allowable tolerances (i.e., DIN 7–9). The different colors indicate which error, $f_{h\alpha}$ or $f_{h\beta}$, is varied, while the other is kept at 0. In the far right bars of Figure 2 the modifications are optimized for steel, and those modifications are applied to PM. The result is that PM mean stresses increase slightly; but more importantly, the maximum stress the PM gear may be subjected to is 50% higher (1,200 MPa to 1,800 MPa), leading to a higher failure probability of the PM gears using a copied steel design. Instead, the micro design values in the black frame under "PM corrected DIN 7" should be used for a more robust design.

This type of analysis will determine if it is possible to use an existing micro design, or if that design is sub-optimized. The same type of analysis can be performed to predict TE, for instance.

Macro Design

PM manufacturing technology allows, to a certain extent, material to be put where it is needed. And where it is not needed, efforts can be made to remove it. Figure 3 shows the 4th drive gear in a six-speed manual transmission; it is compacted into the shape in the picture with lightening holes, bore spline, and a 32-degree helix angle. The remaining operation — setting the final shape — is teeth grinding after heat treatment. This gear is operational in a demo car and is driven every day; it is 15% lighter than the original solid steel gear. Half of the weight reduction comes from the lower density, the other half from the holes in the web.

PM Gear Materials

The choice of PM material is dependent upon the process and size of the gears. Smaller gears can utilize a leaner alloy, while larger gears typically require more alloying content due to the slower cooling rate of a larger-mass gear. If surface densification by rolling is used, low-carbon, chromium-alloyed materials seem to give better results under repetitive yielding than molybdenum alloys. Larger gears (modules around 2 mm) typically need 1.85% molybdenum or 1.8% chrome. But chrome is sensitive to oxygen content, so not all heat treatment equipment can handle it. For very fine module gears, heat treated with conventional gas carburizing and oil quenching, a leaner- alloyed material may be used since the case layer is thinner, requiring less cooling speed to avoid the bainite nose in the CCT diagram. If induction hardening is used, an alloy with 3% chrome and 0.5% molybdenum with admixed graphite, around 3%, could be a good selection. In PM gear production the choice of lubricant of the powder will play an important role. It affects productivity, surface finish and density distribution in the gear and can be the source — and remedy — to many issues in manufacturing.

Root Optimization

Another feature of direct gear design is that the root can be freely formed to reduce the bending stress. This also widens the design window and enables a different balancing of the root stress and contact stress. In Figure 3 the original gear (left) has fewer teeth and a larger modulus, compared to the PM redesigned gear (right). This increases contact ratio, reduces contact stress, and for a conventional gear, increases bending stress. However, since the root could be optimized for the PM gear, bending stress did not increase with this design change; it still decreased, compared to the bending stress of the original gear.

Figure 3 Original gear to the left and weight reduced PM design to the right.

Table 1 shows a comparison of stresses between the original gears of a six-speed manual with full fillet radius in the root, compared to the PM gears with optimized roots. The comparison has been normalized with the original steel gear stress set to 1. As can be seen, the elliptical root shape shows the best results.

There are different algorithms for constructing the root; in this case, the elliptical roots were designed using an available function in the *KISSsoft* software. Finite element models were used to cross-check the results.

Table 1 Normalized root stress for different root designs in a 6-speed manual automotive gearbox

Root form	1st input	1st output	4th input	4th outputill	6th input	6th output
Original	1	1	1	1	1	1
Spline	1	1	0.96	0.94	0.93	0.93
Elliptic	0.92	0.96	0.82	0.76	0.83	0.70

Figure 4 Left: Smart fortwo; right: Mitsubishi EVO × in WRC competition.

The lower Young's modulus for PM does not reduce the bending stress; however, it does reduce the contact stress. Contacting surfaces, if Hertz's theory is used, will have a wider semi-contact width and lower contact stresses. If two 7.25 g/cc density gears mate, the reduction in max contact stress is 14%. If a steel gear mates against a 7.25 g/cc PM gear, the reduction is 8%. Therefore it is favorable to run PM against PM since contact stress is reduced the most.

Efficiency studies have been conducted (Ref. 5) where PM and solid steel FZG type C gears were used in a dedicated back-to-back gear tester built by Strama machines in Germany. This machine has the capability to measure frictional losses in gear contacts when using different oils, for instance. In Sosa's work, no conclusive results were found, regarding a difference in efficiency between PM and steel gears; what *was* found was that the scatter in the results was less for PM. The reasons for this are still under investigation. It could be caused by the machine dynamics, assembly errors of the gears, or difference in frictional behavior between the two materials.

Application Examples

A Smart Fortwo (*Ed.'s note: The Smart Fortwo is a rear-engine, rear-wheel-drive, 2-seater, 2-door hatchback city car manufactured and marketed by the Smart division of Daimler AG, introduced in 1998*) was used as a test platform for a redesigned and rebuilt PM transmission. Seven gears were made in PM and put in the transmission, which is of the AMT type. The transmission was run for more than 180,000 km (112,000 miles) without failures or noise issues; see Figure 4. The process for making these gears was:

- Compaction-Sinter-CQT-Hard finish

The max contact stress for these gears is around 1,000 MPa, and the max bending stress varies from 380 MPa to 500 MPa, or within reach for PM. The transmission remains in service and the car is driven every day.

A rally car was also rebuilt with PM gears to prove that the strength of PM is a matter of material and process know-how. The car was in competition for three years, and in the final year, all gears were made using PM. No problems were ever recorded with the PM gears in this extreme application.

The process used for the rally car dog-box was:

- Compaction-Sinter-HIP-CQT-Hard finish

During these three years, several track cars (Mitsubishi EVO IX Rally edition) were equipped with a PM transmission where the 4th gear stage was made in PM, using the same process route as for the smart car (no HIP), and was test driven over 1,000 km (620 miles) on racetracks with this non-synchronized race box. After 1,000 km the gearbox was disassembled and the gears inspected; there were no visible damages.

The smart car and the rally car represent two opposite types of vehicles. To close the gap a Saab 95 six-speed manual was redesigned from scratch, keeping only the housing and final drive

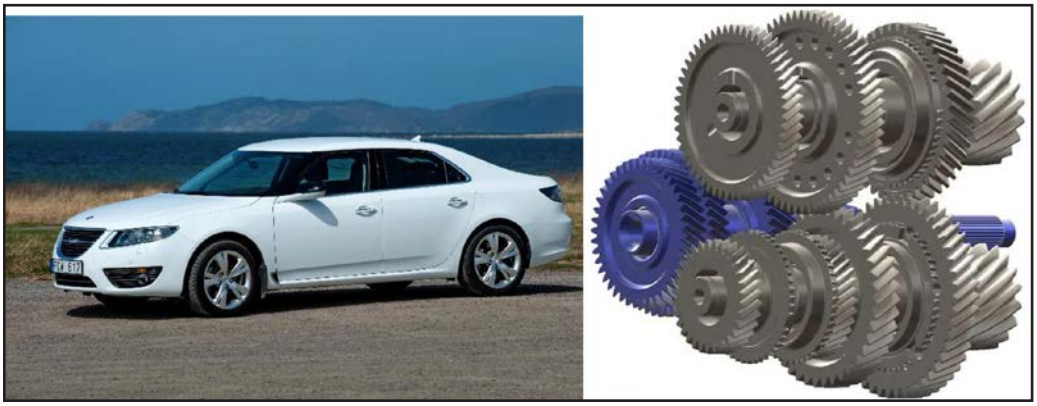


Figure 5 Left: Saab 95 demo vehicle; right: CAD model of transmission.

Piece costs (total cost)

Cost in Euro	Steel gear 4:th gear Fixed	Steel gear 4:th gear Loose
Forged Rough Part		
Material Cost	0,65	0,65
Manufacturing Cost & Profit	0,75	0,75
Soft Machining Costs		
Turning, Hobbing …..	2,5	3,3
Subtotal	**3,9**	**4,7**

Cost in Euro	PM gear 4:th gear Fixed	PM gear 4:th gear Loose
PM rough part		
Material Cost	0,5	0,6
Manufacturing Cost & Profit	3	3
Packaging & Transportation	0,2	0,2
Subtotal	**3,7**	**3,8**

Includes direct and indirect labour
Manufacturing costs (variable and fixed)
Overhead
Manufacturing conditions
Green Field
Manufacturing in Western Europe

400 000 parts/year
2 derivatives:
Diesel and gasoline

Figure 6 Cost breakdown comparison between steel and PM — before CQT and hard finishing (with permission from Dr. Strehl at Getrag Ford).

(Fig. 5).

The Saab has made it through several OEM test drive sessions with flying colors. The gears have 35, 000 km (21,748 miles) of usage without problems. The analytical work behind the design predicts 300, 000 km (186,400 miles) with 99% reliability. In order to cope with the high stresses on first, second, and reverse asymmetric gears, (2nd gear stage) and Convoloid gears (1st and reverse) are used. A total reduction of 1.1 kg of material was achieved, thanks to PM technology. This car is also in service and driven every day.

Cost

The cost reduction often associated with PM technology is one of its major benefits. For gears, that is most often true as well; however, it is a case-by-case scenario. Sometimes, gears are bundled in a package, and the cost of one of the parts subsidizes another. In addition, depreciation of the machines and how the cost is calculated in-house versus by an external supplier will also serve to influence the overall cost comparison. There are union issues, supplier base issues, investment decisions, policies, etc. that play an important role rather than just the techno-commercial facts. Getrag Ford made an interesting presentation (Ref.6) on cost analysis (Fig. 6), where cost was compared between in-house production and buying a PM gear as sintered. The PM gear came out cheaper, even though the process with roll densification was used. PM gears will likely be the choice when capacity has to be increased for existing platforms or when new plants have to be built. The investment cost can then be reduced by around 30%, since much of the soft machining equipment and the floors pace do not have to be part of the investment (Ref.7).

Another untapped opportunity is the ring gear in automatic transmissions, where PM has an even greater potential to reduce cost and improve performance. This will be the next step in the development of PM gears where the isotropic material behavior will reduce scrap-rate from CQT, and the roll forming process can shape the gear teeth in the lead direction, creating very smooth surfaces.

Summary

- This paper has addressed both the technical aspects of PM gear technology as well as some of the commercial question marks. Today PM gears can replace many existing gears in automotive applications, and it is in the starting blocks for a few future transmission platforms, which is a great breakthrough. The technology will gradually gain ground as it develops and as confidence is built up in the automotive gear community. This has been the pattern for timing gears in engines, synchronizer hubs, and other high-end components in PM steel.
- Some design aspects that the gear designer needs to keep in mind in order to get the most out of PM gears has been presented, together with implemented designs in different types of demo vehicles.
- Process and materials have been discussed, where fewer process steps and shorter processing times with PM have been presented.
- OEM cost reduction has been demonstrated by examples referenced from Getrag Ford.
- Also, PM gear strength is material and process dependent. The material and process for making gears or parts can be tailored to suit the intended application requirements to match any solid steel part. The choice then becomes dependent on total cost and what supply chains are available. **PTE**

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Gear Design Effects on Performance of High-Speed Helical Geartrains as Used in Aerospace Drive Systems

Robert Handschuh, Charles J. Kilmain, Ryan T. Ehinger, and Eric A. Sinusas

The performance of high-speed helical geartrains is of particular importance for tiltrotor aircraft drive systems. These drive systems are used to provide speed reduction/torque multiplication from the gas turbine output shaft and provide the necessary offset between these parallel shafts in the aircraft. Four different design configurations have been tested in the NASA Glenn Research Center, High-Speed Helical Geartrain Test Facility. The design configurations included the current aircraft design, current design with isotropic superfinished gear surfaces, double-helical design (inward and outward pumping), increased pitch (finer teeth), and an increased helix angle. All designs were tested at multiple input shaft speeds (up to 15,000 rpm) and applied power (up to 5,000 hp). Also two lubrication, system-related, variables were tested: oil inlet temperature (160–250° F) and lubricating jet pressure (60–80 psig). Experimental data recorded from these tests included power loss of the helical system under study, the temperature increase of the lubricant from inlet to outlet of the drive system and fling-off temperatures (radially and axially). Also, all gear systems were tested with and without shrouds around the gears.

The empirical data resulting from this study will be useful to the design of future helical geartrain systems anticipated for next-generation rotorcraft drive systems.

Introduction

Rotorcraft drive systems are critical to the high efficiency and lightweight requirements of the propulsion system. Tiltrotor aircraft, as currently designed, utilize the drive system as a means to fly — even when one engine is inoperative through the use of shafting and other gearboxes to connect the two rotors together. A sketch of the entire propulsion system is shown (Fig. 1) and a close-up of the wing-tipped nacelle propulsion system is shown in further detail (Fig. 2) (Ref. 1).

Also in a tiltrotor aircraft, the entire propulsion system is required to tilt from the vertical position (helicopter mode) to that of the horizontal position (forward flight — airplane mode). These unique capabilities allow this aircraft to fly at a high rate of speed in the airplane mode and land vertically, greatly enhancing the aircraft's usefulness in fulfilling a number of military missions.

The drive system contained within the prop-rotor gearbox connects the parallel shafts of the gas turbine engine to that of the propeller via a geartrain of helical gears. The geartrain operates at high rotational speeds that produce high pitch line velocity of the gears that can affect the overall drive system

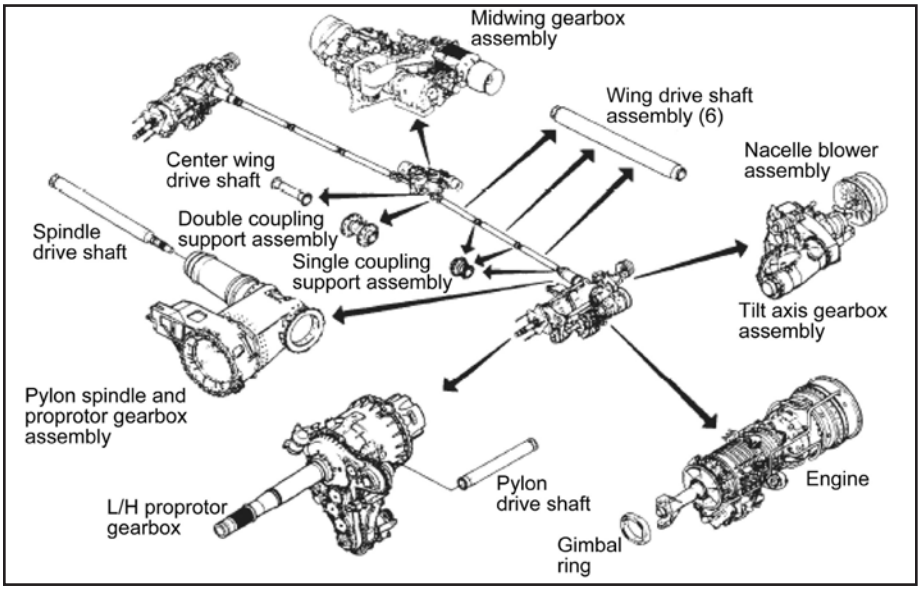

Figure 1 Tilt rotor propulsion system components (Ref. 1).

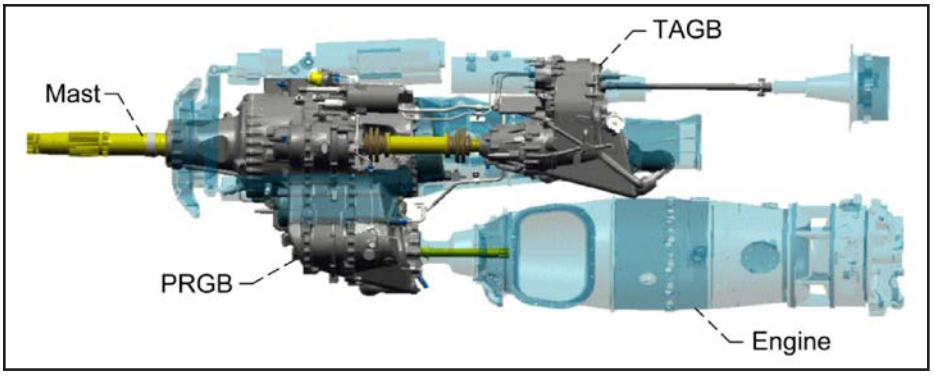

Figure 2 Propulsion system components that reside within aircraft nacelle — tilt axis gearbox (TAGB), and prop-rotor gearbox (PRGB).

This paper was first presented at the 69th Annual Forum and Technology Display [Forum 69] sponsored by the American Helicopter Society, Phoenix, Arizona, 2013

performance through an increase in windage power losses *(Windage is the air resistance of a moving object, such as a vessel or a rotating machine part, or the force of the wind on a stationary object.)*. It is of the utmost importance for drive system efficiency to make the transition from the gas turbine engine to the propeller with the minimum amount of power loss. High power loss is absorbed by the lubricant, or expelled through the gearbox housing in the form of heat. Therefore improved performance of the gearbox can result in more power available to the rotor, increased load capacity, or extended range.

The objective of this study is to experimentally determine how operating conditions, gear design, and gear shrouding can influence the performance of high-speed helical gear trains, as used in tiltrotor aircraft.

Test Facility, Test Hardware and Test Method

Test facility. The test facility used in this study is the high-speed helical geartrain test facility located at NASA Glenn Research Center just outside Cleveland, OH (Ref. 2). The test facility arrangement is shown (Fig. 3), as is a sketch of the key test system components (Fig. 4).

Referring to Figure 3 for the discussion, the facility operates as a closed-loop test facility. Power is circulated from the test gearbox to the slave gearbox and then returns to complete the torque loop. A rotating torque actuator in the slave gearbox provides an adjustable loop torque while the drive motor must provide for all of the gear, bearing, and windage losses. With the current components, up to 5,000 hp can be circulated around the test to the slave gearbox loop. The high-speed shaft, simulating the power turbine shaft, can be rotated to 15,000 rpm. Most of the test conditions that will be reported in this paper have to do with the hover and forward flight speed conditions. The drive system input shaft rotates at 15,000 and 12,500 rpm, respectively, at these conditions. Both gearboxes have separate lubrication systems that include supply and scavenge pumps, filters (3 μm), heaters, heat exchangers, etc. The test and slave gearboxes operate in a dry sump mode where the lubricant that is jet-fed to the gears and bearings is removed immediately after lubricating and cooling via the scavenge pumps. For all the data presented in this report, the slave gearbox operating conditions were constant, at ~160° F lubricant inlet temperature, and ~80 psi jet pressure.

Test hardware. The gearing components used in the test program included four different gear designs. There is the baseline (currently used aircraft design), baseline with isotropic superfinishing (ISF), double-helical, fine pitch, and increased helix angle designs. The design information for all four cases is provided in Table 1. The same gear material, Pyrowear 53, was used in all gearing components and all were manufactured with the same surface finish and gear quality. A photograph of the input gear designs is shown (Fig. 5). The gearing components are shown dur-

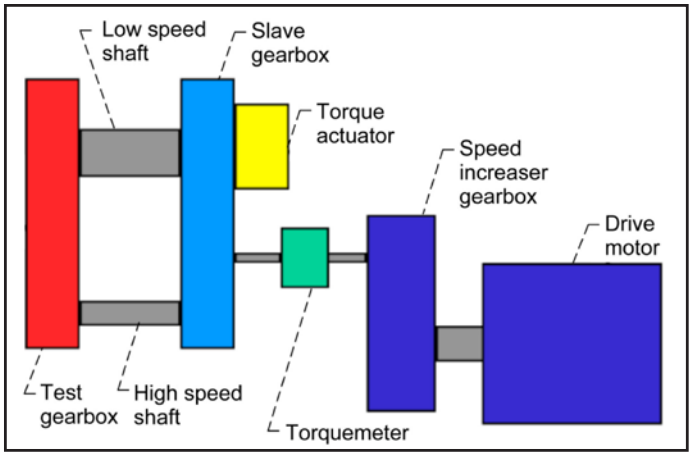

Figure 3 Test facility arrangement.

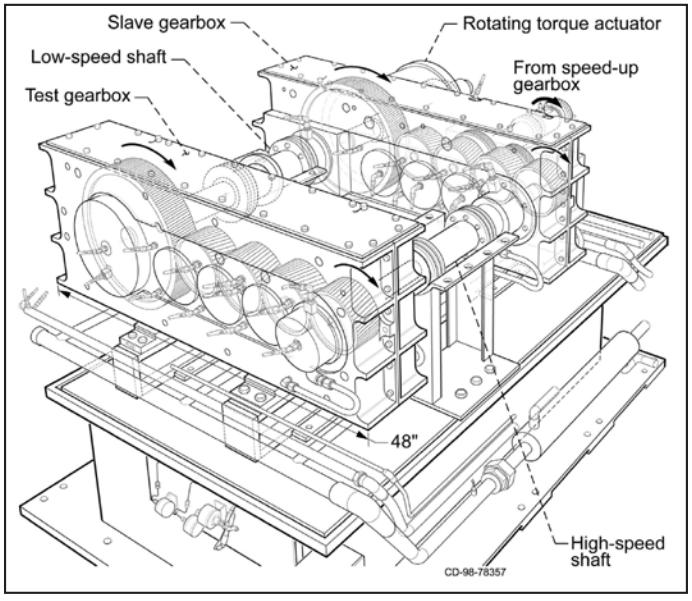

Figure 4 Sketch of test facility primary components.

Figure 5 Photograph of input gear designs; baseline, baseline + ISF, double-helical, fine pitch, and increased helix angle.

Table 1 Basic gear design information

	Baseline design	Double helical design	Fine pitch design	Increased helix angle design
Number of teeth, input and 2nd idler/lst and 3rd idler/bull gear	50/51/139	50/51/139	70/73/196	50/51/139
Normal module, mm, (diametral pitch, (1/in.))	3.033 (8.375)	2.540 (10.000)	2.142 (11.858)	2.9136 (8.7177)
Face Width, mm (in.)	66.68 (2.625)	78.23 (3.08)	66.68 (2.625)	66.68 (2.625)
Normal pressure angle, deg.	20	20	20	20
Transverse helix angle at pitch diameter, deg.	12	35	12	20

Figure 6 Baseline test hardware during installation.

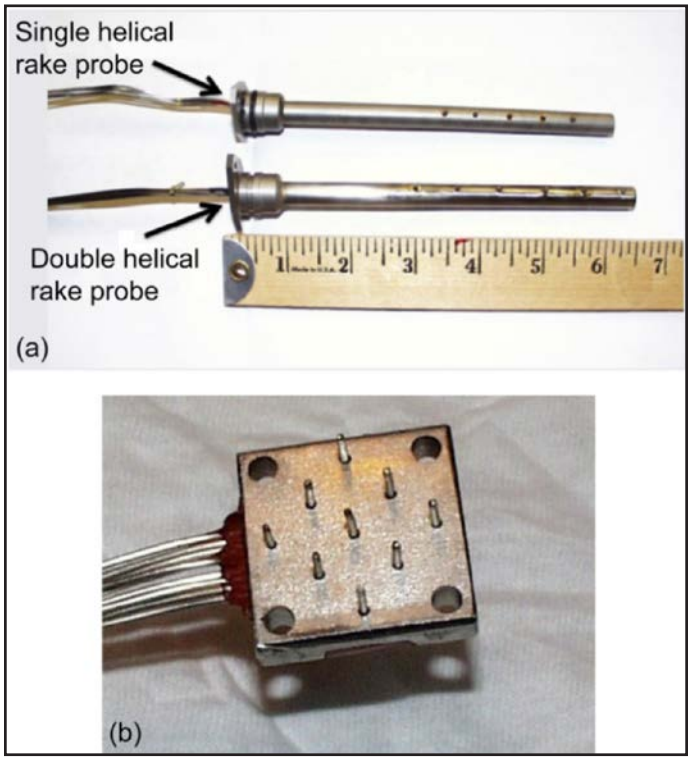

Figure 7 Rake probes (a) and array probe (b).

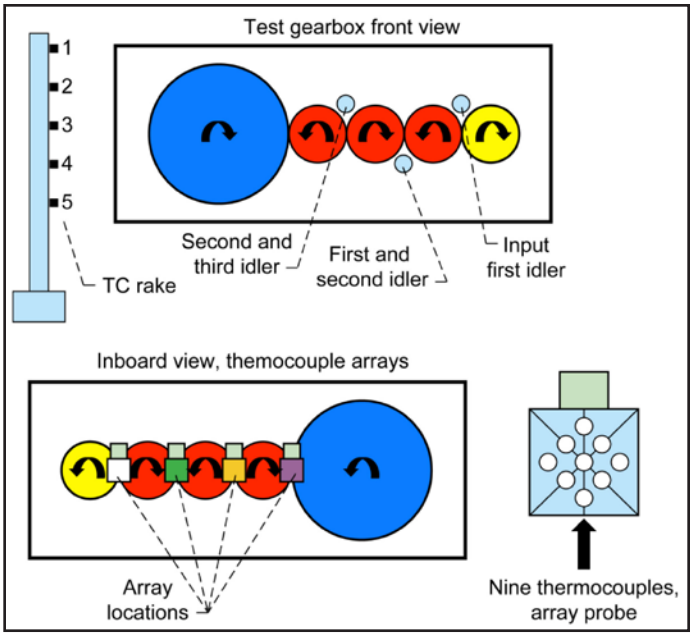

Figure 8 Locations of the rake (a) and array (b) probes in test gearbox.

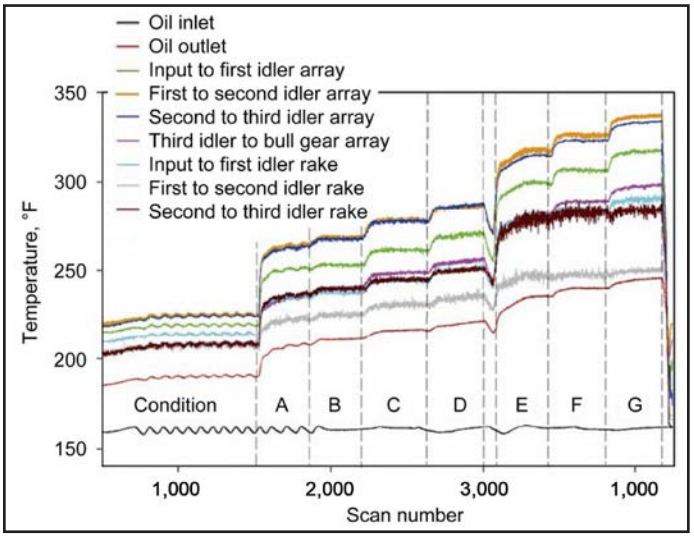

Figure 9 Temperature data at mid-face of rake and at array probe center for all sensor locations (conditions shown in Table 2; one scan = 2 sec, 160° F oil inlet temperature) super-finished baseline design test results.

ing their installation into the gearbox housing (Fig. 6, baseline design).

Test method. The test facility was operated at all conditions at such length to establish steady state conditions. This typically took ~5 min to attain once the first test condition was reached. An example of this will be presented later in this paper. Data taken was stored remotely for playback, if needed. The rate of data acquisition for all tests was 0.5 or 1.0 Hz.

Test gearbox instrumentation. The test facility provided for five operational condition measurements: 1) drive motor power; 2) drive motor speed; 3) test system loop power; 4) lubricant pressure; 5) and all the facility temperatures. Drive motor power to the facility is monitored via a commercially available torque meter. Loop power is measured using a torque-bridge telemetry system attached to the bull gear connect shaft between the test and slave gearboxes. A plethora of thermocouples monitor the lubricant, gearbox housing, bearings, and fling-off temperatures. Fling-off temperatures are found via two different probe types.

Rake and array thermocouple probes were designed and fabricated to indicate the lubricant temperature radially flung off and axially pumped, respectively (Ref. 3). The two different probe types are shown (Fig. 7). The rake probes had five thermocouples across the face width of the gear (six for double-helical design) and the array probe had nine thermocouples in a 25.4-by-25.4-mm (1-by-1-in.) substrate.

Both probes were located very closely to the mesh position of the gears; rake and array probes were located within the test gearbox (Fig. 8).

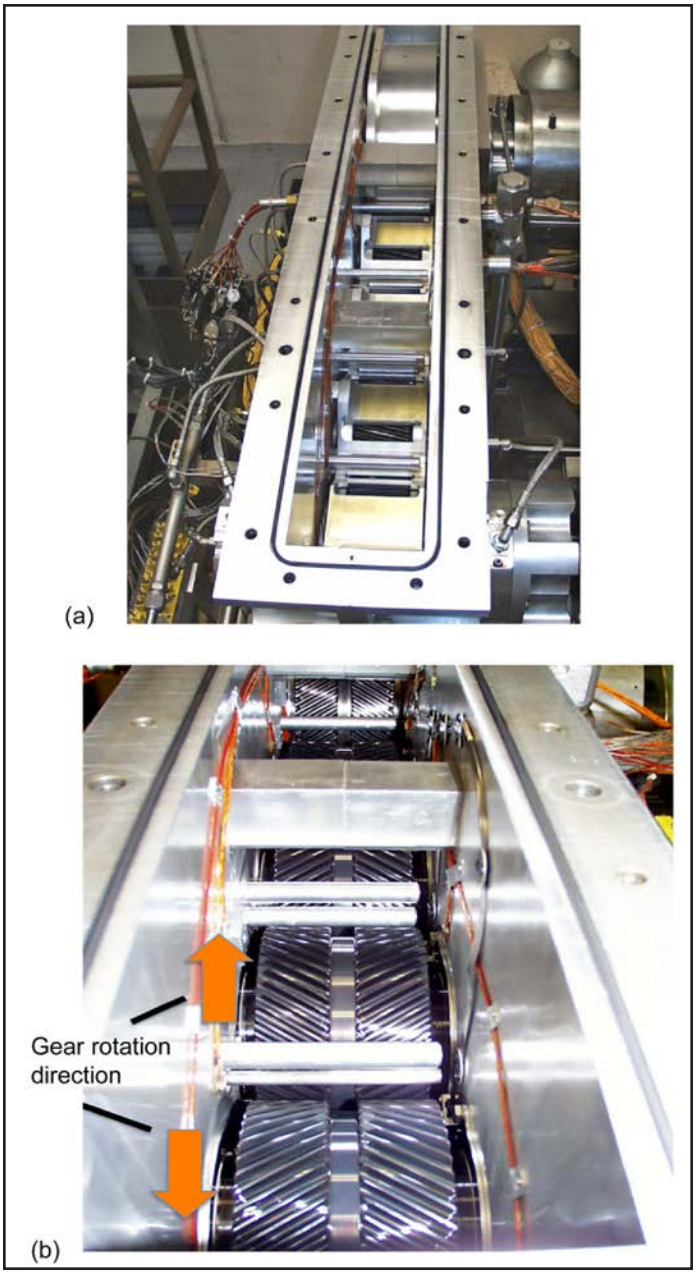

Figure 10 Test gearbox with the shrouding installed and removed — a) shrouding installed (baseline); b) shrouding removed (double-helical inward pumping).

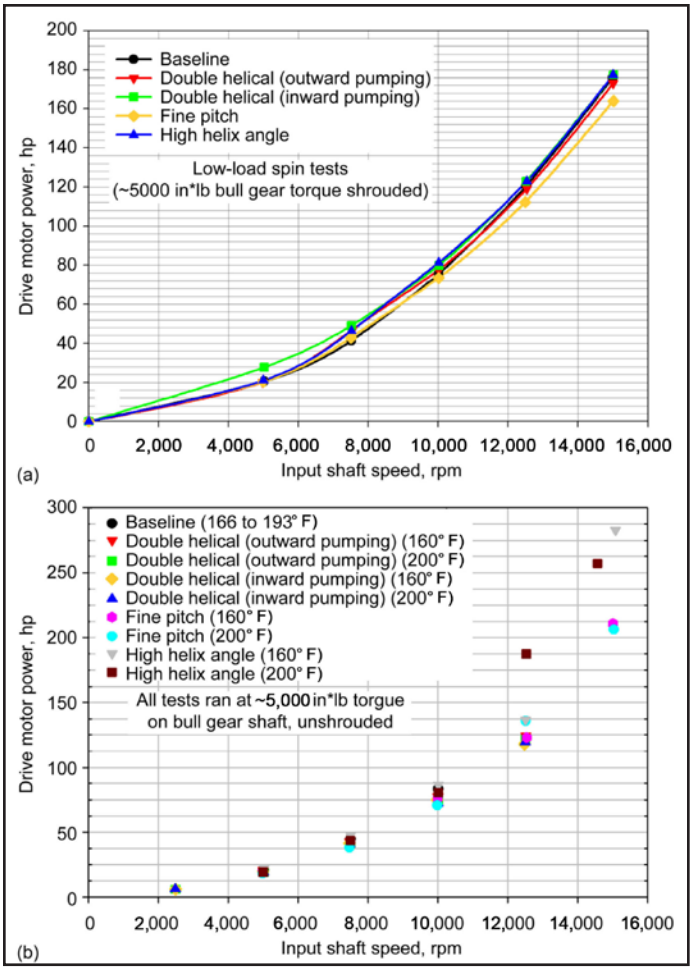

Figure 11 Spin loss data for (a) shrouded and (b) unshrouded conditions.

Table 2 Conditions for Figure 9. Gears were baseline design, superfinished, and 160° F oil inlet temperature

Condition	Input shaft speed (krpm)	Lower power (hp)	Temperature increase across gearbox (° F)	Drive motor power (hp)
A	Warm up			
B	12.5	1,379	50.6	138.0
C	12.5	2,801	55.1	149.2
D	12.5	4,170	59.7	160.1
E	15.0	1,657	73.8	201.9
F	15.0	3,366	79.1	213.2
G	15.0	4,986	83.0	225.1

Test Data

Test operation. Test operation was conducted in the following manner. First the rotational speed and applied load were established and then the temperatures of the facility were allowed to come to steady state, once the oil inlet and outlet temperatures stabilized. An example of a typical time history of a test is shown (Fig. 9) for the conditions given in Table 2 (Ref. 4). In the data to be presented, values from all important variables will be presented at a steady state operating point.

Spin loss data. In order to understand the drive system losses, experimental tests were conducted to full speed (except in some unshrouded cases) at approximately 10% of the full torque of the facility. The data generated was for the various gear designs — with and without shrouding. The test gearbox (top cover removed) with the shrouding installed is shown (Fig. 10(a)) and shrouding removed in (b).

The results from the shrouded and unshrouded tests are shown in Figures 11(a) and (b), respectively. The shrouded gear tests were run at ~160° F lubricant inlet temperature. The unshrouded gear tests were run for most of the gear designs at two lubricant inlet temperatures — ~160 and 200° F.

The non-linear increase in drive motor power requirement for these tests resembles the windage power loss curves generated in Reference 5. The data plotted in all the curves here, and those to come later with respect to "drive motor power," refer to the entire test system (test and slave gearboxes). As shown (Fig. 11(b), for the high helix angle gear design, the facility could not stably run at the 12,500 and 15,000 rpm conditions in the unshrouded case. This is an indication of the windage from the gears interrupting the scavenging of lubri-

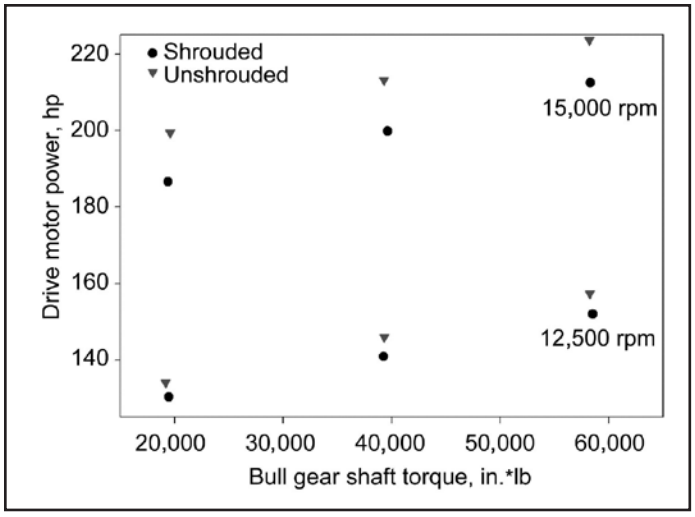

Figure 12 Effect of shrouding on drive motor power. Double-helical gears, outward pumping 200° F oil inlet temperature.

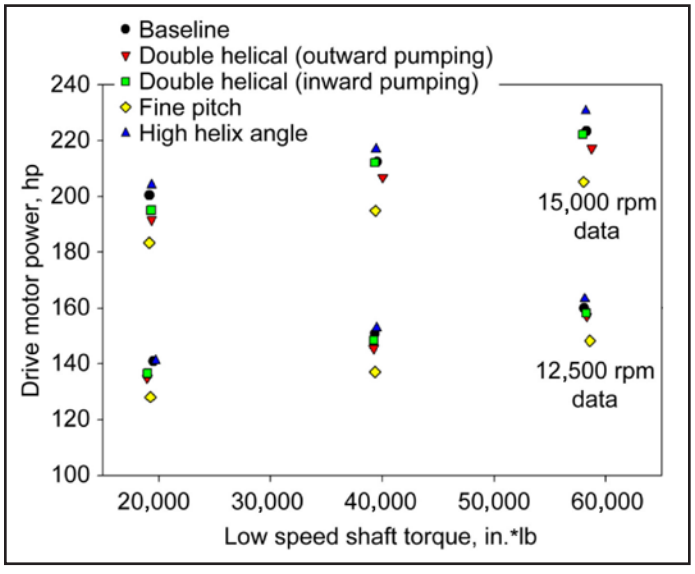

Figure 13 Effect of gear design shrouded on drive motor power, 160° F lubricant inlet temperature.

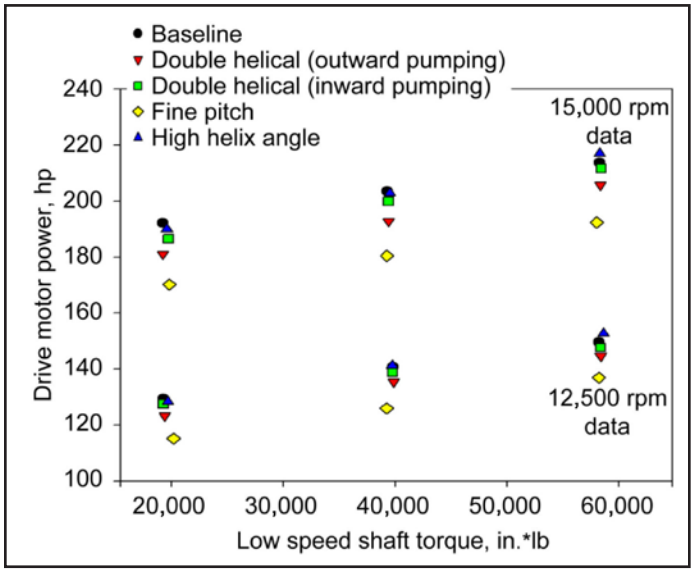

Figure 14 Effect of gear design (shrouded) on drive motor power, 250° F lubricant inlet temperature.

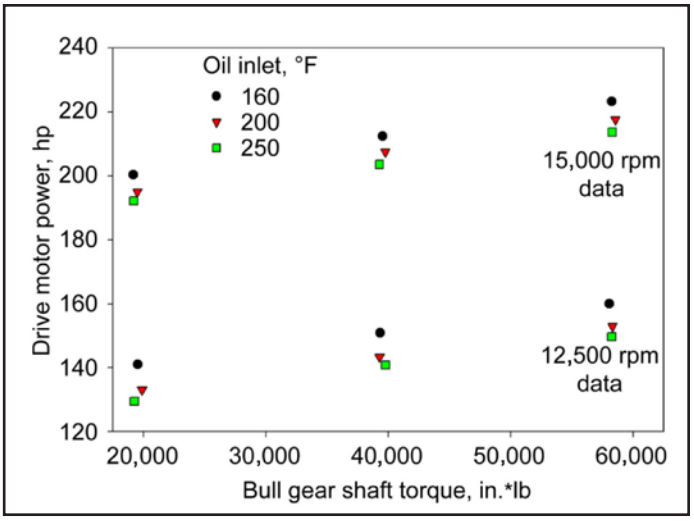

Figure 15 Lubricant inlet temperature effects on drive motor power required (gears shrouded).

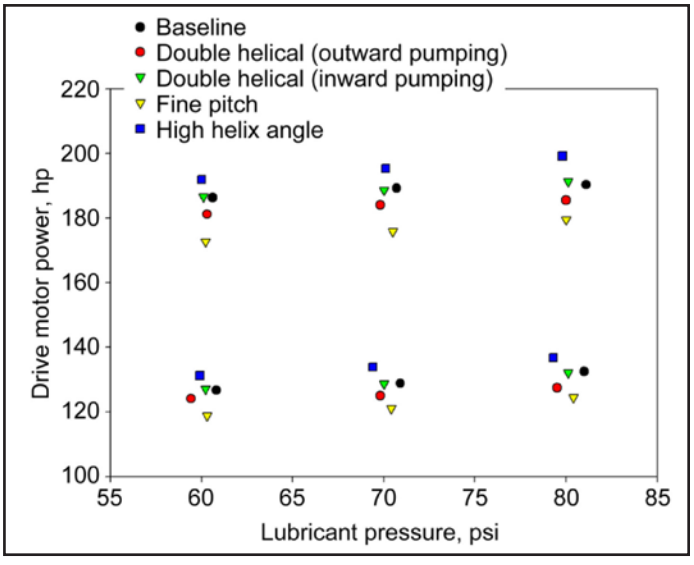

Figure 16 Lubricant pressure effects on drive motor power requirements; shrouded gears, ~19,000 in.*lb torque, 200° F oil inlet temperature.

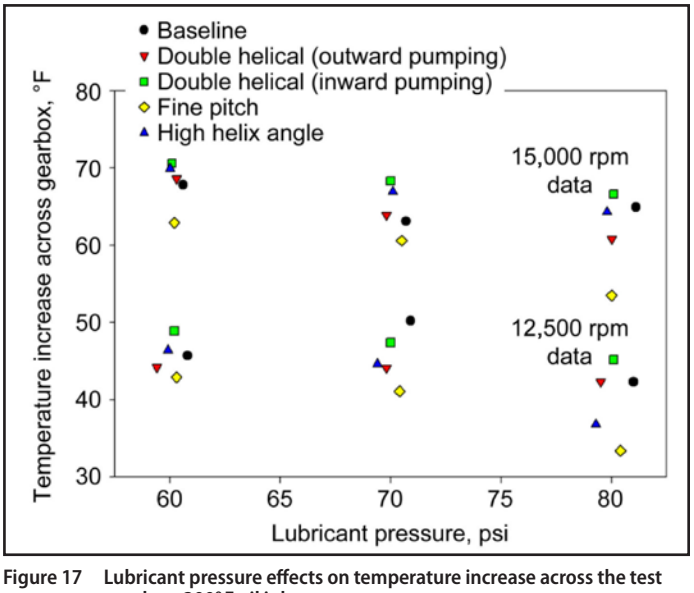

Figure 17 Lubricant pressure effects on temperature increase across the test gearbox, 200° F oil inlet temperature.

cant from the test gearbox.

A comparison of the double-helical — outward pumping design — is shown (Fig. 12). The data indicates the effect of having the shrouds installed. The drive system power requirement difference is a direct measurement of the shroud effectiveness at a given speed and torque combination. Note that rotational speed change is far more important than the level of applied load, meaning that the windage part of the losses is dominating the drive motor power requirements.

Gear design effects. An indication of how the different gear designs affect the performance for the same operating conditions for all four designs is addressed in this section. In Figure 13 the design effect is shown at 160° F lubricant inlet temperature and in Figure 14 at 250° F lubricant inlet temperature as a function of applied bull gear torque at two different rotational speeds. Both figures were for shrouded gears.

It is apparent from these two figures that the rotational speed had the largest effect on the results for a given design. Higher lubricant inlet temperature reduced the power requirement, and the baseline or high helix angle designs produced the largest power requirements. The fine pitch design produced the lowest power requirements for all conditions shown. This result must be tempered by the fact that the test and slave gearboxes had this type of gearing, therefore the power savings of an individual gearbox would be similar to that of the double-helical gear design that were operated in the outward pumping arrangement.

As an example of how the lubricant inlet temperature affects the power loss of a given configuration is shown (Fig. 15). In this figure the drive motor power is plotted vs. bull gear shaft torque for two input shaft speeds for the baseline design. Higher lubricant inlet temperature reduces the power loss of the geartrain at all speed and load conditions. For the baseline design this resulted in a ~10 hp reduction in power loss by increasing the lubricant inlet temperature from 160 – 250° F.

Lubrication jet pressure tests. Three lubricant jet pressure (flow rate) conditions are shown for the two speed conditions and one level of applied load (~33 percent of full torque). The drive motor power required is shown in Figure 16 and the lubricant temperature increase across the gearbox (exit temperature minus inlet temperature) is shown (Fig. 17). In either figure the lower symbol for a given design is the 12,500 rpm data and upper symbol is the 15,000 rpm data. As would be expected, higher flow rate of lubricant reduced the temperature change, but higher jet pressure (flow) increased the power loss for all conditions. The fine pitch design had the lowest drive motor required (note fine pitch gears were installed in both the test and slave gearbox) and minimum temperature increase for any rotational speed or loop torque requirement.

Internal gearbox instrumentation. The final comparison to be made in this paper is how the instrumentation inside the gearbox, and fling-off temperatures, were affected by gear designs and operation conditions. As described earlier, rake probes (radial) and array probes (axially) will be used to generate the data discussed here. The data presented was the maximum from any of the three rake probes or the four array thermocouple sensors. Generally speaking, the highest

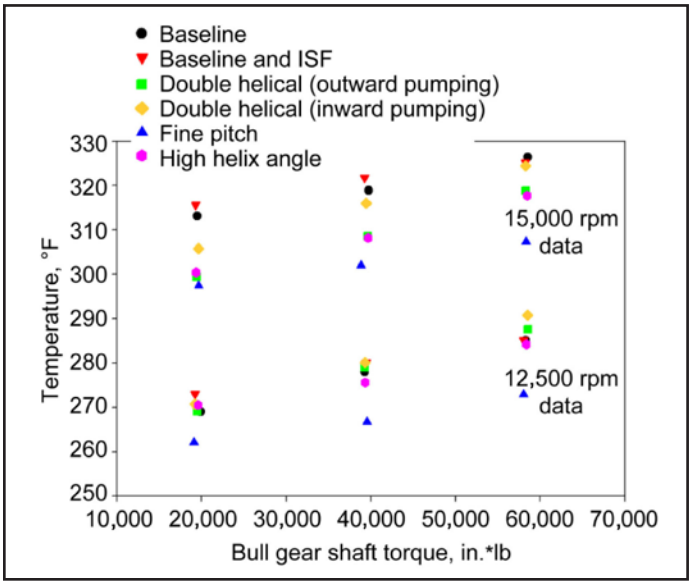

Figure 18 Rake probe lubricant fling-off data, maximum for a given speed and load condition, 200° F oil inlet temperature.

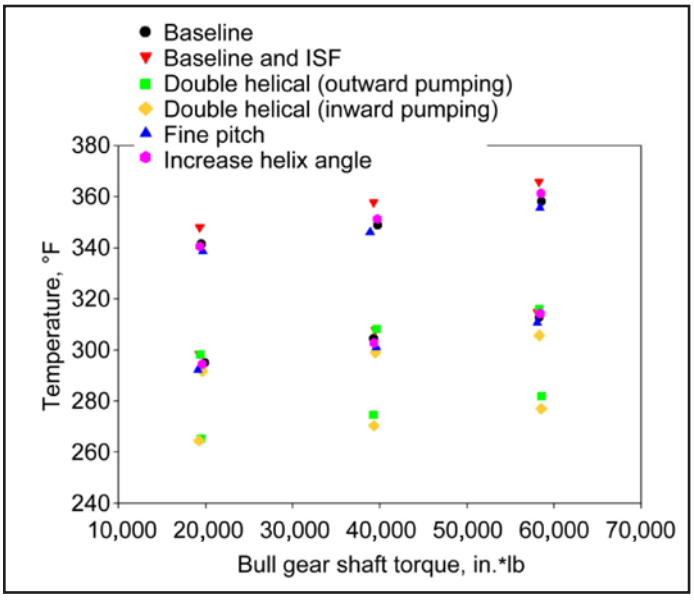

Figure 19 Array probe fling-off data, maximum values for a given speed and load, 200° F oil inlet temperature (Note: Data at higher symbol is at 15,000 rpm, and lower symbol 12,500 rpm).

temperature locations were those at the idler gear positions.

An example of the rake probe data is shown (Fig. 18); the lubricant inlet temperature for this data was 200° F. Six different test configurations are shown — all with the gears shrouded. As with all the other data presented in this study, the fine pitch gear design performed the best, and rotational speed was a larger factor than applied load on the results. The fling-off temperature from the rake probes could be in excess of 125° F higher than the lubricant inlet temperature.

An example of the array probe data is shown (Fig. 19). This data was also taken at the same inlet lubricant temperatures as the data from Figure 18. This data requires a little more explanation than the rake data. The array probe data is influenced by the axially pumped air-lubricant mixture due to the helical gear meshing action. For the single helical gear designs, the air-lubricant mixture expended from the ends of

the teeth impinge directly upon the array sensor. Therefore the single helical gear design data is clustered at a higher temperature than either of the double-helical results. The outward pumping helical gears have approximately one-half of the face width before the air lubricant mixture impinges on the array sensor. The distance that the air-lubricant mixture is pumped in a single helical gear is the complete face width. Therefore single helical results would be expected to have a higher, axially pumped, measured temperature.

Conclusions

Based on the results attained in this study, the following conclusions can be made:

- High-speed gearing benefits from the use of shrouding when the pitch line velocity exceeds ~15,000 ft/min. At conditions above this pitch line speed, the windage losses can dominate those from other sources (gear meshing and bearing losses). Gear design characteristics can also impact the drive system power losses. For the tests conducted in this study, the fine pitch gear design had the least power loss and lowest temperature increase of the lubricant across the gearbox.
- Lubricant inlet temperature changes indicated that higher inlet temperature required less drive motor power for identical conditions for all designs.
- Lubricant jet pressure (flow) affects the power loss and temperature change from inlet to exit of the gearbox. Lower flow resulted in less power required, but resulted in an increase in temperature across the gearbox.
- Special rake and array probes indicated that the temperature of the lubricant that is flung off radially and pumped axially far exceeds the bulk flow temperature exiting the gearbox. The temperature rise can exceed 125° F radially (rake probe), and 165° F axially (array probe) — depending on speed, load and other conditions applied. **PTE**

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Dr. Robert Handschuh has over 30 years of experience with NASA and Department of Defense rotorcraft drive system analysis and experimental methods. He has served as the Drive Systems team leader for the Tribology & Mechanical Components Branch at NASA Glenn Research Center in Cleveland, Ohio for over 15 years, and currently leads the research there in high-speed gearing, including windage, loss-of-lubrication technology, and hybrid gearing. Handschuh is credited with successfully developing many experimental research test facilities at Glenn, and has conducted testing in the following areas: high-temperature, ceramic seal erosion; blade-shroud seal rub; planetary geartrains; spiral bevel gears and face gears; high-speed, helical geartrains; single-tooth-bending fatigue; and high-speed gear windage.

Charles (Charley) J. Kilmain is Repair Strategy Lead for Bell's Customer Support and Service organization and is responsible for further developing aftermarket support, overhaul, and repair strategies. In this responsibility he is able to leverage his over 30-year engineering career at Bell with positions of Director of Mechanical Systems, Director of Operations, and Director of Production Engineering. Kilmain started in Bell's drive system design group on the FSD V-22 proprotor gearbox and has increased in responsibility since. Kilmain has worked within military and commercial production programs, helicopter and tilt-rotor design, pre-design, and R&D programs, and manufacturing. He is also Chairman of the University of Maryland Mechanical Engineering Visiting Committee, where he graduated in 1985 with a BSME. Kilmain is a longstanding AHS member serving on various committees and has several publications and patents in related fields.

Ryan T. Ehinger currently serves as Chief Engineer for Bell's V-280 Valor advanced tiltrotor program, and has held previous positions there including Program and Technology Manager for the Bell Helicopter/Army Aviation Applied Technology Directorate (AATD); Future Advanced Rotorcraft Drive System (FARDS) program; and Drive System IPT Lead for the Bell Helicopter/AATD Operations Support and Sustainment Technology (OSST) program. He holds a BS in Mechanical Engineering from Texas A&M, an MS in Engineering Management from Southern Methodist University, and was hired by Bell Helicopter as a Drive System Design Engineer in 2004. Ehinger has authored/coauthored several technical papers, was presented with the American Helicopter Society's François-Xavier Bagnoud award, and holds several U.S. patents related to drive system technology.

Eric A. Sinusas was hired at Bell Helicopter as a Drive System Design Engineer in 2005. He eventually became the Manager of the Drive Systems Engineering group, and is currently the Chief Engineer for Light Helicopters. He holds a Bachelor's Degree in Mechanical Engineering from Lehigh University and a Master's Degree in Business Administration from Southern Methodist University. Sinusas has authored/coauthored several papers published by the American Helicopter Society (AHS) International, and holds several U.S. patents. Sinusas is currently serving as Chairman of the AHS International Propulsion Technical Committee. AHS International presented him with the Francois-Xavier Bagnoud award, given to "an individual Society member under the age of 35 for their career-to-date outstanding contributions to vertical flight technology."

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Global Industrial Outlook: Reality Sinks In

Brian Langenberg

Our "Batten Down The Hatches" call proved timely as the market sold off by about (10 percent) before staging a partial recovery.

This column is not, and will not become, a "market letter" but the point is that financial markets transmit information and what transpired is an increased realization that corporate outlooks, particularly with respect to those supplying heavy capital equipment, have not fully incorporated the scope of what dramatically lower oil prices is meaning for their outlook.

Fundamentally there is no plausible near-term improvement. WTI (West Texas Intermediate) crude oil futures are now at about $30/barrel. Any headline touting a "rally" that moves oil back to $35, $40, or even $45 won't do it because companies are now going bankrupt and prior overinvestment decisions were made on oil prices starting at $60 or higher.

Negative interest rates signal potential deflation. The Fed is out of policy levers as we do not believe cutting interest rates from 0.50 to 0.25 percent or even zero will stimulate anybody to do anything.

Our "Batten down the hatches" call proved timely, as the market sold off by about 10% — before staging a partial recovery.

Political uncertainty dampens spending. CEO's like certainty. They like knowing the ground rules so they can compete. They like to control their own destiny or at least influence the debate. Right now, they don't and it makes them confused. And when they do not know what to do ***they do not do anything*** involving capacity expansion.

Driving financial engineering and cost synergistic deal making. Honeywell's recent overture to United Technologies is telling. It also had precedent given that UTX tried to buy Honeywell fifteen years ago before a trump bid by

Emerging market headwinds have stomped demand for machinery and heavy equipment in a range of sectors, yet Boeing trudges on.

GE that was later gunned down by the European Union. Basically, it would have been a cost synergy deal that would "wring costs" (i.e. pricing) out of you and other suppliers along with facility consolidation and headcount reductions. It is the kind of deal you pitch because you are short on growth ideas and are thinking about how you deliver growth over the next few years.

FEATURED COMPANY: BOEING (BA)

Emerging market headwinds have stomped demand for machinery and heavy equipment in a range of sectors, yet Boeing trudges on. The investment world has looked at the commercial aviation cycle as just about impervious to anything based upon the historically strong relationship between strong airline cash flows and subsequent capital investment.

This has, in fact, largely been playing out to date except that supply chains are stretched by OEM demands for higher production rates that are testing some lower tier suppliers. While production rate cuts have occurred here and there the balance of our work supports a constructive bullish view for both Airbus and Boeing.

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Brian K. Langenberg, CFA has earned recognition as a member of the Institutional Investor All-America Research Team, a Wall Street Journal All-Star, and Starmine Best on the Street. As Principal of Langenberg & Company, he advises CEOs and senior executives on strategy and capital markets, and makes numerous public speaking appearances. In July 2015 he was named Chair (and Lecturer)of Graduate Business Programs at Aurora University.

WABCO

ACQUIRES MICO INCORPORATED

WABCO, an innovator and global supplier of technologies that improve the safety and efficiency of commercial vehicles, recently announced that it is expanding its global business by acquiring MICO Incorporated (MICO), a global market leader in hydraulic components, controls and brake systems for heavy-duty, off-highway vehicles in agriculture, construction, mining and similar industries. MICO generated revenues of approximately $52 million in 2015 and is headquartered in North Mankato, Minnesota.

A long-time industry leader in pneumatic braking systems, WABCO is expanding its product offerings through the acquisition to become the first and only supplier with a portfolio of complete pneumatic and hydraulic braking and control systems for off-highway vehicles worldwide.

Jon Morrison (left), WABCO President, Americas, and Brent McGrath, MICO President.

In addition to this unique offering, the acquisition harnesses powerful synergies between technology leaders WABCO and MICO. WABCO's strong global presence provides increased access to growth markets and customers worldwide for MICO products. In return, WABCO gains improved access to the off-highway market in North America while expanding its operational footprint in the region. Both companies will also be able to build on demonstrated world-class engineering and manufacturing capabilities.

"We are excited to welcome our MICO colleagues to the WABCO family," said Jon Morrison, WABCO president, Americas. "We are committed to growing our off-highway business worldwide and to strengthen our presence in North America. MICO is key to our growth and expansion. Over the past 70 years, the team at MICO has done a tremendous job of developing world-class products and engineering and manufacturing capabilities. We are honored and excited to be taking the next steps with them."

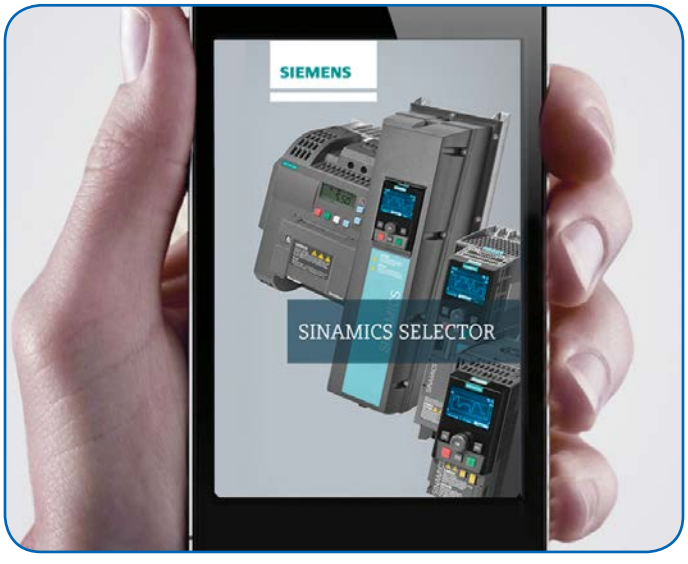
"We are thrilled to join WABCO, a technology leader in the commercial vehicle industry that is known and respected worldwide," said Brent McGrath, MICO president. "This acquisition presents exciting new opportunities for MICO, our customers, and our employees. We look forward to working with our new colleagues to leverage our respective strengths to better serve customers in the off-highway industry. Together, we are ready to enhance MICO's long-term competitiveness, innovation and growth."

Siemens Drive Selector App

INTEGRATES RESISTANCE, PEAK PERFORMANCE AND CONTINUOUS POWER RATINGS

For some time, it has been apparent that mobile apps have been spreading more and more across the industrial environment and have become a popular medium among users. One special feature in this field is the variable frequency drive app for the easy selection of all necessary components from the respective corporate portfolio. The online selection is always up-to-date, available in many different language versions and saves the user time — laboriously poring over catalogs is now a thing of the past.

Due to the special requirements in some cases, selecting the right drive is not always straightforward and can often waste valuable time. After all, the fields of application and the requirements regarding operating behavior and costs are wide-ranging. Whether the drives are used to operate pumps, fans or compressors, or to drive conveyors, mixers or kneaders, it is important to find the appropriate drive for the required range of performance and voltage quickly and easily for each of these applications. And wherever possible, this must be done without the need for expert knowledge of drive technology.



Assembling components by smartphone

In order to simplify this sometimes complex process, Siemens, for example, has been offering its Sinamics Selector app free-of-charge. This is a solution that displays the entire collection of products from the portfolio of low-voltage frequency drives — Sinamics V20, G120C, G120 and G120P — on the most popular iOS and Android smartphones and can be used both online and offline. This offline capability is of particular importance in regions which do not have full cellphone coverage. Since Version 4.0, not only have brochures, product videos and application examples (Fig. 1) been available to users and electrical distributors, but also more language versions.

Everything up-to-date

Katharina Roehrlein, marketing manager for Sinamics drive systems at the Siemens Digital Factory division, explains additional innovations: "With the latest update, Version 5.0, we have adopted the second generation of the Sinamics G120 modular Frame Size D-E, as well as the Sinamics V20 Power Extension up to 30 kW, into the app. In addition, we have integrated more technical values such as resistance, peak performance and continuous power ratings into the logic of the app. And for good reason, because we want to make it as easy as possible for our customers to find the right drive in order to save valuable time."

As a matter of principle, when assembling the appropriate components, the Sinamics Selector app offers not only a product-specific, but also an application-specific approach. In other words: either the user knows from the outset which frequency drive is required, or the app guides the user step-by-step to the right drive by asking for key parameters (Fig. 2). The information held by the Sinamics Selector app is kept up-to-date at all times by the central storage of data and continuous updates. Bob Hendrickson, applications engineer at Wesco, one of the largest distributors in the United States, regards this as an enormous advantage over conventional catalogs, especially when the app can save him a great deal of time in preparing a bid. "The Sinamics Selector app is very helpful as it lets me create a complete bill of materials for a customer offer very quickly. This option saves me a huge amount of time since I no longer have to create bills of materials by hand. The app also makes it easier for me to respond to queries arising from projects when I'm on the road and don't have any catalogs or other documents to hand."

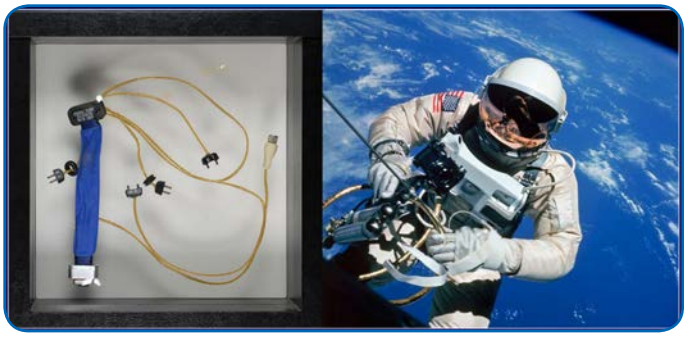
Bid preparation made easy

After choosing the required type of frequency inverter, the rated output, device options and accessories can then be selected and adapted individually — if necessary, also with the support of the respective Siemens contact, whose details are also stored in the app. Once the components have been selected, the user has the option of either saving or emailing them. To make it easier for end-users to get in touch later, the headers and footers of the email can be adapted individually, for example, with personal contact information. The overview includes actual part numbers for all of the selected components. This can be used as information for the customer, but also as the basis for ordering specific components or preparing an offer at the local dealer/distributor. Kevin Young, application engineer at electrical distributor C&E Sales Inc., in the U.S., also confirms this: "I really like the Sinamics Selector app. I copy the result into my bill of materials, which enables me to immediately present a bid to my customer." His colleague Jay Swank adds, "I use the application almost every day now."

Cicoil

ACQUIRES LONG-LOST SPACE CABLE

Almost 50 years after an Apollo Spacewalk, a long-lost flat cable harness returned back home to Cicoil. The "bio-harness" assembly, built by Cicoil for the 1969 Apollo 9 Space Flight, was acquired by Cicoil in a NASA Apollo Space Program Auction. Amazingly, the harness looks virtually brand-new, considering its age and the number of miles it has travelled.



The 26 inch long electrical biomedical harness was worn by Commander Jim McDivitt during the Apollo 9 flight, that launched into orbit on March 3 and returned to Earth 10 days later. Typically, the "Bio-Harness" was worn underneath the Intra-Vehicular Constant Wear Garment when in the spacecraft, and under the extra-vehicular (EV) pressure suit during spacewalk activities.

The assembly enabled continuous monitoring of vital signs, such as blood pressure, respiration, body temperature and pulse rate for each astronaut during flight, orbit and spacewalk operations. In addition to Commander McDivitt, astronauts David Scott and Rusty Schweickart also utilized bio-harnesses made by Cicoil on the Apollo 9 Space Mission as well.

Cicoil's space flight approved bio-medical instrumentation and telemetry harnesses were chosen for their unique ability to separately encase shielded signal pairs to eliminate electronic interference; provide uninterrupted signal integrity during the harsh rigors of space flight; exceptional performance when exposed to temperature extremes (-65°C to +260°C); resistance to UV Light, radiation and vibration; high efficiency in dissipating heat between inner cable components; highly flexible and lightweight materials; and high reliability in mission critical applications.

The flawless operational performance of Cicoil's biomedical instrumentation and telemetry harness designs were, in NASA's words, "Vital to the successful achievement" of these history-making flights."

Cicoil's flat cable harnesses were also there to help Astronaut John Glenn (Mercury-Atlas 6) to become the first American to orbit the Earth, Edward White (Gemini 4) to be the First American to walk in space, Neil Armstrong (Apollo 11) to take his historical "First Step" on the surface of the moon and Buzz Aldrin (Apollo 11) to take his infamous second walk on the Moon.

In addition to every Apollo space flight, Cicoil has manufactured cable assemblies for the Mercury and Gemini space missions, Skylab, Mercury Voyager, the Space Shuttle, Tri-Athlete Lunar Vehicle, the Mars Rover; and today are utilized on space transport rockets and satellites.

For an out of this world experience, be sure to check out the Cicoil bio-harnesses worn on the Apollo 9, 11 and 17 missions at the Smithsonian Museum in Washington DC.

If you would like to learn how Cicoil developed the First IDC Ribbon Cable, helped put a Man on the Moon, and find out more about our Innovative Flat Cable Technology, please contact our office at 661-295-1295 to discuss your application or to set up an on-site visit to your location.

Heidenhain

HIRES VICE PRESIDENT OF SALES AND MARKETING

Heidenhain Corporation announces the new hire of **David Doyle,** as vice president, sales and marketing in North America. With over 25 years of extensive management experience, Doyle joins the Heidenhain family to assume the day-to-day responsibilities of the sales and marketing departments.

With Heidenhain based in Schaumburg, IL, Doyle moved from Oregon where he most recently served as vice president, material characterization business unit of nanometrics, a manufacturer of automated metrology solutions, supporting semiconductor industries.

Serving other high technology industries in corporate management positions over the years, Doyle originally started his career by earning a bachelor's of science degree in chemistry and experimental physics from the National University of Ireland, where he earned double honors.

Matrix Design

OPENS INDIANAPOLIS SALES OFFICE

Matrix Design, LLC has announced the opening of their Indianapolis sales office. The new sales office will be lead by Tim Fenner, who recently joined Matrix as a sales specialist. "We are thrilled that Tim has joined our team to lead our Indianapolis sales office. Tim has a wealth of experience in robotics, automation and manufacturing and looks forward to working closely with manufacturers to identify and implement automation solutions as the demand for automation continues to grow at a rapid pace," said Jeff Bennett, vice president of sales and marketing at Matrix Design, LLC. "Our Indianapolis office gives us a more focused presence to better serve industries in Indiana, Ohio, Kentucky and surrounding regions, where more and more manufacturers are looking for robotics to improve their competitiveness."

Gilman

LAUNCHES CANADIAN WEBSITE

The launch of Gilman Precision's Canadian website is the final step in expanding Canadian operations, a project that began in May of 2015 with the addition of RGW Sales Canada to Gilman's sales force. This new site will not only further extend Gilman's international business opportunities, but more importantly, offer Canadian customers a user friendly and convenient online experience.

The Canadian host site allows Gilman to optimize international search engine results, therefore improving viewers' ability to search, review, and communicate with Gilman in a simple and safe manner. English and French Canadian translations are available to fully accommodate visitor preferences. Furthermore, all information unique to Canadian customers is located on the new site, including Canadian sales representatives, news updates and more.

"The investment in a Canadian site empowers customers to find the information they require and communicate with

us in an easy and familiar way," remarked Douglas Biggs, vice president sales and marketing at Gilman Precision, "We are very excited to offer this opportunity and continue standing as a trusted resource for quality products and outstanding customer care."

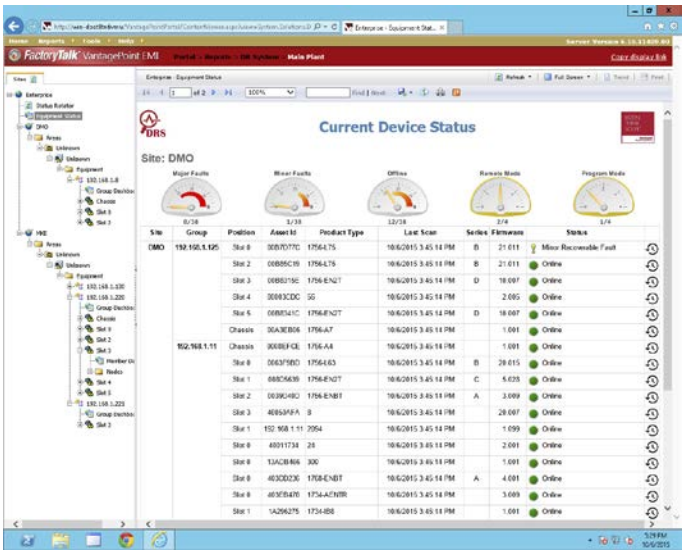
Additional international sites are available to provide support for prospects in Australia and Singapore. Gilman hopes to continue growing international relations in 2016, and is currently investigating and pursuing new markets for expansion.

Rockwell Automation

IMPROVES MAINTENANCE STRATEGIES AND OPERATIONAL EFFECTIVENESS

The new diagnostic reliability service from Rockwell Automation helps manufacturers and industrial producers drive a streamlined maintenance strategy on these mission-critical, integrated equipment lines. The solution deploys a layer of technology across plant devices and equipment to monitor and perform analysis, and create a continuous improvement approach to reliability maintenance, reducing operational risk. As part of the service, a Rockwell Automation domain service expert also closely tracks equipment performance to advise on reliability improvements to the production facility.

"Our customers have access to a huge amount of data within their assets, but they often struggle to turn data into useful operational intelligence," said Ryan Williams, product manager, Rockwell Automation. "In the past, companies relied on maintenance personnel on-site to check the status of equipment in the field and then develop corrective action plans. Now, with the diagnostic reliability service, they can transform maintenance data into asset intelligence. This helps build a more Connected Enterprise, leveraging interconnected data systems and producing actionable information. Companies can better prioritize choices on maintenance and production, and do more with less."



All Eyes on U.S.

This year's Hannover Messe will be an important one for the United States. As this year's partner country, we'll be at the center of the trade show's already impressive festivities.

Alex Cannella, News Editor

Hannover Messe always promises to be one of the landmark trade shows of the year. Their massive attendance numbers are no secret. In 2015, they saw 6,500 exhibitors and 220,000 trade visitors, and they boast that 68 percent of their visitors are decision makers. In recent years, the show has built a tradition showcasing the latest Industry 4.0 advances and technology, and this year continues that tradition. The theme, Integrated Industry - Discover Solutions, will make an effort to show off concrete, practical examples of the Industrial Internet across numerous fields ranging from energy solutions to predictive maintenance.

But this year is also going to be even bigger than usual. The show's expanded to include another exhibition hall. The Industrial Internet Consortium (IIC), an international, U.S. based organization working to establish standards for the Industrial Internet, will be in attendance for the first time.

Oh, and President Obama is going to be there, too.

Far and away the biggest news surrounding Hannover Messe 2016 is that this year's partner country will be none other than the United States, a first in the trade show's history. This not only firmly places the global industrial spotlight on the U.S., but also means that this year is particularly worth following, or even attending. The show is already expecting over 250 U.S. exhibitors (more than double the usual number), as well as a personal visit from the President himself to open the show. For every major topic being covered at the show this year, there will be a U.S.-centric pavilion and joint stand to provide a natural meeting place for networking opportunities, as well as another pavilion in hall 3 for investors interested in U.S. companies (and, of course, companies looking for investors) to flock to.

"The United States is proud to be the partner country," U.S. Ambassador John B. Emerson said at January's preshow press conference. "This will offer the American delegation maximum exposure and numerous face-to-face opportunities to connect to the global industrial technology marketplace and discover new business prospects."

For anyone seeking investors, looking for new customers or expanding their exports, Hannover Messe 2016 is almost a no-brainer. This year's show is giving U.S. businesses every opportunity to network and make international contacts, sales and investments. If ever there was a year to care about Hannover Messe, this is the one, because this year, Hannover Messe cares about you.

Partner country status notwithstanding, there's still plenty of reason to pay attention to Hannover Messe, foremost amongst them being the theme, Integrated Industry - Discover Solutions. The Industrial Internet has been a rising force in industry the past few years, but still remains a nebulous, vague topic in many minds.

Hannover Messe's Press Team Leader, Onuora Ogbukagu, put it best: "I think you'll agree with me if I say that everybody's talking about the factory of the future, everybody's trying to figure out how digitalization of the industry will change manufacturing, but nobody really has a clue where the journey is going."

This year's theme is focusing on clarifying our vision of that journey. With over 100 practical examples on display of Industry 4.0 technology already in use today across numerous fields, Hannover Messe is looking to present a concrete view of what the future has in store, and why you should buy into it.

The unique crossroads Industry 4.0 is currently at makes this theme timely. We're at the point where the Industrial Internet is becoming a big deal, and everyone is scrambling to implement it, but at the same time, a lot of the tech

is fresh, and nobody quite knows how to use it best. Even at Hannover Messe itself, Industry 4.0 has been discussed and hyped at length, but this is the deepest they've ever gone into the nitty gritty details, and no doubt a wealth of curated examples of Industrial Internet processes will be a welcome addition to the show.

The trade show is presenting its theme in five sub-categories. Industrial Automation focuses on automation technology and how it relates to Industry 4.0, while the Digital Factory looks at the IT and software side of the equation. Energy will focus on the energy industry, promising to show every part of the industry value chain from generation to distribution and beyond. Industrial Supply looks at new technologies and solutions emerging for industrial supply chains. Finally, Research & Technology will take a look at what lies beyond today's emerging tech, touching on everything from bionics to nanotechnology. Predictive maintenance will also get its place in the spotlight.

"Here, Integrated Industry is more exciting than ever," Dr. Jochen Köckler, one of Deutsche Messe's managing board members, said at January's press conference. "It's not just looking at the question of whether we will feel it or what kind of impact it will have. Here, you will find your solutions on your journey of discovery."

Hannover Messe is also bringing back the Industry 4.0 Forum, which attracted 6,600 visitors last year. The forum will be headed by the IIC, the German Engineering Federation (VDMA) and the German Electrical and Electronic Manufacturers' Association (ZVEI), but many attending exhibitors will also be filling out the ranks of experts. A wide range of topics will be discussed, but a few of the highlights will be standards of communication between devices, IT security, Cloud technology, and business models based off of Big Data.

Also being enthusiastically pushed are the two hour guided tours, which Hannover Messe is expanding. Each tour covers the broad strokes of one of the trade show's main themes and visits selected booths. They should be particularly useful for those looking for a primer in one particular field and will provide some of those aforementioned concrete examples of the Industrial Internet at work.

Even if you can't attend this year's Hannover Messe, it will undoubtedly be worth tuning in to from home. Once a year, the world's collective gaze always rests on Hannover, but this year, it will also be firmly fixed on us. All of Hannover Messe's usual selling points - the massive crowds, the business and networking opportunities, the wealth of knowledge practically being handed out, and bleeding edge technology from around the world - are magnified this year by the United States' partner country status. By partnering up with the biggest trade show in Europe, U.S. businesses will uniquely be at the heart of this year's show, and when doing business, there's no better place to be. **PTE**

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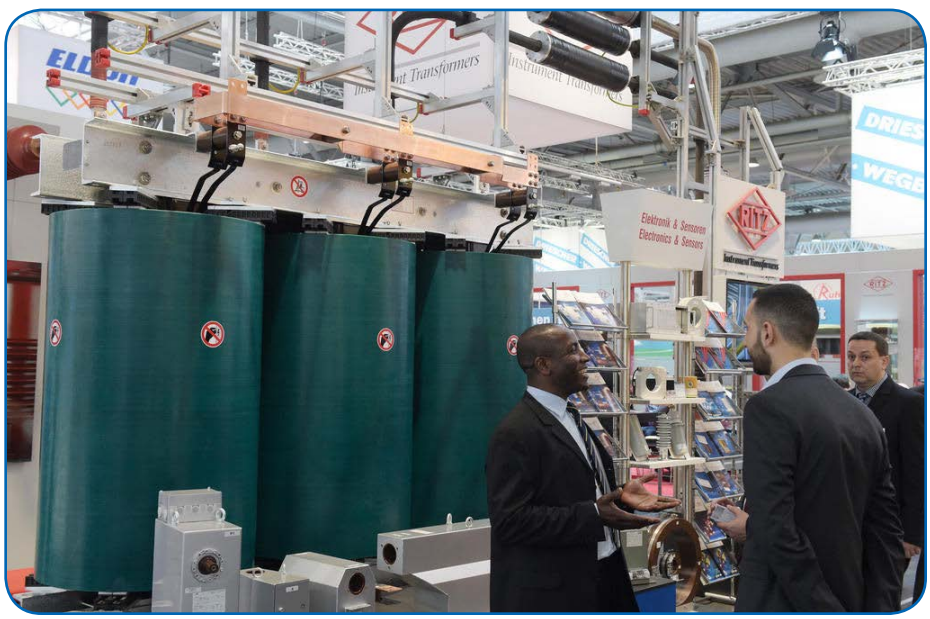

April 4–8—2016 Basic Training for Gear Manufacturing: April Chicago, Illinois. Instructors Dwight Smith, Pete Grossi and Allen Bird teach students the fundamentals of gear manufacturing in this classroom and hands-on course. This course offers training in gearing and nomenclature, principles of inspection, gear manufacturing methods, and hobbing and shaping. In the hands-on gear lab, using manual machines, students can see the interaction between the cutting tool and the workpiece. They understand the process and the physics of making a gear and can apply this knowledge in working with CNC equipment commonly in use. The Basic Course is designed primarily for newer employees with at least six months experience in setup or machine operation, it has also proved beneficial to quality control managers, sales representatives, management, and executives. For more information, visit *www.agma.org*.

April 5–7—2016 Reliable Plant 2016 Louisville, Kentucky. This three-day event offers attendees learning sessions and case studies on the latest industrial lubrication and oil analysis technologies. The comprehensive conference schedule covers every facet of the machinery lubrication industry and includes workshops on topics such as employee performance, lubrication fundamentals, condition-based maintenance and maintenance planning. The 150,000 square foot exhibit hall, receptions and educational sessions facilitate networking opportunities as well as the implementation of new ideas attendees can bring back to their manufacturing facilities. Reliable Plant is focused on both entry level and management positions within the lubrication industry including engineers, plant managers, maintenance professionals, safety personnel, planners, quality managers and more. For more information, visit *http://conference.reliableplant.com*.

April 15—International Conference of Transportation Engineering 2016 Washington D.C. The International Conference of Transportation Engineering (TEC) promotes innovation and progress in transportation engineering through research. This conference intends to facilitate this goal through an objective and interdisciplinary setting. TEC 2016 focuses on sharing information on transportation practice and policy by researchers and practitioners. The conference stimulates research and offers research management services that promote technical excellence. The one-day schedule includes short courses, panel discussions, workshops, training lectures, papers and plenary lectures. For more information, visit *www.gtconf.com*.

April 14–15—AGMA Spring Marketing & Forecasting Conference Crowne Plaza O'Hare, Rosemont, Illinois. Growing automotive production, housing construction and capital spending are positive indicators for gearing in the near term. But, our industry faces risks from uncertain government policies, a slowing energy sector and weak markets in Europe and Asia. Speakers include Randy Disharoon, vice president-strategic accounts at Rexnord and Tom Runiewicz, senior principal economist, IHS Economics, US and World Industry Service. Pricing is $425 first registrant and $375 for each additional registrant from the same company. It is only open to employees of AGMA member companies. For more information, visit *www.agma.org*.

April 16–19—BSA 2016 Convention Aventura, Florida. The Bearing Specialists Association (BSA) brings together the top leadership of authorized bearing distributors and manufacturers and offers an opportunity to grow relationships with trusted supply chain partners. Highlights include the BSA celebrating 50 years of excellence, an annual industry update from John Ruth, president/COO of BDI and BSA vice president and an ABMA update on growth in the bearing industry from Brian Lindsay, CEO, NSK Americas. In addition, performers from Second City will portray the past, present and future of the bearing industry. Rick Smith, co-founder, CloudDDM, will also present "Our 3D Printed Future: How to Successfully Navigate this Historic Shift." For more information, visit *www.bsaconventions.org*.

April 19–21—AC Machine Design Fundamentals Madison, Wisconsin. Learn the knowledge and practice of AC electrical machine design so that you can develop competitive electric motors and generators for industrial applications, electric vehicles, appliances, aerospace and naval applications. This three-day introductory course will help attendees gain critical knowledge needed for new products or refining existing designs. This intro-course will teach the basics of electromagnetic laws, magnetic circuit calculations, terminology, fundamentals of loss mechanisms, mechanical design, vibration, noise and thermal analysis and more. By participating in this course, attendees can earn 20 professional development hours (PDH) or 2.0 continuing education units (CEU). This event includes instructors from the University of Wisconsin-Madison, ABB Corporate Research and the University of Kentucky-Lexington. It is a valuable course for electrical engineers, mechanical design engineers, system engineers, project engineers, system integrators, program managers and technical leaders. For more information, visit *epd.wisc.edu/RA01413*.

May 2–5—2016 Offshore Technology Conference Houston, Texas. OTC gives attendees access to leading-edge technical information, the industry's largest equipment exhibition, and valuable new professional contacts from around the world. Its large international participation provides excellent opportunities for global sharing of technology, expertise, products, and best practices. OTC brings together industry leaders, investors, buyers, and entrepreneurs to develop markets and business partnerships. The event includes a technical program, R&D topics, OTC training courses and an awards luncheon. For more information, visit *2016.otcnet.org*.

May 3–5—Gearbox System Design: The Rest of the Story... Sheraton Sand Key Resort, Clearwater Beach, Florida. This course focuses on the supporting elements of a gearbox that allow gears and bearings to do their jobs most efficiently. Learn about seals, lubrication, lubricants, housings, breathers, and other details that go into designing gearbox systems. Sponsored by AGMA, this course is taught by Raymond J. Drago, chief engineer, and Steve Cymbala, senior drives engineer, at Drive Systems Technology, Inc. This seminar will start with the basics and then focus on the pros and cons of types of housing construction, housing elements, bearing mounting, selection and role of gearbox accessories, appropriate lubricant selection and more. AGMA members ($1,895) and non-members ($2,395). For additional information, visit *www.agma.org*.

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Seeking Higher Ground

Early Chicago Rises from the Muck

Jack McGuinn, Senior Editor

Raising a block of buildings on Lake Street (Photo Wikipedia).

Even for a toddlin' town famous for making "no small plans" — such as, for example, reversing in 1900 the Chicago River to secure clean drinking water, or rebuilding itself seemingly overnight after the devastating "Great Chicago Fire" (1871) — to physically — and successfully — elevate itself as much as 14 feet above its original ground level defies not only description but credulity.

But it happened. And here's how: jack screws — lots and lots of jackscrews.

First, some history behind the history is required. While being founded on the banks of a Great Lake, i.e., Michigan, certainly has its advantages, Chicago was actually built on a marsh-like area along the lakefront. And as reported in "Raising Chicago" by WBEZ-Radio reporter John R. Schmidt, "As the population grew, this became a public health problem. Cholera outbreaks were frequent. In 1854 alone, the disease wiped out 1 in 20 Chicagoans.

"City officials decided to construct a sewer system that would take care of the deadly waste. But drainage would be difficult, since Chicago sat only a few feet above Lake Michigan. There were two options: (A) abandon all of downtown and start over on higher ground, or (B) jack up all the buildings where they were."

Thank goodness they chose "B" or we wouldn't have a Power Play.

The work began in earnest in 1856 (and would last 20 years); one of the very first of many major contractors was an enterprising young guy from New York by the name of George Pullman, presenting himself as a cabinet maker. According to the WBEZ piece, "Pullman contracted to raise an entire block on Lake Street. He had *6,000 jackscrews* put under the buildings, and hired *600* men to take charge of ten jacks each. On the signal, each man turned the screws on his ten jacks, one notch each; the buildings went up a *fraction of an inch*.

Some buildings were reportedly elevated up to fourteen feet. The "B" option also many times included the actual relocation of the building, deeming the original location no longer desirable. The moved buildings would then receive new foundations at their new locations. New sewers and streets were then laid atop the old street level; the land was filled in to meet the new levels. Last was actual paving of the new streets on top of the fill.

The following excerpt from *Wikipedia* captures the flavor of that time in Chicago:

"Consequently, the practice of putting the old multi-story, intact and furnished wooden buildings — sometimes entire rows of them — en bloc — on rollers and moving them to the outskirts of town or to the suburbs was so common as to be considered nothing more than routine traffic. Traveler David Macrae wrote incredulously, 'Never a day passed during my stay in the city that I did not meet one or more houses shifting their quarters. One day I met nine. Going out Great Madison Street in the horse cars we had to stop twice to let houses get across.' (As mentioned above) business did not suffer; shop owners would keep their shops open, even as people had to climb in through a moving front door. Brick buildings also were moved from one location to another, and in 1866, the first of these — a building of two and a half stories — made the short move from Madison Street out to Monroe Street. Later, many other brick buildings were rolled much greater distances across Chicago."

In the mid-nineteenth century, most buildings were of course still constructed of wood. So it wasn't until two years later, 1858, that the city felt confident enough to lift and move the first masonry building — a four-story, 70-foot-long, 750-ton brick structure situated at the northeast corner of Randolph and Dearborn Streets. The structure was hoisted with 200 jackscrews to its new grade — or 6 feet 2 inches higher than the previous level — all with no damage to the building. It would be the first of more than 50 similar properties to be raised and/or moved that year.

One of the most notable raisings was that of the Tremont House Hotel at Lake and Dearborn Streets, led by the team of Ely, Smith and Pullman. The brick-constructed edifice, "luxuriously appointed," was six stories high on a one-acre parcel. Incredibly, and something like a Titanic scenario in reverse (among hotel guests were several VIPs and a U.S. Senator) as hotel guests went about their business, the engineering crew (500 men operating 5,000 jackscrews) went about theirs — lifting the Tremont House a full six feet above its existing foundation without incident. However, one patron was in fact puzzled to note that the front steps leading from the street into the hotel were becoming steeper every day. When he checked out, the windows were several feet above his head. When he checked in, they were at eye level. Cue *Twilight Zone* theme. **PTE**

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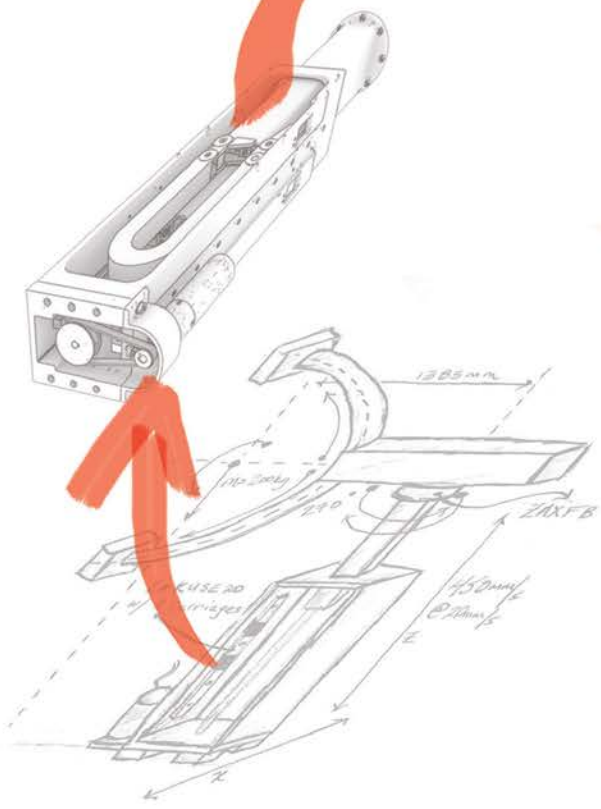

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