Power Transmission Engineering®

JUNE 2017

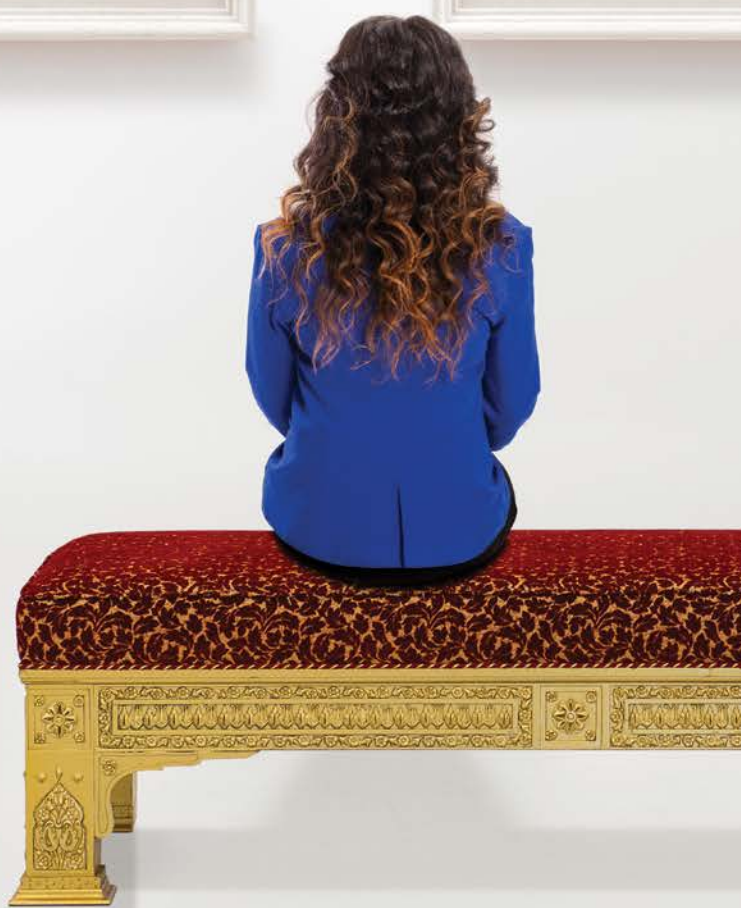
MOTORS

- Miniature Motors
- Motor Basics
- How to Select a DC Motor

Guide to V-Belt Selection & Replacement

www.powertransmission.com

Who says you need a brush to create a masterpiece?



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Power Transmission Engineering®

JUNE 2017

[20]

FEATURE ARTICLES

TECHNICAL ARTICLES

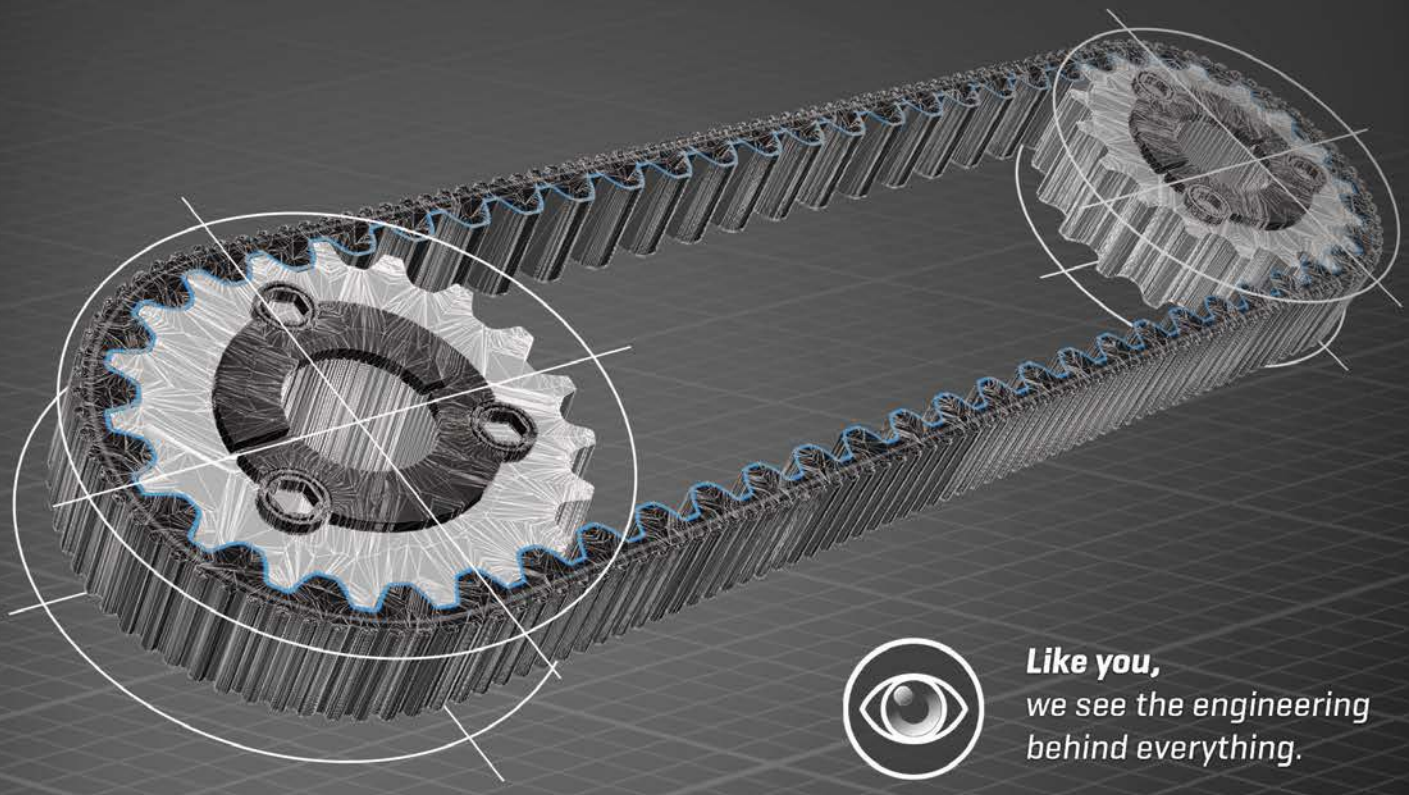
Vol. 11, No. 4. POWER TRANSMISSION ENGINEERING (ISSN 2331-2483) is published monthly except in January, May, July and November by Randall Publications LLC, 1840 Jarvis Ave., Elk Grove Village, IL 60007, (847) 437-6604. Cover price $7.00. U.S. Periodicals Postage Paid at Elk Grove Village IL and at additional mailing offices. Send address changes to POWER TRANSMISSION ENGINEERING, 1840 Jarvis Ave., Elk Grove Village, IL 60007.

Power Transmission Engineering
VOL. 11, NO. 4

Photo by David Ropinski

Gates DESIGN CENTER

Driven by Vision.



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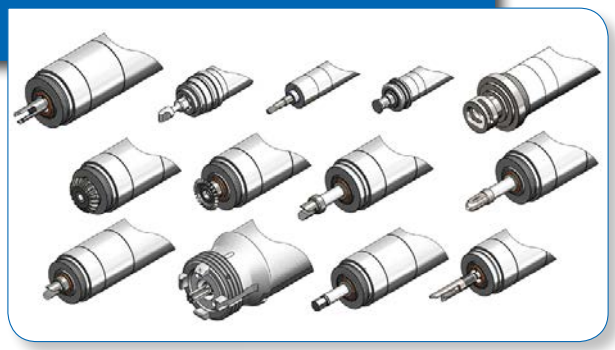
PTE Videos
DC Motor Testing

Portescap's in-house testing process is used to validate the design of miniature motors in demanding end applications in medical and surgical devices and applications. These include ENT shavers, orthopedic drills and saws, and gastrointestinal staplers and more. Check out the video at:

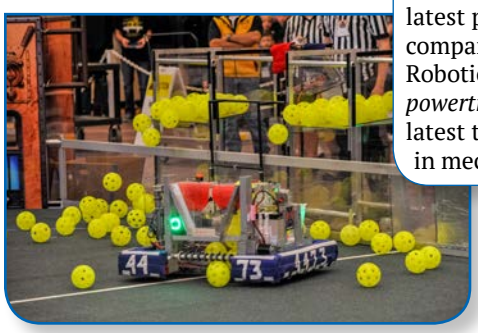


How to Install and Remove Taper Grip Bushing

Sumitomo Drive Technologies demonstrates the proper way to install and remove a taper grip bushing. Check out similar videos at *www.motionindustries.com*.

Get Social:

Twitter, Facebook and LinkedIn offer the latest product and industry news items from companies such as Bauer, AWEA, FIRST Robotics, Baldor, SKF and more. Visit *www.powertransmission.com* to stay on top of the latest trends, technologies and developments in mechanical motion.



The Bearing Blog with Norm Parker

Reducing a duty cycle is a very niche skill and for reasons that are beyond Parker, people get territorial and emotional about sharing their methods. In two separate blog entries (There Must Be 50 Ways to Reduce a Duty Cycle: Part 1 and 2) Parker discusses this process in-depth. Visit (*http://powertransmission.com/blog/category/bearings-with-norm*) for details.

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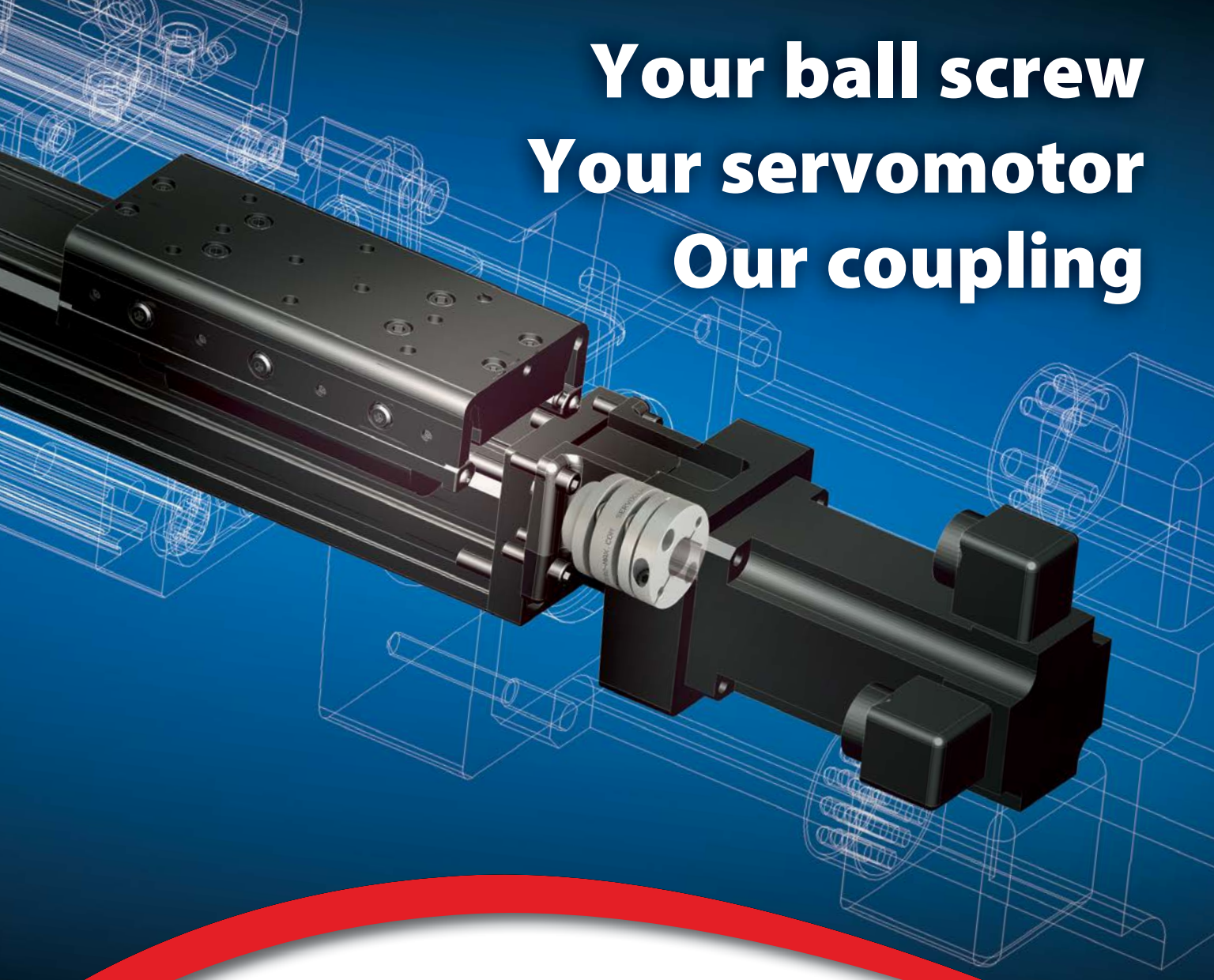
Your ball screw
Your servomotor
Our coupling



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Randy Stott, Managing Editor

Moving in the Right Direction

Here at Power Transmission Engineering, we get to talk to a lot of different people from a wide variety of manufacturing industries. Over the past several months, members of our staff have traveled quite a bit, and we've had a lot of opportunities to gauge their confidence. And while nobody is overwhelmingly enthusiastic—nobody has told us this is their best year ever—almost everyone seems at least content with the stability that slow and steady growth provides.

These aren't just my impressions or gut feelings, either. Members of our staff have visited with industry suppliers at trade shows like Automate and Hannover Messe. They've gone to trade association annual meetings and marketing presentations. They've visited manufacturers of gears, bearings, motors, couplings and gearboxes. And almost all of these companies seem fairly positive.

But anecdotal evidence can be misleading. When you talk to a salesman at a trade show, it's his job to be optimistic. And salesman or no, pretty much anyone talking to an editor will try to put a positive spin on things. After all, nobody wants us to report on their companies' bad news.

So we like to have some facts at our disposal before we jump to any conclusions. Fortunately, there are a number of organizations that report on the economic conditions of various manufacturing industries, and I've assembled some of the most recent reports here.

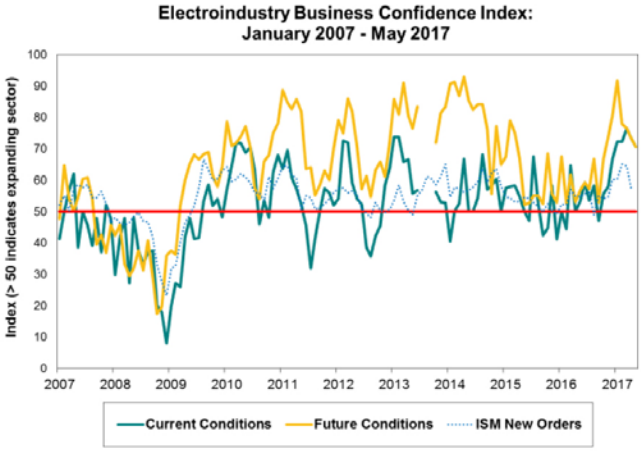
Fortunately, what we hear with our ear-to-the-ground methods seems to match up well with the more scientific research. So we're confident that the current trends are likely to continue for some time.

And while rapid growth and supercharged sales are always enticing, the stability offered by slow and steady growth provides for much greater opportunity to plan and make meaningful changes to your business and operation.

I encourage you to study the numbers, keep an eye on the horizon, and take advantage where you can.

NEMA Electroindustry Business Condition Index.

NEMA's EBCI indexes are based on the results of a monthly survey of senior managers at NEMA member companies and are designed to provide a measure of changes in the business environment facing electrical equipment manufacturers. In May 2017, the index indicated that businesses in these industries remain firmly in the expansionary range (indicated by the red line in the chart).



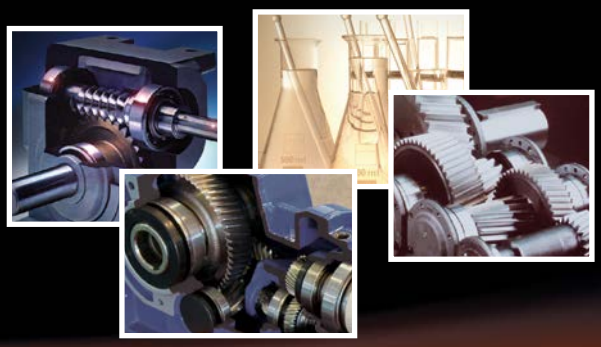
ISM Purchasing Manager's Index (PMI).

According to ISM's latest report on business, "Economic activity in the manufacturing sector expanded in May, and the overall economy grew for the 96th consecutive month." The May 2017 PMI registered 54.9 percent, a very slight increase from April 2017.

MANUFACTURING AT A GLANCE
May 2017

Index	Series Index May	Series Index Apr	Percentage Point Change	Direction	Rate of Change	Trend* (Months)
PMI®	54.9	54.8	+0.1	Growing	Faster	9
New Orders	59.5	57.5	+2.0	Growing	Faster	9
Production	57.1	58.6	-1.5	Growing	Slower	9
Employment	53.5	52.0	+1.5	Growing	Faster	8
Supplier Deliveries	53.1	55.1	-2.0	Slowing	Slower	13
Inventories	51.5	51.0	+0.5	Growing	Faster	2
Customers' Inventories	49.5	45.5	+4.0	Too Low	Slower	8
Prices	60.5	68.5	-8.0	Increasing	Slower	15
Backlog of Orders	55.0	57.0	-2.0	Growing	Slower	4
New Export Orders	57.5	59.5	-2.0	Growing	Slower	15
Imports	53.5	55.5	-2.0	Growing	Slower	4
OVERALL ECONOMY				Growing	Faster	96
Manufacturing Sector				Growing	Faster	9

REDEFINING
HIGH-PERFORMANCE SYNTHETIC GEAR LUBRICANTS



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For Heavy-Duty Applications.

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High-Performance, 100% Synthetic, H1 Fluids.
Provides Excellent Oxidation Resistance.

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Gear Expo — The Drive Technology Show

Jenny Blackford, Vice President Marketing, AGMA

Where do you go to find new suppliers for your power transmission projects? Where do you test drive the latest technologies available?

More than 30 years ago a small group of gear manufacturers and suppliers realized that there was no event that focused on the gear industry and power transmission. Sure, there were shows like IMTS that focused on machine tools, and vertical shows focusing on one industry — such as ConExpo-CON/AGG and MineExpo — but there was nothing specifically for power transmission professionals. This group of AGMA members proposed a new show, Gear Expo, which started as a small number of table top exhibits in a Cincinnati hotel ballroom in 1986. Today, Gear Expo has expanded to be the "Drive Technology Show," bringing more than 200 global companies and covering more than 60,000 square feet of the Greater Columbus Convention Center in Columbus, Ohio this October. We invite you to join us.

Gear Expo focuses on bringing all aspects of the mechanical power transmission industry together in one place. Leading manufacturers of gearing, bearings, lubrication, inspection and machine tools are all on display side by side for customers to be able to compare solutions, see the latest technologies, and interact with existing suppliers. Product engineers can bring their latest project specs and get valuable information and begin the specification process with potential suppliers conveniently in a matter of hours instead of stretching meetings over weeks. Purchasing managers can talk to a large number of their vendors all in one place — and compare offerings of new companies that may become suppliers in the future. And executives will have their peers in the industry all in one place for invaluable connecting.

Beyond the show floor, education opportunities abound for all levels of product, manufacturing and design engineers. These seminars are designed to provide practical knowledge in a short amount of time — either a half day or one full day — and give you a chance to visit the exhibit hall as well. Of particular interest to power transmission engineers, there are seminars on bearing failures, gearbox maintenance, and understanding gear inspection reports. New this year is a half-day seminar, "Gearbox Field Inspection — Load Distribution, Lubrication and Condition Monitoring," that focuses on potential causes of gearbox failure, and how they can be identified and avoided. These educational offerings are taught by professionals who have spent their careers doing this work, thereby brining years of experience into the classrooms.

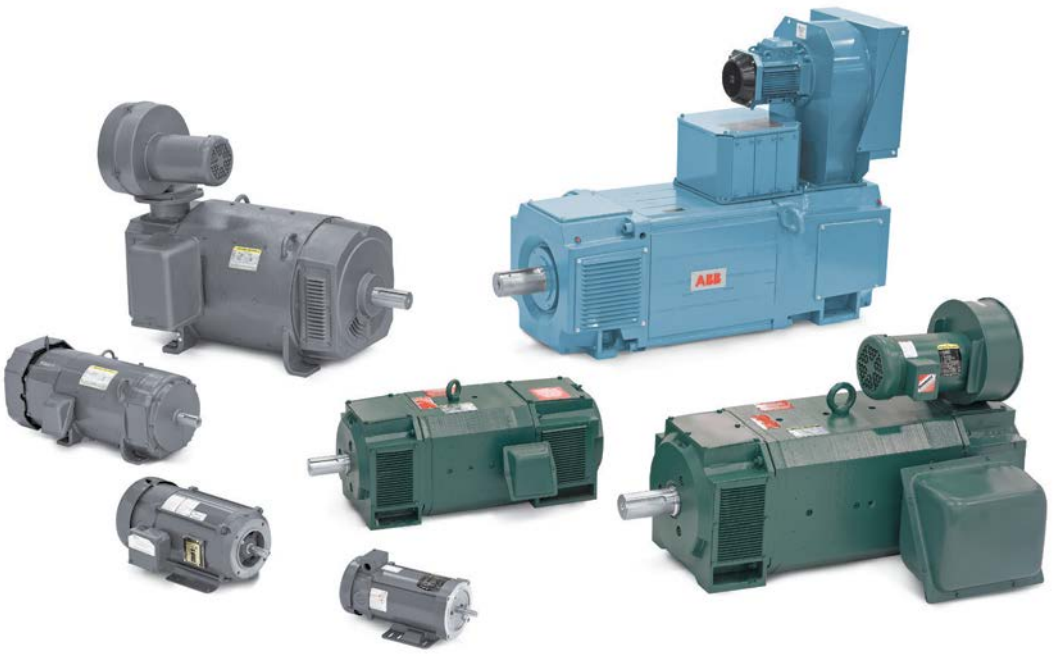
In addition to these seminars, Gear Expo has free education on the show floor at the Solutions Center. Each day exhibitors will showcase their latest capabilities and solutions to manufacturing problems in brief, 20-minute presentations open to all attendees. Pop by the Solutions Center for a short primer on a topic and then head to the exhibitor's booth to find out more about their potential solution that could boost your productivity or give you a new idea to solve an existing problem.

We will also have keynote speakers each day at the Solutions Center. This year, the keynotes will discuss important emerging technologies. Come hear about Smart Manufacturing IoT/Industry 4.0 solutions for your plants and supply chains. And then hear from Jay Rogers, founder and CEO of Local Motors on Thursday, October 26. Local Motors is a company focused on manufacturing of open source motor vehicles, mostly 3D printed, using talent from across the world in what he describes as micro-factories. All the presentations in the Solutions Center will inform, hopefully inspire, and in some cases make you think outside the box for improvements to your own business endeavors.

In three short days, power transmission professionals can learn from the best experts in the industry, have conversations with existing and potential new suppliers, see and test drive the latest power transmission technologies, and interact with thousands of your peers. What's the cost of one new idea? For a day or two out of the office you can gain invaluable amount of new information.

I hope to see you in Columbus, October 24–26. **PTE**

DC On Demand



While other manufacturers have chosen to leave the DC motor market, ABB and Baldor continue to invest in product development and U.S. manufacturing in order to offer the widest variety of permanent magnet and wound field industrial DC motors in the world.

DC motors continue to provide the right solutions to many application requirements. We now can supply IEC or NEMA frame motors, stock motors from 1/50 to 500 Hp or custom-designed motors to 3000 Hp to meet your specific application. If you need a DC motor anywhere in the world, call Baldor!

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- The Most DC Choices
- Unmatched Quality
- Superior Reliability
- Quickest Delivery Available

BALDOR®

A MEMBER OF THE ABB GROUP

Schaeffler

STRENGTHENS STANDARD BEARING BUSINESS WITH DEEP GROOVE BALL BEARINGS

Schaeffler is significantly expanding its standard rolling bearing business with FAG Generation C deep groove ball bearings through substantial investments in new production and logistics capacities as well as improved product characteristics. In March, the first new high-volume production line was put into operation at the Schaeffler location in Yinchuan/China.

"Our investments will help us satisfy the high level of demand for standard deep groove ball bearings, especially from China and the Asia/Pacific region, and help us meet the specific requirements of this high-volume business in an optimum way," explains Dr. Stefan Spindler, CEO Industrial at Schaeffler. Electric motors, household appliances, pumps and fans, electric power tools, and two-wheel vehicles are the fields of application in which FAG Generation C deep groove ball bearings are most commonly used.

More durable, less noise, low friction and cost-effective

Ever since FAG Generation C deep groove ball bearings were established in 2008, their product characteristics have been subject to continuous improvement.

"We looked at the product, production, and logistics, and developed solutions in all areas that fulfill the highest requirements in the market," explains Thomas Kreis, project manager for the deep groove ball bearing high-volume business at Schaeffler.

The new Z-type dust shield with its labyrinth seal helps to reduce the egress of grease by 20 percent, and prevents contamination by 30 percent in comparison with the previous design. The patented ELS lip seal, which is optionally available, provides maximum sealing action at low friction and is particularly suitable for alternating axial loads, such as in wheel bearings in motorcycles. The improved sealing action, without any additional friction loss, is due to the innovative lip shape that is perfectly matched to the ring recess.

The high-quality of the balls and the noise-optimized cage mean that FAG Generation C deep groove ball bearings run significantly more quietly than conventional offerrings. In addition, optimized osculation reduces friction. These characteristics can be attributed to the numerous optimizations to raceway parameters with regard to roundness, waviness, roughness and tighter manufacturing tolerances. Reduced friction also means lower energy costs during operation.

For more information:

Schaeffler Group USA, Inc.
Phone: (803) 548-8500
www.schaeffler.us

The first new high-volume production line was put into operation at the Schaeffler location in Yinchuan/China (All photos courtesy of Schaeffler).

Bonfiglioli

LAUNCHES PLANETARY GEAR 300M SERIES FOR INDUSTRIAL APPLICATIONS

Bonfiglioli recently launched the new planetary gear 300M series for industrial applications. The 300M series offers a higher torque density for the same compact dimensions and is available in 20 sizes with an output torque of 1.3 to 1,300 kNm. The planetary drives of the 300M series are equipped with newly designed planet bearings, which grant up to 50 percent more torque at a high numbers of cycles. The 300M series is fully interchangeable with the well-known planetary gear 300 series and is suitable for integrated geared motors, IEC and NEMA electric and hydraulic motors.

Optionally, Bonfiglioli offers a compact self-cooling system for the entire planetary gear series, which increases the thermal performance by three times. The self-cooling system is robust and connects directly to the motor in a reliable way, allowing use of the full mechanical power without needing further external cooling circuits.

The 300M series, thanks to the enhancement of the planet bearings arrangements, ensures compactness, cost savings as well as up to 20 percent more lifetime and reliability. With the optional integrated self-cooling system, the new 300M series allows either a saving of at least one size or is an outstanding alternative to helical gearboxes. In addition, this integrated option is environmentally-friendly as no external cooling system is needed. Typical industries for the application are material handling, cranes and winches, mining, recycling, water and waste water, food and beverages, as well as numerous other industries where it comes down to a high torque density with an optimized space requirement.

For more information:
Bonfiglioli
Phone: (859) 334-3333
www.bonfiglioli.com

R+W

ADDS LPZ SHORT SPACER INTO DISC COUPLING LINE

In its effort to fill in and complete its flexible disc coupling offering, R+W has added a standard coupling adapter which provides customers with more configuration and connection options when selecting couplings for industrial applications.

The LPZ spacer accompanies a quickly expanding product line and offers lateral misalignment capabilities in a very small package. It is available in six sizes ranging from 500 Nm to 12,000 Nm and is able to mate with any LP coupling hub R+W has to offer within the corresponding size. Both ends of this spacer connect via a precision machined stainless steel disc pack, which transfers torque through a pure friction-drive design. This ensures that shear force on the fastening bolts is eliminated and the assembly is completely backlash-free.

While this spacer is made entirely of steel, all R+W coupling components can be made from special materials and balanced for higher speeds if the applications demands it.

For more information:
R+W America
Phone: (630) 521-9911
www.rw-america.com/products/industrial-drive-couplings/disc-pack-couplings/lpz.html

Maxon Motors

INTRODUCES STERILIZABLE DRIVE SYSTEM

Maxon Motor's NEW ENX EASY is a sterilizable encoder for use with Maxon's brushless DC motors. This opens up a range of new possibilities in medical technology. It is available in an incremental (1,024 counts) and absolute version (4,096 steps), both designed for 1,000 autoclave cycles.

As of now, the ENX EASY can be combined with matching BLDC motors and planetary gearheads. The encoder can be integrated into the brushless drives ECX 13 and ECX 16 SPEED (up to 120,000 rpm and 104 W) without any increase in length. When the gearheads GPX 13 and GPX 16 SPEED (0.2 Nm max. continuous torque) are added to the combination, customers receive a fully sterilizable positioning system. This opens up an entire new range of possibilities.

For more information:
Maxon Precision Motors
Phone: (508) 677-0520
www.maxonmotorusa.com

Force Control

POSITORQ BRAKES PROVIDE TORQUE CONTROL

A full line of Positorq oil shear tension control brakes from Force Control Industries provide simple, precise torque control over the entire speed range, even down to 0 rpm. Operational speeds are precisely controlled without chatter, stick slip or torque variation — thus eliminating marking during leveling, polishing and coating. Torque is controlled by pneumatic or hydraulic actuation pressure and is independent of speed. Sizes range from 53 lb. ft. up to 300,000 lb. ft., with continuous heat absorption capability up to 3000 thermal horsepower. Positorq Oil Shear brakes are ideal for tension control applications such as unwind stands in steel mills, where very high torque is required at very low speed.

Oil Shear technology eliminates normal maintenance and adjustment, allows smooth operation, and lasts up to 10-times longer than standard dry friction brakes, making them ideal for many industrial applications. Totally enclosed housings make these brakes a trouble-free solution for steel mills because the enclosed housing reduces wear and torque changes due to moisture, scale and chips in the friction material.

In addition to transmitting torque, a patented fluid recirculation system assures the fluid is continually flowing through the friction area and carrying the heat to the housing for dissipation. This eliminates the major problem of heat buildup in the friction area of traditional dry brakes. The fluid also serves to continually lubricate all components of the oil shear brake, including bearings and splines, increasing service life of all the internal components.

For more information:
Force Control Industries
Phone: (513) 868-0900
www.forcecontrol.com

SKF

INSOCOAT BEARINGS PREVENT PASSAGE OF HARMFUL ELECTRICAL CURRENTS

SKF's INSOCOAT bearings range comprises bearings with an electrically insulating coating on the external surfaces of its inner or outer ring, plasma-sprayed with an aluminium oxide coating. The coating, which is naturally hygroscopic, is sealed with a resin to protect against the conductive effects of high humidity and moisture ingress. These bearings are specially designed and manufactured for use in rotating electrical machines, such as industrial electric motors, traction motors and generators. They prevent the passage of harmful electrical currents from the rotor to the machine frame via the bearings, which causes progressive electrical erosion of the bearings' rolling contact surfaces and ultimately premature failure.

Following the introduction of an improved plasma spray coating process and optimised ceramic layer, SKF can provide this insulating coating as standard and off-the-shelf across its entire INSOCOAT range.

INSOCOAT bearings are now able to withstand voltages of 3,000 V DC sufficient to cope with the vast majority of stray bearing current problems in electrical machines.

In addition, the upgraded moisture-resistant coating provides greater protection against humidity storage environments which can compromise a bearing's insulating properties before it is even placed in service, making INSOCOAT bearings highly robust during transport and handling.

Combining both bearing and insulation in a single solution, INSOCOAT protects against electrical erosion at significantly lower total cost of ownership compared with other techniques such as shaft or housing insulation.

For more information:
SKF USA Inc.
Phone: (267) 436-6772
www.skfusa.com

Miki Pulley

EXPANDS BX BRAKE SERIES

Electromagnetic Miki Pulley BX series brakes are a power-off, engaged type brake. When the stator is energized, the brake is disengaged allowing free rotation. When no current is applied, compression springs halt the brake rotor thereby stopping the input shaft rotation. This is an ideal feature to prevent power failure events.

Of the BX series, the BXR-LE has expanded to three additional sizes. (Six total size configurations to choose from.) These brakes boast advantages including a slim design and high holding torque in a compact package. They provide quiet operation with long service life. This brake was designed for smaller machine and robotic applications, where cantilevered loads can negatively impact operation. The brake's unique compact and lightweight design optimizes machine design efficiency. With accompanying voltage controller, power consumption is stepped down to 7VDC after a split second of 24VDC for brake actuation.

When compared to the other BX brakes in the Miki lineup, this BXR-LE design provides just one-third power consumption and heat generation in one-half the overall size thickness.

Specifications include a maximum rpm of 6,000; static friction torque range between 0.06 Nm–3.20 Nm (0.044 ft-lbs–2.36 ft-lbs) and an ambient operating temperature of –20°C–60°C (–4°F–140°F).

Applications include robotic arm joints, Z-axis ball screw brake on CNC machine centers, internal brake for direct drive servo motors, pan/tilt brake for security cameras, brakes for locking sensor alignment and Z-axis brake.

For more information:
Miki Pulley US
Phone: (800) 533-1731
www.mikipulley-us.com

SICK

INTRODUCES KTS AND KTX SENSORS

With its KTS and KTX product families, SICK is presenting new, powerful contrast sensors from a forward-looking, innovative platform. The patented TwinEye technology for improved contrast detection and sensing distance tolerance (±5 mm), the specially developed three-color LED with its high-precision, color-mixed light spot, and the jitter that has been minimized to a level never before seen, coupled with absolute high-speed switching frequencies, open up a world of new possibilities when it comes to detecting contrasts and—for the first time in a sensor—colors too.

IO-Link and additional integrated functions such as recipe management ensure maximum versatility, while the innovative, multifunctional 7-segment display guarantees simple yet customized sensor setup, operation, and visualization.

Familiar applications such as the detection of print marks or the control of industrial labeling processes benefit from even greater process stability and performance. The sensors detect high-gloss materials and complex contrasts, even on heavily jittering materials. The integrated color mode also enables reliable detection of even the most minor contrast differences and color features.

The KTX product family offers compatibility without compromise: Both the hole pattern for mounting the sensors and the electrical connectiv-

Festo Motion Terminal

OFFERS PROGRAMMABLE PLATFORM FOR AUTOMATION AND PNEUMATICS

The machinery and plant construction industry is faced with the challenge of catering to the increasing consumer demand for individually adaptable products at affordable prices. Along with the continuing need for mass-produced goods for the world's population, which will soon reach the eight-billion mark, demand is also growing for small-series production down to lot size 1.

Digitalization in the course of Industry 4.0 is providing the necessary key technologies. Festo has developed a universal, programmable platform for highly flexible and adaptive automation with digitalized pneumatics.

With the Festo Motion Terminal, the company has merged hardware and software to produce a digital valve. Over a three-year development period not only an intelligent pneumatic automation platform for Industry 4.0 was created, but in fact an entirely new solution for the manufacture of products for the future.

For more information:
Festo
Phone: (866) 463-3786
www.festo.com

ity facilitate a 1:1 migration from the SICK product families that are already proven and widespread on the market to the new technology platform. In its space-saving compact housing, the KTS meets all requirements of modern machine concepts.

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Digital productivity can make a significant contribution to a company's bottom line. "From the procurement of new equipment, through its installation, use and asset management, customers can expect a return on mission-critical investments," said Rick Morse, vice president, digital solutions, of Rexnord's process and motion platform. "The DiRXN platform delivers on operational savings and metric-driven goals, including mean time between failure (MTBF) and mean time to replace (MTTR), as well as overall equipment effectiveness. These are key performance indicators that DiRXN can positively impact for global customers."

"Rexnord has been a vital part of industrial infrastructure for more than 125 years," said Kevin Zaba, president of Rexnord's process and motion control platform. "We're digitizing over a century of application expertise and applying it to traditional tasks and problems allowing customers to solve them in smarter, more efficient ways, while giving Rexnord more visibility to customer and product behaviors that will further improve our portfolio of industry solutions."

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Miniature Motion Solutions

Motor Technology Thrives in Aerospace/Defense Applications.

Matthew Jaster, Senior Editor

Maxon offers a variety of miniature motors for aerospace and defense applications.

Let's talk big picture for a moment. The motors pictured to the right are no different than many components that frequent the pages of this magazine. They're all shiny, mechanical magicians tasked with making things move. Perhaps they're used in control valves, radar antennas or gas pumps. We typically think of applications like industrial fans, power tools or household appliances for small and miniature motors, but there's much more going on inside these tiny, highly-engineered devices.

They operate the wheels of rovers for missions to the Moon as well as Mars. They're also found in autopilot system actuators, control valves for rocket engines and gyroscopes. An underlying theme within these applications is selecting a component that can handle the challenges that come from high-temp, hazardous and highly-critical environments. They need to be properly-equipped to function under the most extreme circumstances (occasionally 33.9 million miles away from the closest engineer).

When companies like Boeing, General Dynamics, Lockheed Martin or Northrup Grumman need to develop cost-effective, aircraft and aerospace components for commercial and military applications they study weight, power and fuel consumption. These are the critical areas where the difference in a few pounds can make or break an entire project.

Power Transmission Engineering caught up with three motor manufacturers (Portescap, Maxon and Allied Motion) to discuss miniature motors for aerospace and military applications. Each company is putting an emphasis on performance, expanding customizable options and attempting to keep up with evolving machine technologies.

Evolving Markets and Technologies

Aerospace and defense applications do not lack opportunities. Each year, new airplane, spacecraft and satellite technology need motors to run a variety of components.

Civil and defense aviation utilizes Maxon Motors for air and liquid control valves, gas pumps, seats, window shades, entertainment displays, fly-by-wire actuators, autopilot system actuators and radar antennas. Space applications include cameras, drills and wheels for space exploration vehicles (rovers, reaction wheels and deployment actuators and control valves for rocket engines. They are also used in control surface actuators and generators for unmanned aerial vehicles (UAVs).

Portescap's motors have been used in a wide variety of commercial aerospace applications, including seat actuation, window shades, surveillance camera systems, valves, onboard instrumentation, electric actuators, fuel metering systems, gyroscopes, in-cabin televisions, indicators, and satellites.

Allied Motion's frameless torque motors have been utilized in airborne and ground-mobile gimbal systems for satellite communications, stabilized platforms, remote weapons systems, missile control actuation systems and aerospace pumps.

In fixed and rotary wing aircrafts they're used in electronics cooling, autopilot servos, stall warning devices, trim and control surface actuators, fuel lift and transfer pumps. In defense applications — safe and arm actuators, control surface actuators, track vehicle fuel lift and transfer pumps, fire control as well as target acquisition (azimuth and elevation drives) applications.

These keep changing as aircraft technology advances and engineers seek out new energy efficient solutions. And an added bonus to working in this industry is that they frequently can be applied to other critical applications (automotive, wind, mining, etc.).

The Importance of Engineering Expertise

"There is a clear market responsibility and strategy for the aerospace industry. This will ensure we can supply our aerospace and defense customers with the most innovative and reliable technology in motion control," said Roger Villiger, head business development aerospace at Maxon Motor AG.

Villiger said that Maxon's entire portfolio of motion control solutions may be applied to aerospace applications. As regulations and contractual demands of customers continuously rise, Maxon concentrates on selling solutions made of new drive components with increased robustness.

Portescap's technology and design expertise has helped provide solutions for a variety of commercial aerospace applications. The company offers a selection of compact and efficient brush DC motors that enable smooth and quiet operation while reducing weight and size, according to David Beckstoffer, product manager at Portescap.

You'll find small yet very capable motors inside an unmanned aerial vehicle (UAV).

Philip Lucia, business development manager at Allied Motion Technologies cites both slotted and slotless miniature brushless motors as pivotal for the company's success in aerospace.

Torque, power density and product quality are so vital in these applications where failure is not an option. Lucia said that the wide range of size options and tailor-made product features allow Allied Motion to power a variety of challenging and cutting-edge technologies.

Allied Motion Dayton has the brush *and* brushless family of DC motors ranging in size from .750 inch to 2.25 inches diameter that are all suitable for use in harsh environments, according to John Burke, sales manager at Allied Motion Dayton.

"Brush motors incorporate alnico magnets which provide consistent performance over a wide temperature range. In addition, high reliability brushless DC motors utilize various magnet materials. Planetary gearboxes are available for use with each motor frame size and deliver high torque output. All motors are manufactured in an AS9100 environment," Burke said.

An Emphasis on Size, Speed, Weight and Power

Weight, size, acceleration and power are the driving forces behind aerospace applications. Here, motor companies need to address complex specifications in order to keep up with industry demands. The smaller, lighter and more powerful components will always have an advantage over their counterparts.

Each motor application has unique challenges but aerospace motors are notably sensitive to motor size and weight (photo courtesy Allied Motion).

Beckstoffer said that aerospace applications require miniature motors with high power density, allowing smaller motors to be used in the application providing an overall reduction in weight. Fuel consumption is also critical to the overall cost of operation, so high power and lightweight motion solutions provide additional cost savings to the OEM. Coreless and slotless motor designs enable high acceleration capability of the motor, allowing guidance systems the ability to track and respond to changing conditions in an instant.

Lucia believes each application has its own unique challenges, but airborne applications in particular are notably sensitive to motor size and weight. Maximum power density per unit mass is a crucial figure of merit in motor selection for these applications, and oversizing a motor can result in spiraling inefficiencies on other axes in the system. Lucia also said it was critically important to have an experienced applications engineer assist with motor sizing.

Burke added that weight has become critical in missile technology and smaller diameter configurations in multiple platform usage. Trends will be to higher power densities and more efficient motors as well as components that will provide higher output than the motors/components that preceded them.

Villiger at Maxon stated that modern passenger planes need to be very fuel efficient to provide a lot of room and convenience. Consequentially, such planes contain hundreds of DC drives. Maxon is able to provide these lightweight, compact and high powered drives throughout the aircraft.

Custom Requirements

Beckstoffer states that customization is essential to providing the optimum motor performance, taking into consideration the various application requirements to create the ideal motion solution.

"Every application will be slightly different in its needs, so the ability to adapt standard products to the electrical and mechanical envelope of the design creates an ideal situation for the designer," he said.

Customization is often crucial to the motor design due to the pressing need to select the optimal product for mission-critical functions and to ensure that strict application-specific requirements are met and quality standards maintained, according to Lucia.

"While off-the-shelf and catalog components can be helpful for refining system requirements and performance parameters early in a development cycle, customized components typically become the most effective means of ensuring later iterations of your project result in a fully functional and hardened final system design," Lucia said.

He also believes that application-specific custom validation test procedures, when identified early and designed thoughtfully with creative consideration for real-world scenarios, can prevent issues down the road.

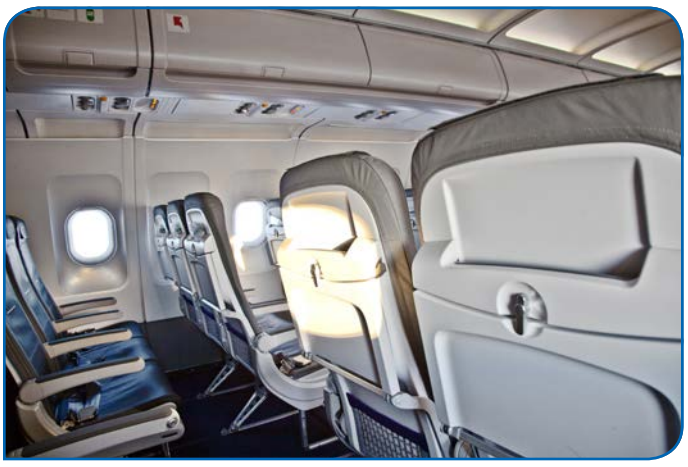
It's true what they say about aerospace technology: If you're not testing, verifying and validating every step of the way, you're probably in the wrong line of work.

Future Aerospace Demands

These motor manufacturers are well-positioned to handle the current demands of the aerospace and defense industries. Villiger at Maxon noted that the project pipeline is full and the organization is keeping close tabs on areas such as automation, IIoT and support and service for future considerations.

Allied's precision brushless motor technology is currently pushing the boundaries of what's possible in motor efficiency and the company will continue to invest in cutting-edge R&D.

"This market will continue to seek incremental improvements in motor performance, and advances in complementary technologies like drives and feedback devices will drive



Portescap motors are utilized all over an aircraft including seat actuation, in-cabin televisions and window shades.

motor design adjustments to help enable those improvements. Customization will remain crucial to meeting application-specific requirements," Lucia said.

Developing and maintaining technical capabilities, higher power density designs and using alternative magnetic and special material solutions will be required to compete in the future, according to Burke. There will be an increased emphasis on autonomous designs and technology with fewer OEMs due to consolidation in the industry. The focus will be on increasing product reliability requirements, power density, and torque output for motors, gearmotors and devices used in new applications.

"In addition, aerospace and defense OEMs will face increasing government and industry regulations they will need to incorporate and flow down to select suppliers. Missiles and guided weapons will require increased accuracy to limit collateral damage," Burke said.

For Beckhoffer at Portescap, the future will be all about exceeding expectations. There will be a significant push for motor efficiency to provide lower operating costs. A cost-savings in one critical area can lead to additional cost-savings down the road.

"Aerospace applications will continue to reduce their overall footprint, going to faster machines with higher capabilitie," Beckhoffer said. "New features will be added into existing platforms as technology moves forward, requiring a motion solution that can keep pace with each and every new advancement." **PTE**

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A Strong Yet Subdued Aerospace Market

According to Deloitte, the global aerospace and defense industry is likely to experience stronger growth than previous years. The company believes industry growth in 2017 will be about 2 percent higher than 2016. They also believe the industry will continue to see positive growth in the next few years, but it will be very slow growth. Here is some data to back these findings:

Stable global gross domestic product (GDP) growth, relatively lower commodity prices including crude oil, and strong passenger travel demand, especially in the Middle East and Asia Pacific regions, will likely drive the commercial aerospace sub-sector growth.

Despite an expected increase of 96 additional large commercial aircraft being produced in 2017, continued pricing pressure and product mix changes by airline operators will likely result in only a marginal increase of 0.3 percent in commercial aerospace sub-sector revenues.

Defense sub-sector revenues are likely to grow at a much faster 3.2 percent in 2017 as defense spending in the United States has returned to growth after multi-year declines in defense budgets, and future growth may be driven by the current administration's increased focus on strengthening the U.S. military.

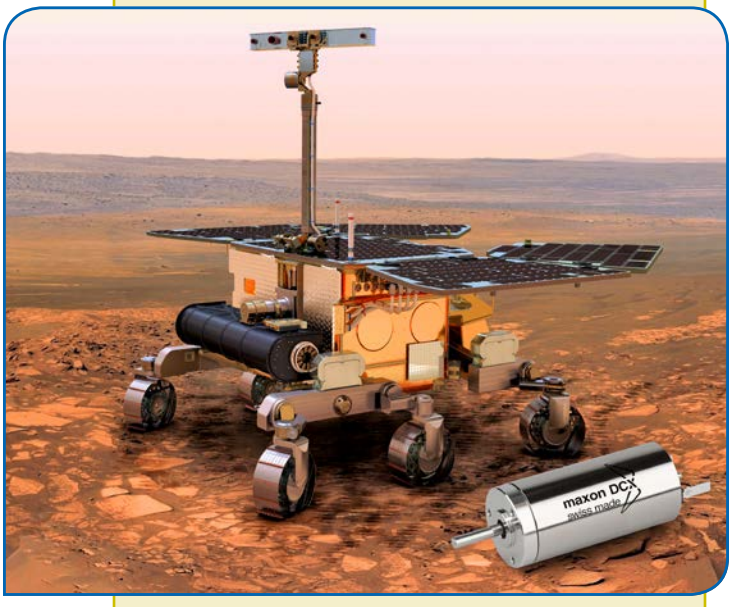
Rising global tensions have led to increasing demand for defense and military products in the Middle East, Eastern Europe, North Korea, and the East and South China Seas. This is, in turn, resulting in increased defense spending globally, especially in the United Arab Emirates (UAE), Saudi Arabia, South Korea, Japan, India, China and Russia. **PTE** (*www2.deloitte.com*)

Aerospace Megatrends

In a speech in Washington D.C. earlier this year, Dave Melcher, president and CEO of the Aerospace Industries Association (AIA), called attention to four megatrends that would influence the aerospace and defense industry moving forward:

The four megatrends include: the state of deficit politics, U.S. leadership in the global economy, smart regulations and the digital economy.

"The sorry state of deficit politics is the first megatrend that requires much greater attention," said Melcher. "We deeply regret the prolonged budget uncertainty, and unthinking austerity of recent years—especially when it comes to funding real and emerging security needs, and the technological investment that will pay untold dividends in the civil aviation and space arenas."



"Second, we're disturbed by the increasing threats to policies that expand our industry's trade competitiveness that have led to self-inflicted wounds to U.S. leadership in the global economy. We intend to continue assertively making the case for positive engagement in global trade."

"Third, we see a need for smart regulation to reduce the burden imposed by government rules, regulations and executive orders on industry."

"And fourth, the rapid transition to a digital global economy that we're witnessing presents significant opportunities and challenges as more attention is paid to big data analytics and addressing cyber risks," he said. **PTE** (*www.aia-aerospace.org*)

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Guide to V-Belt Selection and Replacement

Lance Lachney, Product Line Manager, V-Belt Drives, Gates Corporation

V-belts look like relatively benign and simple pieces of equipment. They're basically a glorified rubber band, right? Need a replacement? Just measure the top width and circumference, find another belt with the same dimensions, and slap it on the drive. There's only one problem: that approach is about as wrong as you can get.

Like their synchronous belt cousins, V-belts have undergone tremendous technological development since their invention by John Gates in 1917. New synthetic rubber compounds, cover materials, construction methods, tensile cord advancements, and cross-section profiles have led to an often confusing array of V-belts that are highly application specific and deliver vastly different levels of performance.

In this article we'll review some V-belt basics to help you make better sense of which belt to use in a given application to make your belt drives last longer, run more efficiently, and save you downtime and money.

Size Isn't Everything

Take a look at the accompanying chart (Figure 1). Each of these belts has a ½-inch top width and 50-inch circumference.

However, notice the differences in cord materials, body compounds, cover configurations, temperature ranges and application requirements. Despite their outward similarities, each of these belts is designed for a distinct purpose. Using the wrong belt could cause equipment damage or pose serious safety issues. What is the right belt for the job? It depends on the application. Following are some environmental and application design criteria that will influence belt selection:

- Ambient temperature
- Oil resistance
- Ozone resistance
- Static conductivity
- Power capacity
- Pulsation or shock loading
- Small sheave diameters
- Backside idlers
- Misalignment tolerance
- Serpentine or quarter turn layout
- Minimal take-up
- Clutching
- High speeds
- Energy efficiency
- Dust and abrasives

As you can see, there are many factors to consider before choosing the right V-belt for the job.

Generally speaking, V-belts fall into these classifications:

- Heavy-duty
  - ◊ Industrial machinery
  - ◊ Continuous operation
  - ◊ Heavy loads and often harsh conditions
- Light-duty
  - ◊ Fractional horsepower applications
  - ◊ Intermittent usage
- Automotive

For this article, we'll confine our discussion to industrial heavy-duty and light-duty V-belts.

How V-Belts Work

Unlike flat belts, which rely solely on friction and can track and slip off pulleys, V-belts have sidewalls that fit into corresponding sheave grooves, providing additional surface area and greater stability. As belts operate, belt tension applies a wedging force perpendicular to their tops, pushing their sidewalls against the sides of the sheave grooves, which multiplies frictional forces that allow the drive to transmit higher loads. (Figure 2) How a V-belt fits into the groove of the sheave while operating under tension impacts its performance.

V-belts are made from rubber or synthetic rubber stocks, so they have the flexibility to bend around the sheaves in drive systems. Fabric materials of various kinds may cover the stock material to provide a layer of protection and reinforcement.

V-Belt Profiles (Cross Sections)

- V-belts are manufactured in various industry standard cross-sections, or profiles, including the following:
- Classical
- Narrow
- Metric
- Fractional Horsepower

The classical V-belt profile dates back to industry standards developed in the 1930s. Belts manufactured with this profile come in several sizes (A, B, C, D, E) and lengths (Figure 3), and are

Figure 1 V-belts with identical top widths and outside circumferences.

Gates Part #	Gates Product	Top Width	O.C.	Tensile Cord	Compound	Cover	Temperature Range	Application Requirements
AP48	Predator®	0.5"	50"	Aramid	Chloroprene	Clutching	–30 to 180°F	Shock loading, high HP
AX48	Tri-Power®	0.5"	50"	Polyester	Ethylene	Raw Edge	–60 to 250°F	Small diameters, high temperature environment
A48	Hi-Power® II	0.5"	50"	Polyester	Diene	Flex-Weave	–30 to 140°F	Standard industrial power transmission
XPA1257	Metric PowerTM	0.51" (13mm)	50.20" [1275 mm]	Polyester	Ethylene	Raw Edge	–60 to 250°F	Replacement for existing metric belt
4L500K	PoweRated®	0.5"	50"	Aramid	Chloroprene	Clutching	–30 to 180°F	Lawn and Garden equipment
4L500	Truflex®	0.5"	50"	Polyester	Diene	Flex-Weave	–30 to 140°F	Fractional HP, light duty

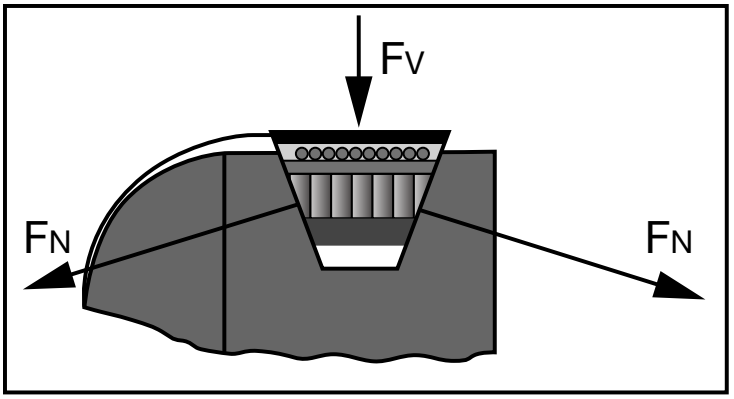

Figure 2 Vertical force (F_v) applied perpendicular to belt top creates high sidewall forces (F_n) to transmit higher loads.

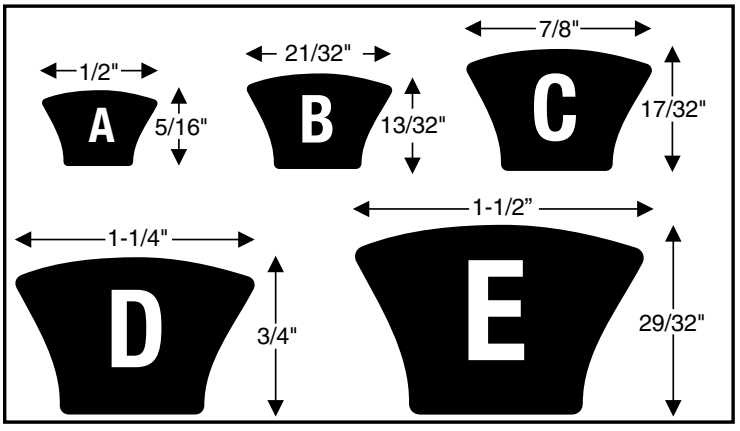

Figure 3 Classical V-Belt Profiles

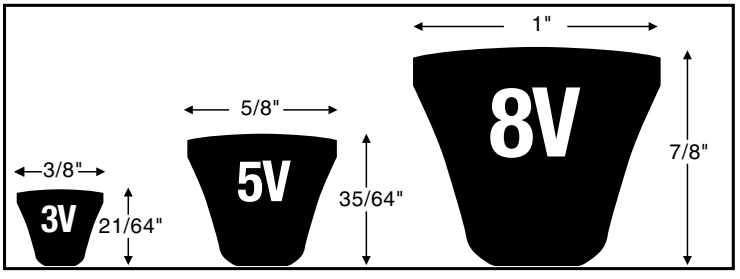

Figure 4 Narrow V-belt Profiles

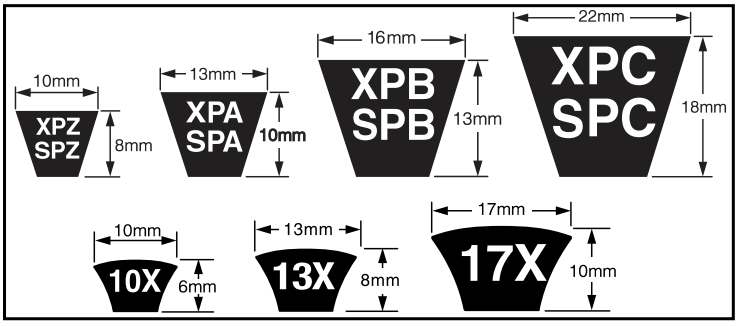

Figure 5 Metric V-belt Profiles

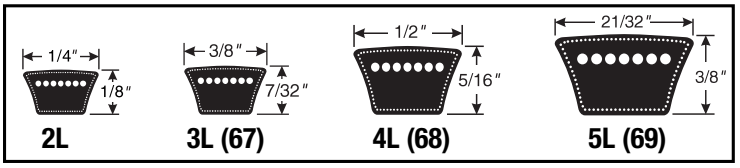

Figure 6 Fractional Horsepower V-belt Profiles

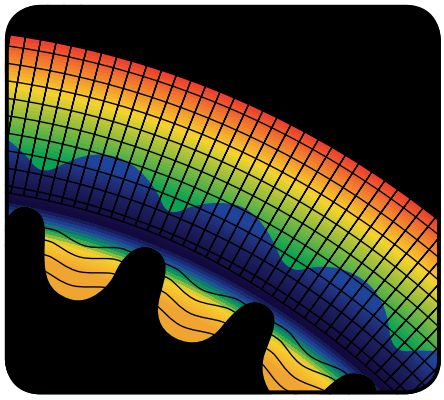

Figure 7 Bending stress (red area) is evenly distributed in a well-engineered notched V-belt, while the tensile cord (between red and yellow bands) remains well supported, all without sacrificing flexibility.

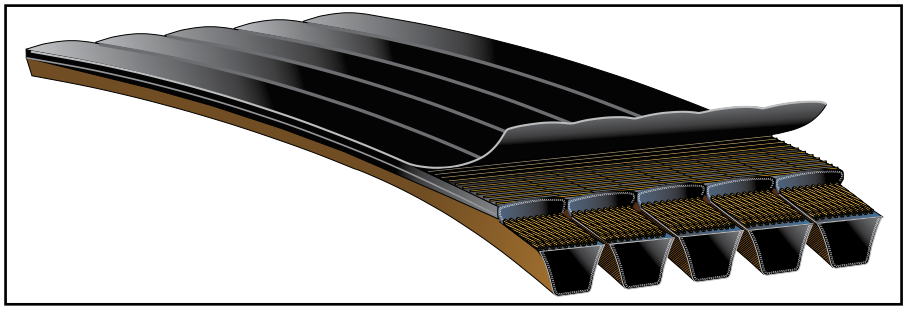

Figure 8 Joined V-belt

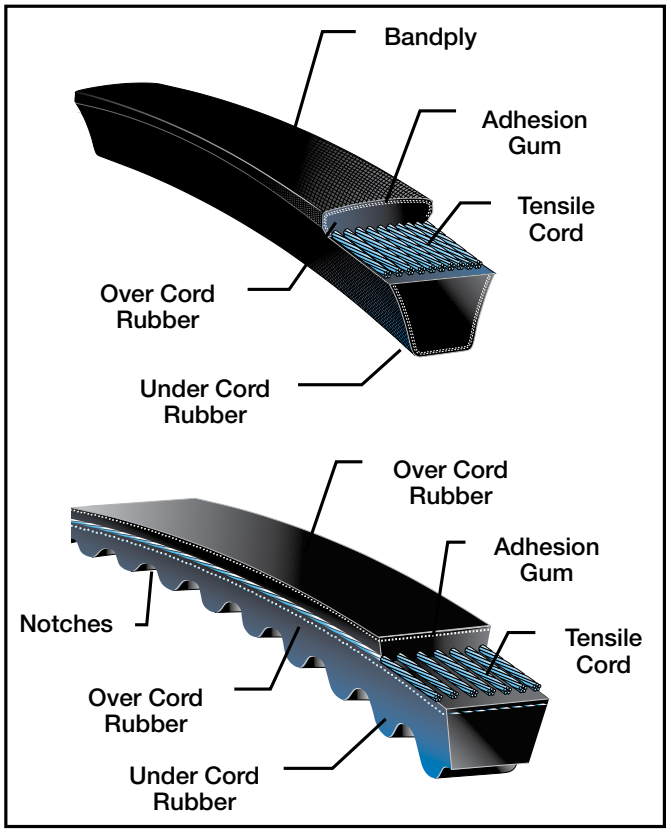

Figure 9 Anatomy of a V-belt.

widely used to replace V-belts in older, existing applications.

V-belts with a narrow profile (3V, 5V, 8V) have more steeply angled sidewalls than classical V-belts (Figure 4), providing increased wedging action and higher load capacity (up to 3x that of comparable classical V-belts)..

Metric V-belts have profiles that adhere to international standards set by organizations such as ISO (International Organization for Standardization) and DIN (the German Institute for Standardization) (Figure 5). They are used to replace belts on industrial machinery manufactured in other parts of the world.

The fractional horsepower V-belt profile is designed for light-duty applications such as lawnmowers, snow blowers, attic or furnace fans, etc. These belts have a thinner cross-section and lighter gauge tensile cord (Figure 6), making them more flexible and able to bend around small sheaves.

Notched or Cogged V-Belts

All of the V-belt types noted above are typically available from manufacturers in "notched" or "cogged" versions. Notches reduce bending stress, allowing the belt to wrap more easily around small diameter pulleys and allowing better heat dissipation. Excessive heat is a major contributor to premature belt failure.

Engineering a notched belt is a balancing act between flexibility, tensile cord support, and stress distribution. Precisely shaped and spaced notches help to evenly distribute stress forces as the belt bends, thereby helping to prevent undercord cracking and extending belt life (Figure 7).

Joined V-Belts

For applications with vibrating or pulsating loads, especially with long center distances, joined V-belts may be the answer. A joined V-belt is, in essence, a number of single V-belts joined together with a continuous tie-band across the back (see Figure 8).

A joined V-belt increases lateral rigidity to reduce belt whip and maintain stability under shock loads. It also simplifies installation and tensioning compared with multiple single belts.

V-Belt Construction and Material

Figure 9 describes the constructional components of standard and notched V-belts. Each component has a vital role to play in how well V-belts perform and how long they last. Different materials and configurations can influence belt performance characteristics in specific applications.

The tensile cord is the load-carrying component of a V-belt. Most V-belts are made with polyester cords, although some belts are constructed with aramid or Kevlar® cords, which offer higher tensile strength, limit stretch, and can handle heavier shock loads. In a well-engineered V-belt, the tensile cords and rubber body of the belt are chemically bonded to form one unit, allowing for equal load distribution and longer belt life.

Tensile cords are supported by rubber stocks, both above (over cord) and beneath (under cord). Various synthetic rubber stocks are used by different manufacturers to provide heat resistance and reduce wear. Some high-performance synthetic rubber compounds, such as ethylene, significantly extend a belt's operating temperature range and resist hardening, cracking, and premature failure.

A well-engineered V-belt will have transverse rigidity, which means a high level of rigidity across its width so that the tensile cords will transfer the load equally. At the same time, the belt must be highly flexible along its length to reduce heat and bending stresses, which in a superior belt is accomplished by parallel alignment of fibers in the rubber compound.

Adhesion gum is the element that forms a strong chemical bond between the tensile cord and the rubber stock. It bonds the belt together so that it acts as a single unit. The gum also absorbs cord stresses and avoids cord pullout.

To protect the core of the belt from destructive environmental forces such as oil, grime and heat, as well as from general wear and tear, some V-belts have a fabric cover, or band ply. In a well-engineered belt, this flexible fabric is treated to form a chemical bond with the belt core materials, allowing it to withstand the stress of constant bending over time and prolonging cover life.

As described earlier, the notches in a notched V-belt are designed to increase belt flexibility and reduce bending stresses, especially on small sheaves.

Don't Forget Sheaves

Sheaves are essential V-belt drive components. As noted earlier, how well a V-belt fits into the sheave determines how much power the belt drive can transmit and how efficiently it operates. Proper fit is a function of both the belt and the metal sheave. A well-engineered belt and a well-machined, matching sheave provide the optimal combination.

Many users replace V-belts repeatedly without bothering to check the sheaves for wear. A worn, broken or damaged sheave decreases belt life. Sheave damage could result from incorrect installation, such as over-tightening the bushing bolts or prying the belt onto the sheave. Another cause

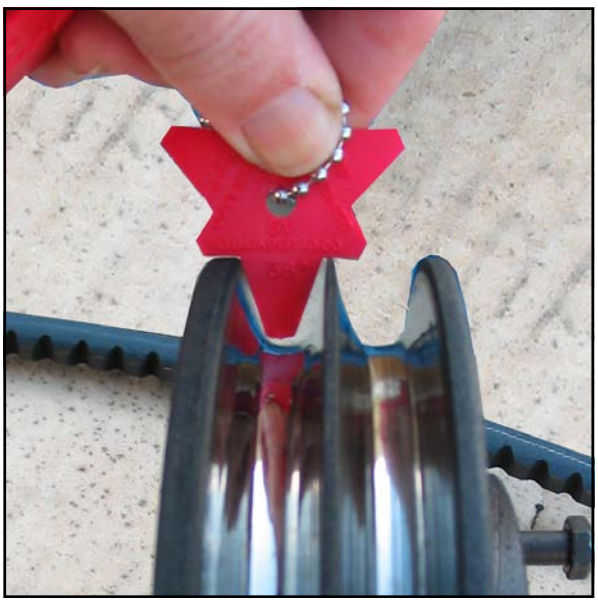

Figure 10 This photo depicts a highly worn sheave, which can cause belt sidewalls to harden and crack, or produce excessive wear on the belt's bottom surface and corners, leading to premature belt failure. In an unworn sheave, the gauge should fit snugly into the groove with no light shining through.

of sheave damage is debris falling into the drive, which can be prevented by installing a drive guard.

Signs of sheave wear include groove sidewall cupping and/or a polished groove sidewall with ridges. Use a sheave gauge (Figure 10) to detect excessive sheave groove wear, and replace sheaves immediately when worn.

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Upgrade V-Belts and Drives for Higher Performance and Savings

Advances in V-belt technology present users the opportunity to upgrade older drives and gain improvements in performance while saving time and money. For example, industry standard V-belts subject to extreme operating conditions, such as stifling heat inside a belt guard, can fail prematurely from heat cracks, stretching or excessive wear. Frequently retensioning and replacing the belts leads to downtime, inefficiency and loss of productivity.

With today's new technologies, however, you can upgrade to notched V-belts made from an ethylene rubber material that can withstand temperature extremes from –70°F (–57°C) to +250°F (+121°C), an 88% improvement over the temperature range for industry standard V-belts. These newer belts resist hardening to avoid cracking, offer improved flexibility, and run smoother in the sheaves to reduce vibration and extend the life of other drive components, such as shafts and bearings.

As another example, replacing an older, classical V-belt drive with a newer, narrow profile notched V-belt made with an ethylene elastomer and aramid fiber tensile cords can yield up to 3x greater load carrying capacity while reducing the weight and size of the drive, relieving stress on shafts, bearings and other components.

When it comes to V-belt drives with multi-groove sheaves, consider your options. If the sheaves are not worn, you can use fewer, higher-performance belts (leaving open grooves), or fill all the grooves with higher-performance belts to increase drive load capacity and extend belt life. If the sheaves are worn and need replacement, you can upgrade to a more compact (but equally powerful) drive to save weight and space, or keep the same drive configuration while increasing drive capacity.

Conclusion

From giant rock crushers to tiny sewing machines, V-belts have found their way into countless industrial applications. Today's V-belts are marvels of modern technology, reflecting the latest advances in mechanical and chemical engineering. The key thing to remember about V-belts, whether on a new drive or a replacement, is "know thy application." The right belt for the job, along with proper installation and maintenance, will provide you trouble-free service for the designed life of the drive. **PTE**

For more information

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Baldor Basics: Applications

Edward Cowern, P.E.

Former Baldor motors expert Edward Cowern PE, is a name known and respected by many in the electric motor industry. During his tenure at Baldor, Cowern — now enjoying his retirement — was tasked with producing a number of motor- and basics-related tutorials. The tutorials were primarily in response to a steady flow of customer questions regarding motors and applications. Today's customers continue asking questions and seeking answers to address their various motor-related concerns. We hope you find these articles useful and would appreciate any comments or thoughts you might have for future improvements, corrections or topics.

Fans, Blowers and Other Funny Loads

A family of motor applications that tend to confuse people who are not regularly involved with them, is that of variable torque loads. These loads represent a high percentage of motor requirements, so it is desirable to have a little extra knowledge of the mysterious aspects of these loads. First, variable torque loads are fans, blowers, and centrifugal pumps. In general fans and blowers are moving air but centrifugal pumps can be moving many kinds of liquids including water, petroleum products, coolants, etc.

There are two mysterious characteristics that these loads have. The first is the way they act when the speed is changed. The rules that cover these characteristics are called the "affinity laws." In order to simplify we will discuss only the performance of these loads when they are applied to systems where the load is not changing. For example, we can discuss a pump arrangement as shown (Fig. 1); this is a pump circulating chilled or hot water through a closed system. What we find is that the torque required to drive the pump goes up as a squared function of speed ($Speed^2$). Thus, increasing the speed causes the torque required by the pump to go up, not directly with speed, but in proportion to the change of speed squared. For example, if we change the speed from 1,160 to 1,760 rpm, the torque required will go up by the ratio of $(1{,}760 \div 1{,}160)^2$. This would mean that the torque required would go up by 2.3 times — to 230% of the original value. Also, since horsepower (HP) is based on speed times torque, and the speed has increased by 52%, the new value of HP would be 2.30×1.52, or almost 350% of the HP required at the original speed.

The dramatic increases in the horsepower required to drive these loads when speed increases is a little difficult to understand, but it is very important. It is also important because small decreases can result in great energy savings. For example, decreasing the speed of a variable torque load by only 20% will result in a driving energy reduction of nearly 50%. This, obviously, has big importance when conservation is considered. It also accounts for the tremendous market that exists for variable frequency drives operating variable air volume (VAV) systems used in heating, ventilating, air conditioning and variable speed pumping used in similar systems.

The second puzzling thing that occurs with variable torque

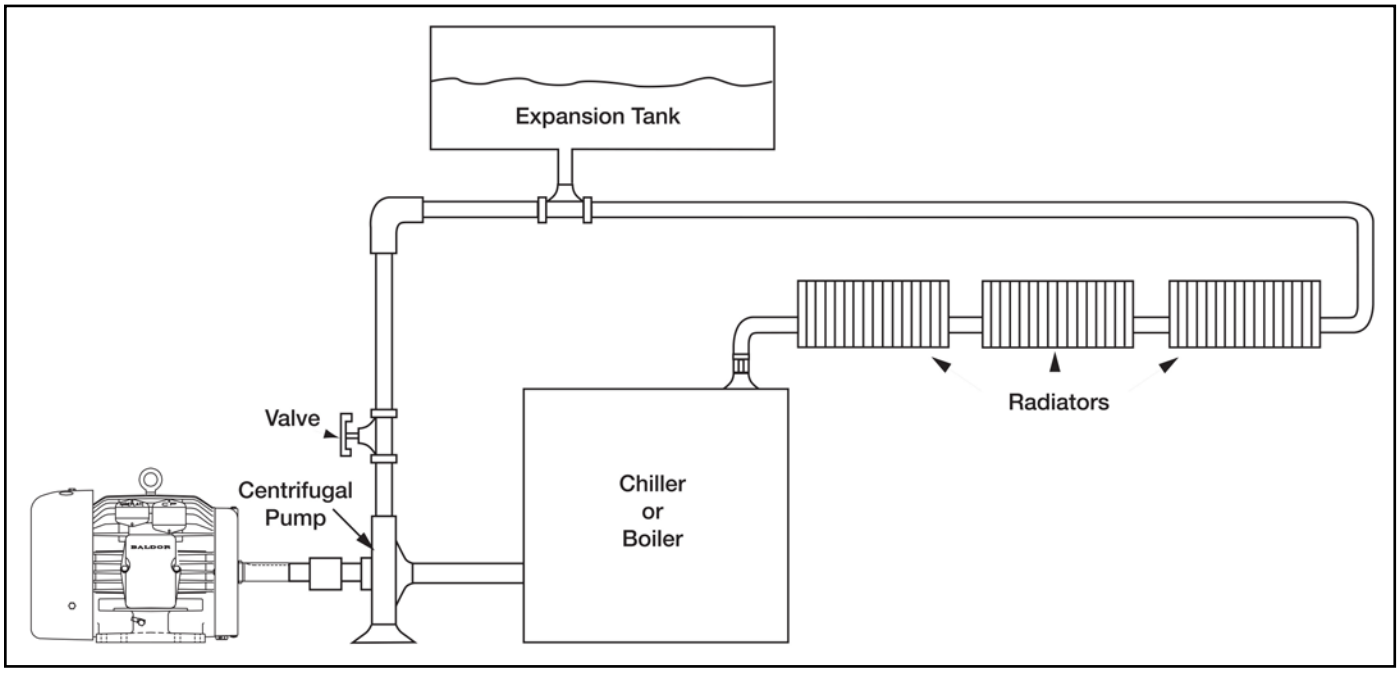


Figure 1 Pump arrangement circulating chilled or hot water through a closed system.

loads is that the motor load actually decreases as the output or input to the blower or pump is blocked off or restricted. This would be the situation in Figure 1, as the valve is closed. The reverse of this is that motor load increases dramatically as restrictions are removed. As an example of this, I once had a call from a motor user who had burned out a motor driving a blower on a heating system. The motor was driving a blower that drew air through a filter and fed it to a ducted distribution system. When I asked if there had been any changes in the system he said, "Well, we extended the ducts into another room and cut the end off to let the air flow, but that would have made it easier for the motor not more difficult." When I told him that the opposite was true he couldn't believe it. It defies good judgement to think that adding a restriction to the output of the blower would decrease the motor load. If you don't believe it, here's a simple test. Take a vacuum cleaner and listen to it carefully while you alternately open and close the suction. At first you might think that the "heavier" noise is the motor straining when the suction is the greatest, but if you listen more carefully you will notice that the pitch of the motor goes up when the suction is closed. What this means is that the load is being reduced on the motor and it speeds up. If you still don't believe, you can do the same test but with an ammeter on the motor. What you will find is that the amps drop as the suction level is increased. The same is true of centrifugal pumps. Closing down or restricting the output causes the pump to draw less mechanical power.

Another way of looking at this is when the output of a centrifugal pump or a squirrel cage blower is closed off, the air or fluid inside the housing becomes a "liquid flywheel;" it just spins around with the vanes of the pump or blower. Since there is no new fluid coming in to be accelerated, the only energy needed is what it takes to make up for the friction losses within the housing of the pump or blower. It doesn't seem to make sense, but that's the way it is!

As another example, think of fans applied to dust collection systems; the maximum load occurs when everything is as clean as can be. As the filter bags get coated with dust, the back pressure increases and the load on the blower and motor is reduced.

The amount of overloading or underloading that occurs as a result of changes in the "back pressure" on the pump or blower will depend on the specific design of impeller used. Some types of pumps and blowers are designed to be non-overloading, but typically the worst-case loading occurs at the open discharge condition.

Fans and Blowers Summary

When dealing with variable torque loads things are not always as they would seem. If there is some question about how this equipment performs, it is best to contact the equipment manufacturer and discuss the matter.

Previously Featured in Baldor Basics

- Types of Motors (December 2016)
- The Mystery of Motor Frame Size (February 2017)
- Primer on Two-Speed Motors (February 2017)
- Motor Temperature Ratings (March 2017)
- Metric Motors (March 2017)
- Understanding Torque (April 2017)

To find these articles quickly and easily, just type "Baldor Basics" in the search bar at *www.powertransmission.com*

Correction

An article in the April issue of *Power Transmission Engineering* — "Baldor Basics: Understanding Torque" — contained several copy editing errors which in several cases led to publishing incorrect formulas for HP (horsepower). None of these errors existed in the Baldor-supplied original material. Our apologies to series author Ed Cowern, ABB/Baldor, and our readers.

The value of the constant changes depending upon the units that are used for torque; the most frequently used combinations are:

$$HP = \frac{T \times S}{5252}$$ T = Torque in lb. ft. S = Speed in RPM

OR

$$HP = \frac{T \times S}{63{,}025}$$ T = Torque in lb. in. S = Speed in RPM

OR

$$HP = \frac{T \times S}{1{,}000{,}000}$$ T = Torque in in. ounces S = Speed in RPM

Rearranging these formulas to obtain torque, we can arrive at the equations:

$$T = \frac{HP \times 5252}{S}$$ T = Torque in lb. ft. S = Speed in RPM

OR

$$T = \frac{HP \times 63{,}025}{S}$$ T = Torque in lb. in. S = Speed in RPM

OR

$$T = \frac{HP \times 1{,}000{,}000}{S}$$ T = Torque in in. ounces S = Speed in RPM

The online version of the article has been corrected. You can download it at *www.powertransmission.com/articles/0417/Baldor_Basics:_Understanding_Torque/*

RMS Horsepower Loading

There are a great many applications — especially in hydraulics and hydraulically-driven machines — that have greatly fluctuating load requirements. In some cases, the peak loads last for relatively short periods during the normal cycle of the machine. At first glance, it might seem that a motor would have to be sized to handle the worst part of the load cycle. For example, if a cycle included a period of time where 18 HP is required, then the natural approach would be to utilize a 20 HP motor. A more practical approach to these types of "duty cycle loads" takes advantage of an electric motor's ability to handle substantial overload conditions, as long as the period of overload is relatively short compared to the total time involved in the cycle.

The method of calculating whether or not the motor will be suitable for a particular cycling application is called the RMS (root mean squared) horsepower loading method. The calculations required to properly size a motor for this type of application are relatively simple and are presented in this paper.

RMS calculations take into account the fact that heat buildup within the motor is very much greater at a 50% overload than it is under normal operating conditions. Thus, the weighted average horsepower is what is significant. RMS calculations determine the weighted average horsepower.

In addition to reducing the size and cost of a motor for a particular application, RMS loading also offers the advantage of being able to improve the overall efficiency and power factor on a duty cycle type of load. For example, when an oversized motor is operated on a light load, the efficiency is generally fairly low, so working the motor harder (with a higher average horsepower), will generally result in improved overall efficiency and reduced operating cost.

In order to use the RMS method of horsepower determination, the duty cycle has to be spelled out in detail (Fig. 1).

In order to determine the RMS loading for the previous cycle, we can use the formula:

$$\text{RMS HP} = \sqrt{\frac{HP_1^2 \times t_1 + HP_2^2 \times t_2 + HP_3^2 \times t_3 + HP_4^2 \times t_4 + \cdots HP_x^2 \times t_x}{t_1 + t_2 + t_3 + t_4 + \cdots t_x}}$$

The easiest way to approach this type of calculation is to make several columns, as shown (Fig. 2).

Figure 2 Method used in determining previous-cycle RMS loading.

Step	Horsepower	HP^2	Duration (Seconds)	$HP^2 \times$ Time
1	3.0	9.0	3	27.0
2	7.5	56.3	10	563.0
3	2.5	6.3	12	75.6
4	12.5	156.3	3	468.8
			28	1134.4

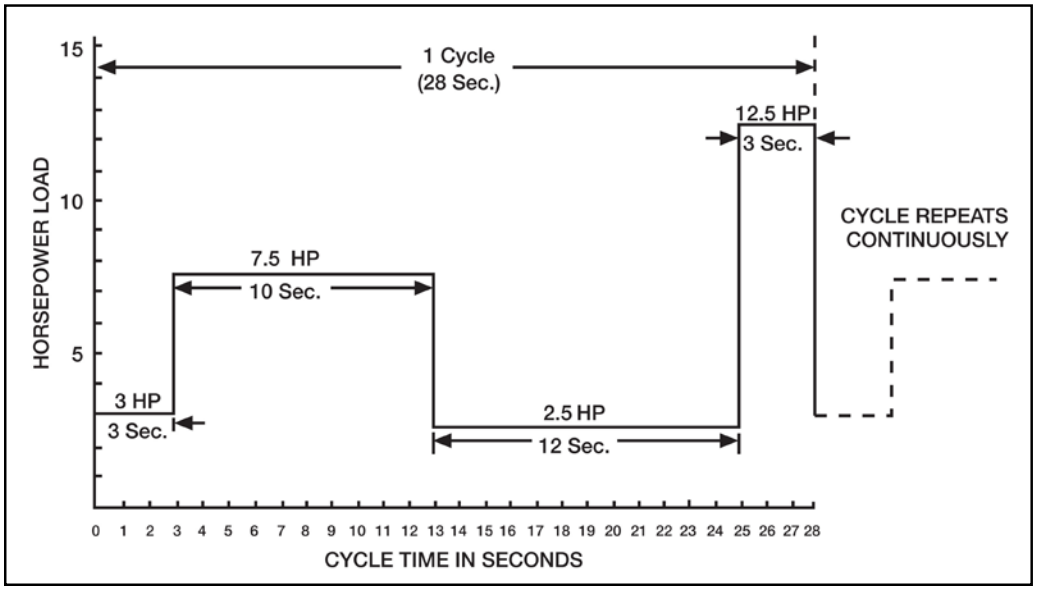
In this case, the total time of the cycle is 28 seconds and the summation of horsepower squared times time for the individual steps in the cycle is 1,134.4. When inserted into the equation, the RMS horsepower comes out to be:

$$\text{RMS HP} = \sqrt{\frac{1134.4}{28}} = \sqrt{40.5} = 6.4$$

At first glance, it appears that a 7½ HP At first glance, it appears that a 7½ HP motor would be adequate to handle the loading required by this duty cycle. One further check has to be made and that is to determine if the motor has adequate pullout torque (breakdown torque) to handle the worst portion of the duty cycle without stalling. In this case, you would have to refer to the manufacturer's data for the motor and determine the percent of pullout torque that is available.

An additional safety factor should be used because the pullout torque of the motor varies with the applied voltage. In fact, the pullout torque varies in relation to applied voltage squared. Thus, when the motor is running on 90% of rated voltage the amount of pullout torque available is only .9 × .9 or approximately 80% of the value that it has at full rated voltage. For this reason, it is never safe to use the full value of the pullout torque to determine if the overload can be handled. As a rule of good practice, it is wise not to use more than 80% of the rated pullout for a determination of adequacy.

In this case, **referring to the Baldor Engineering Data Section on www.Baldor.com**, we would find that a 7½ HP, open drip proof motor with a catalog number M3311T, has



Step	Horsepower	Duration (seconds)
1	3	3
2	7.5	10
3	2.5	12
4	12.5	3
Repeats continuously.		

Figure 1 Using RMS method of horsepower determination requires that duty cycle is spelled out in detail (Fig. 1).

a breakdown torque of 88.2 ft. lbs. and a full load operating torque of 22.3 ft. lbs. Thus, the actual pullout torque is 395% and utilizing 80% of this value, we would find that the available, safe pullout torque would be 316%.

For the duty cycle shown, the required pullout torque percentage can be determined by the ratio of maximum horsepower to rated horsepower as follows:

$$\%\ \text{Pullout torque required} = \frac{12.5\,(\text{Max. HP Point}) \times 100}{7.5\,(\text{Selected HP})} = 167\%$$

Since the available pullout torque at 90% of rated voltage is 316%, this 7½ HP motor would be more than adequate to handle this application.

The previous formula and example can be used for applications where the duty cycle repeats itself continuously, without interruption. When a duty cycle involves a period of shut-off time, a different formula is used. That formula is shown below.

$$\text{RMS HP} = \sqrt{\frac{HP_1^2 \times t_1 + HP_2^2 \times t_2 + HP_3^2 \times t_3 + HP_4^2 \times t_4 + \cdots HP_x^2 \times t_x}{t_1 + t_2 + t_3 + t_4 + \cdots t_x}}$$

Where,

t_s = number of seconds that motor is stopped

C = 3 (open drip-proof motors)

or,

C = 2 (totally enclosed motors)

This formula is the same as the previous one but it is modified to reflect the fact that during the non-operating (motor is at standstill) time, it also loses its capability of cooling itself.

The total amount of time for which RMS loading can be adequately calculated would depend somewhat on the size of the motor but, in general, it would be safe to utilize this method for duty cycles that total less than 5 minutes from start to finish (of one complete cycle). If the total time is beyond 5 minutes, then the application should be referred to the motor manufacturer for more detailed analysis.

Summary

RMS horsepower loading is a very practical way to reduce motor horsepower requirements on cycling loads. With reduced motor horsepower also come a reduction in physical size and a reduction in initial cost, along with somewhat improved efficiency and reduced operating costs. If the selection procedure is handled carefully, you can expect to get very good performance and reliability from the completed unit.

On servomotors and other adjustable speed applications, similar calculations are frequently made. In these cases armature amperes or required torques are substituted in place of horsepower. The resulting RMS amperes or RMS torque requirement is then compared to the motor's continuous and peak ratings to determine adequacy. **PTE**

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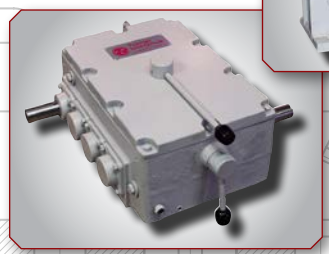

Catalog Multi-speed

OEM Manufacturing

Determination of Load Distributions on Double Helical-Geared Planetary Gearboxes

Dr. Tobias Schulze

Standardized calculation methods such as ISO 6336 and DIN 3990 already exist to determine the load distributions on gears inside a planetary gearbox, but by their very universal nature, these methods offer varying results depending on the gearbox design. Double helical gears, in particular, can benefit from more specific, complex algorithms to reach a maximum level of efficiency. Double helical gears interact with the rest of the gearbox differently than helical or spur gears, and thus benefit from different analytical models outside the standardized methods. The present research project describes the algorithm to determine the load distribution of planetary gearboxes with double helical gears.

The state of the art

High efficiency by maximum usage of available space, high gear ratios, best possible efficiencies and a wide range of applications due to the possibility of switching operations, superposition and summation gearboxes are known properties of planetary gearboxes.

The optimization and effective utilization of planetary gearbox designs requires a detailed consideration of the loads on the gears in the gearbox. Therefore, standardized calculation methods such as ISO 6336 or DIN 3990 can be used. To benefit from the full potential of the teeth, while the safety of the teeth can be assured at all times, advanced analysis of load distribution will be necessary.

Because of the need for these calculation standards to be universally usable, these methods use approximations that cannot cover the special characteristics of planetary gearboxes and therefore cannot be used to optimize the gears to their full potential. For this reason, computer-aided calculation methods have been developed for planetary gearboxes with spur and helical gears that consider the most important influences on the load distribution, including housing deformation, bearing deformation, deformation of the planet carrier, deformation of the wheel bodies and the deformation of the teeth themselves. Using this information, a detailed load distribution is possible to reach the maximum capability of the gears.

Research project for double helical gears

It is of vital importance to interpret and use the single calculation results correctly. The different results are given by different methods in analytical and numerical calculations. Regarding a complex assembly like planetary gearboxes, there is an additional fact to consider by having all results for single elements, depending on the behavior of other elements, in the assembly. An iterative calculation algorithm is inevitable.

The need for high rotational speeds and torques in gearboxes leads to high axial loads and therefore high risks for the additional elements in the assembly — for example, the bearings. The solution for these axial loads can be done by using double helical gears where the axial load components compensate each other. Double helical gears, the resulting loads and the deformation of the wheel bodies, with possible influences from one gear side on the other, cause the assembly to have an entirely different behavior than planetary gear stages with spur or helical gears. Detailed load distributions cannot be calculated at the moment, because the results of the existing calculation algorithms are not regarding these specific characteristics, and approximations cannot be made at this point due to the lack of experience.

The present research project describes the algorithm to determine the load distribution of planetary gearboxes with double helical gears. The detailed calculation methods offer the possibility to use the actual assembly design for the necessary finite element analysis; results have shown that approximated models cannot be used to calculate the load distribution accurately. Additionally, analytical calculations for the bearing deformation are presented. As already mentioned, the process of combining the single information to a final result is of major importance. The interdependent elements of the assembly lead to nontrivial correlations, making multiple calculations inevitable. The research project also offers a structured approach for the iterative calculation process that allows to be transferred into a computer- aided calculation program. This solution enables the possibility of an effective and detailed calculation process for planetary gearboxes with double helical gears.

Software (Ref. 2) has been developed to facilitate the complex calculation of

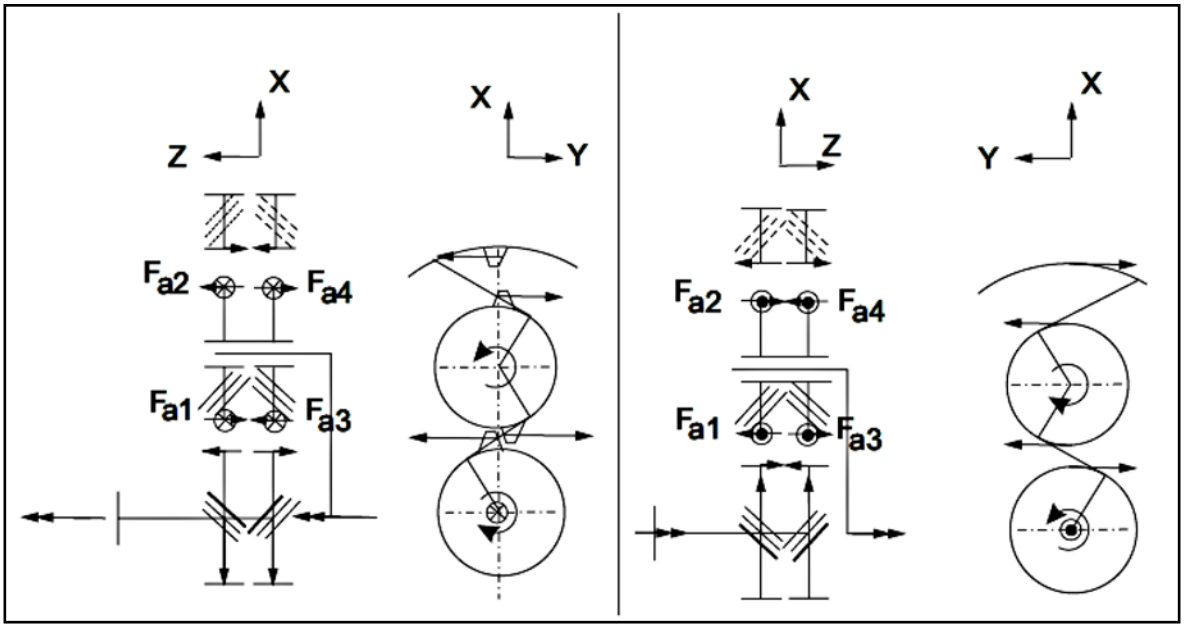

Figure 1 Determination of the loads in double helical-geared gearboxes.

planetary gearboxes and receive information about the whole system with a detailed load distribution along the path of contact of all tooth contacts. Calculations can be made for spur and helical gears in standard, summation and distribution gearboxes. These results are verified by several experiments and analyzed contact patterns of gearboxes in use.

This research project investigates load distribution calculation for double helical gearboxes. Double helical gearboxes are used in different applications in the industry where high rotational speeds, from 500 up to 60,000 rpm, as well as high transmission ratios of up to 35 for two-staged gearboxes, are required. Combined with high torque and transmission of power, the resulting mechanical exposure rises. This study is regarding torque up to 600,000 Nm and power transmission up to 45 MW. Since there are no calculation methods for double helical gearboxes, the research project examines specific characteristics and problems as high torsional deformations, load distribution on the parallel working tooth contacts, and interaction of the left and right gear contact.

Tasks of the research project

Regarding the current calculation options, there are several tasks that have to be added, like extending the contacts, and therefore recalculation of the loads in the gearbox as shown in the example in Fig. 1.

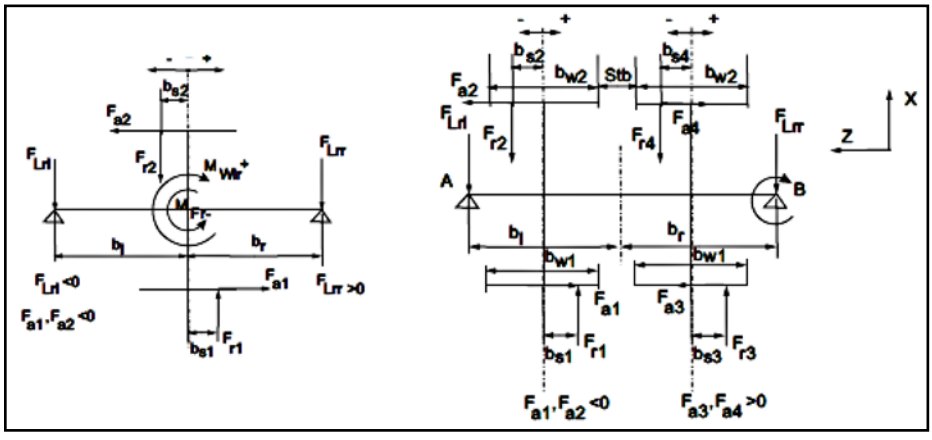

Figure 2 Calculation of planet gear tilt and bearing loads; left: helical gear, right: double helical gear.

Important influence parameters for the load distribution will be affected, like the bearing deformation of the planet bearings caused by unequal bearing loads in consequence of the tilting planet gear with its two tooth contacts. The calculation algorithm of the planet gear tilt and resulting bearing loads has to be extended, as shown in Fig. 2.

The major task for this research is the detailed study of the deformation of the wheel bodies of the gearings. Using approved methods for the load distribution calculation, some specific terms have to be ensured, like that two gear sides of one gear contact shall not influence the deformation of the other gear part more than 1 percent, to exclude errors in terms of the subsequent analytical load distribution calculation.

The realized calculation process shall be used to investigate the behavior of double helical gears that do not occur on helical or spur gears, like a load distribution between the contrary helical gear sides. As there is a default split to 50 percent load on both gear sides, first, results should be developed to intensify the research in the ongoing process of the project.

Need of FEM and analytical calculation methods and their interconnection

The load distribution is affected by various elastic deformations in the system of a planetary gearbox. Generally, the most important influences are caused by tooth deformation, wheel body deformation, shaft deformation, bearing deformation and housing deformation

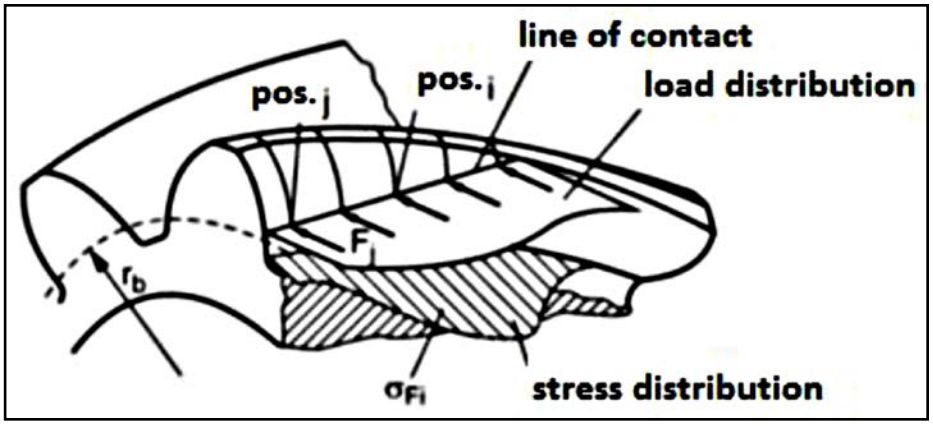

Figure 3 Definition of contact lines and force application points [Ref. 1].

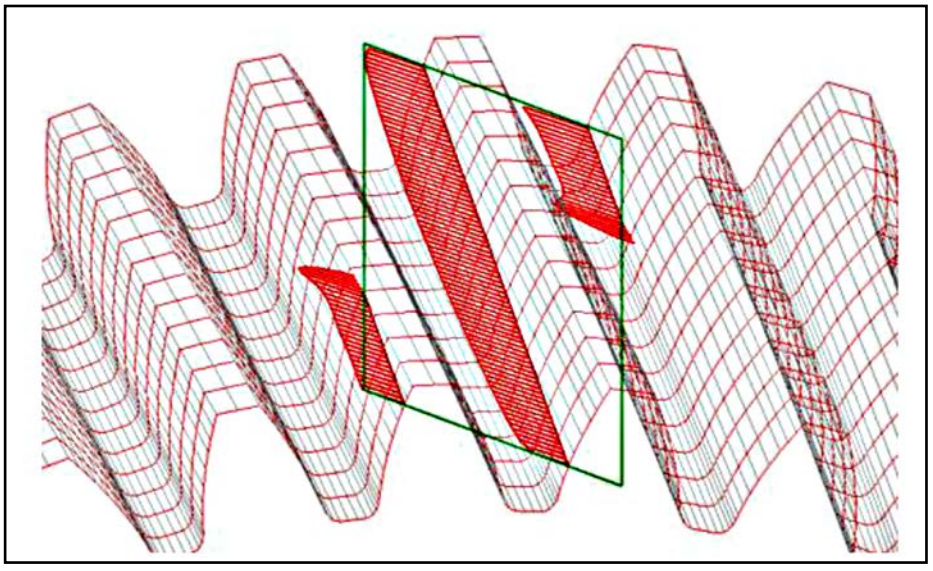

Figure 4 Line load in contact for a single gear side of a double helical gear [Ref. 2].

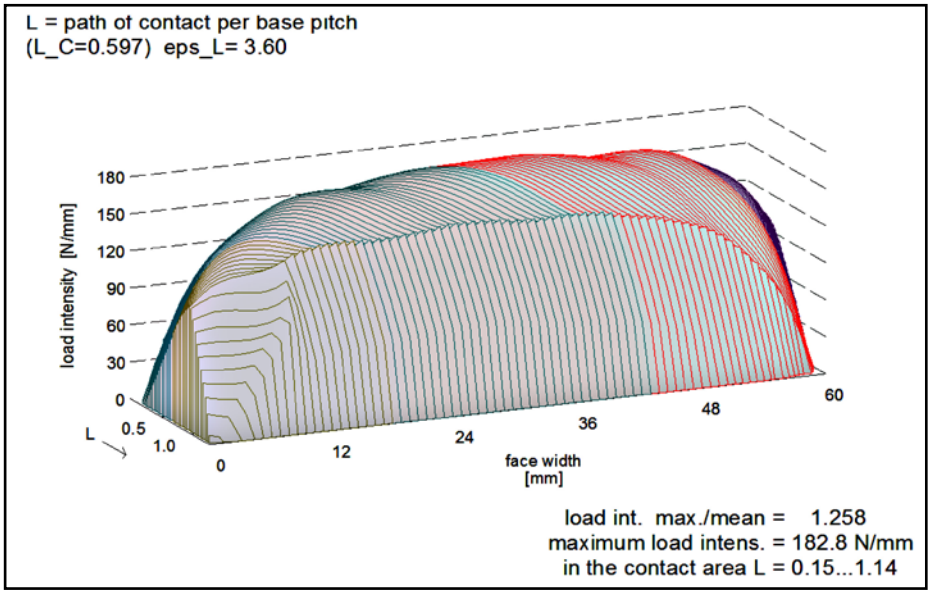

Figure 5 3-D line load distribution in the field of contact [Ref. 2].

The variety and complex interaction of these deformations and their combined influence to the whole system planetary gearbox lead to a time-consuming task to allow a comprehensive statement about the load and deformation behavior. The elements mentioned above can have different causes and consequences, for example: bending deformation, supporting stiffness between tooth and wheel body, shear deformation, Hertzian flattening and compression deformation.

These effects cannot be determined by analytical calculation methods only. FEM models have to be analyzed in terms of deformation and stress concentration under load. The disadvantage of these procedures is high computing times or cost-intensive high-performance computers to achieve efficient development periods. For this reason, there are research projects looking for analytical calculation methods that reflect the results of FEM calculations as precisely as possible. Even though the technical standard of computer-aided calculation rises, finite element analyses and their computing times are not efficient for multiple calculations, as it is needed in a design process or even for further research on specific characteristics in the system. As an example, the calculation software (Ref. 2) uses the influence coefficient method, based on finite element analysis results, to allow real-time calculations of tooth contacts, resulting in a detailed load distribution along the path of contact.

The influence coefficient method is oriented on a bending beam with multiple loads. Every load results in a deformation of all other positions along the beam. The deformations caused by different forces on these positions can be linearly superimposed. Calculating the load distribution, the tooth flanks are separated in several sections for pinion and gear, resulting in a deformation in the contact. Since there cannot be an intrusion or an offset under load, the determined deformation in the contact and the given load lead to the load distribution and transmission error in this contact.

Detailed FE calculations provide the possibility to establish influence coefficients that cover special characteristics

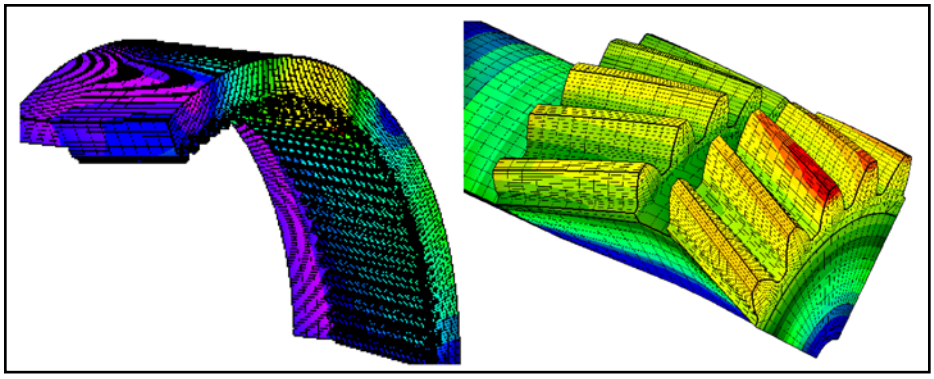

Figure 6 Deformation results for all elements with integrated FE solver [Ref. 2].

of a tooth contact, like multiple teeth in contact, stiffness of the wheel body and stiffness along face width for helical gears, as well as stiffness changes in profile direction or different tooth widths.

Using these influence coefficients and solving the equation system for the deformations in the tooth contact leads to a detailed load distribution. These results have been validated by several experiments, as well as comparisons to running gears and their surface damages.

This approach for the tooth contact analysis can be used in the calculation of planetary gearboxes, but there are no equal calculation methods for all elements. Because of the possibility of any design customized for a specific application, analogous procedures cannot be made for all parts of the planetary gearbox. Therefore, detailed FEM calculations of wheel body, planet carrier and housing deformations are required.

The need for these finite element analyses causes a major complexity in interpreting the system of all elements correctly. All elements in the gearbox interact with each other in terms of load distribution between the elements and therefore deformation changes. The individual result of a single element is an input parameter for the whole system of a planetary gearbox, combining different parts with their specific properties. In order to assure reliable information about a planetary gearbox, an iterative calculation is required.

Automated finite element analysis

The needed FEM calculations have to be as precise as possible to result in system parameters that describe the consequences for the connected parts of this element. Therefore, correct tooth curves are needed to set the loads and contact lines as accurately as possible. The contact angle as well as the contact position in profile and width direction have significant influence on the resulting deformations.

The involute tooth profile described in x and y coordinates is done as follows (Ref. 8):

$$x_y = d_y \cdot \sin(\psi_y)$$
$$y_y = d_y \cdot \cos(\psi_y)$$
$$\psi_y = \frac{\pi + 4 \cdot x \cdot \tan(\alpha_y)}{2 \cdot z} + \mathrm{inv}(\alpha_t) - \mathrm{inv}(\alpha_{yt})$$

The tooth root profile has to be determined iterative under consideration of the manufacturing process, tool, and its addendum coefficient ρ_{a0}. In case of manufacturing with a hob or cutting wheel, the tooth root can be calculated as follows (Ref. 8):

$$x_y = r_{w1} \cdot \sin(\varphi_1) - \left(\frac{\Delta h}{\sin(\psi)} + \rho_{a0}\right) \cdot \cos(\theta)$$
$$y_y = r_{w1} \cdot \cos(\varphi_1) - \left(\frac{\Delta h}{\sin(\psi)} + \rho_{a0}\right) \cdot \sin(\theta)$$

The calculated coordinates have to be transformed from the transverse section to create the tooth along its width. The accuracy of the FE model can be influenced directly, and accurate tooth curves significantly increase the computing time but offer more precise positioning of the force application points of the tooth force. The position of the force application points of a pair of wheels depends on the direction of rotation of the driving wheel and the engaged position. The position of contact, which should be used for the creation of the FE models, is the position in with the shortest total length of the contact lines (Ref. 3).

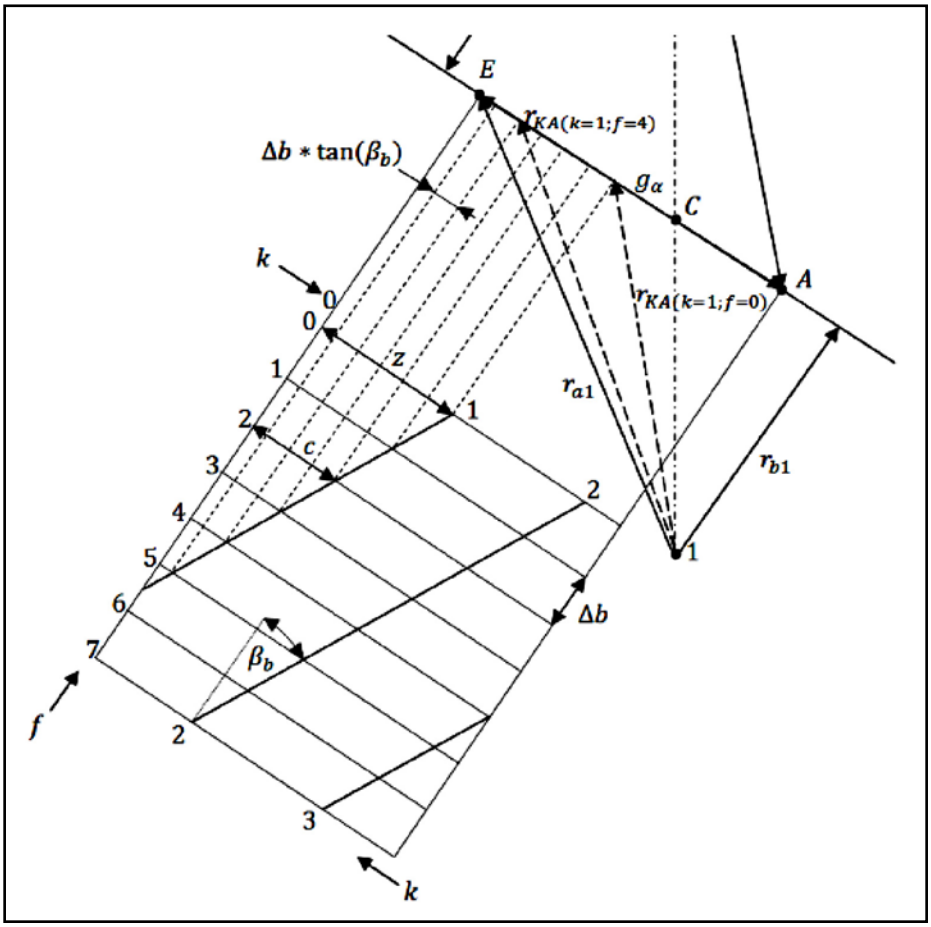

Figure 7 Determination of length of contact lines used in FE models [Ref. 2].

In addition to the contact radii, the correct contact angles have to be determined. Regarding the position of contact, radii of the force application point and contact angle, every single force has to be calculated to result—in addition to the other forces of the application points—in the overall torsional moment of the tooth contact.

The force application points, based on tooth geometry and tooth force, should reflect the real contact line as precisely as possible. Deviations in position and amount of the loads less than 1 percent are considered sufficient.

Furthermore, two load cases — constant and triangular — are calculated for all three gears and the planet carrier. The deformation of a general trapezoidal load distribution can be assembled from the deformation of the base load cases. Because of this, it is not necessary to calculate the FE model for each step of the load distribution iteration.

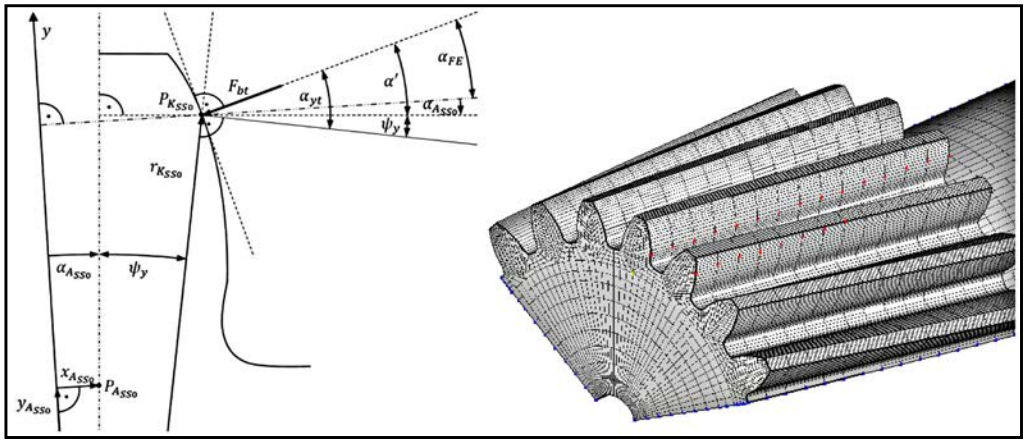

Figure 8 Determination of angles of contact and automated application to FE models [Ref. 2].

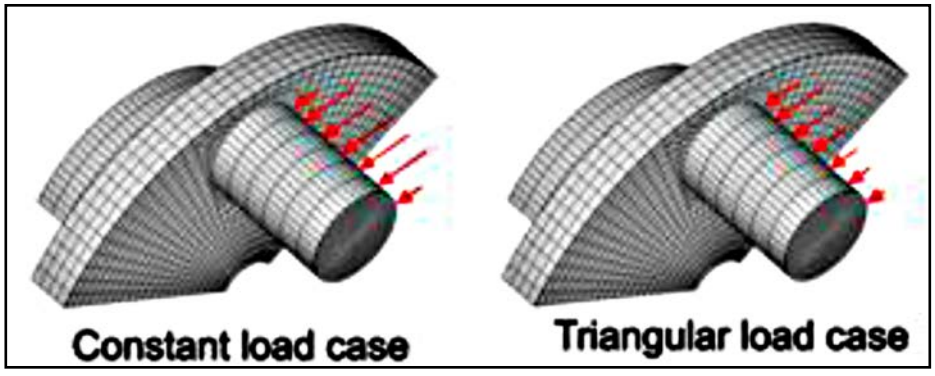

Figure 9 Base load cases for interpolation of load-dependent deformation.

Since there are more tooth contacts in double helical planetary gearboxes, the base load cases as shown in Fig. 9 are extended by additional combinations of load cases between the right and left tooth contact (Fig. 10).

The FEM calculations lead to deformation values of sun gear, planet gear, ring gear, and the planet carrier. All elements have to be interpreted at the points they stay in contact to other elements or have influence to their position in the system. To get to the result of a load distribution, all misalignments and deformations have to be converted into the field of action of the calculated gear pairs and contacts of sun- to-planet gear and planet-to-ring gear.

FEM and analytical methods in an iterative calculation

All results of the finite element analysis and analytical calculations have to be brought together in a calculation

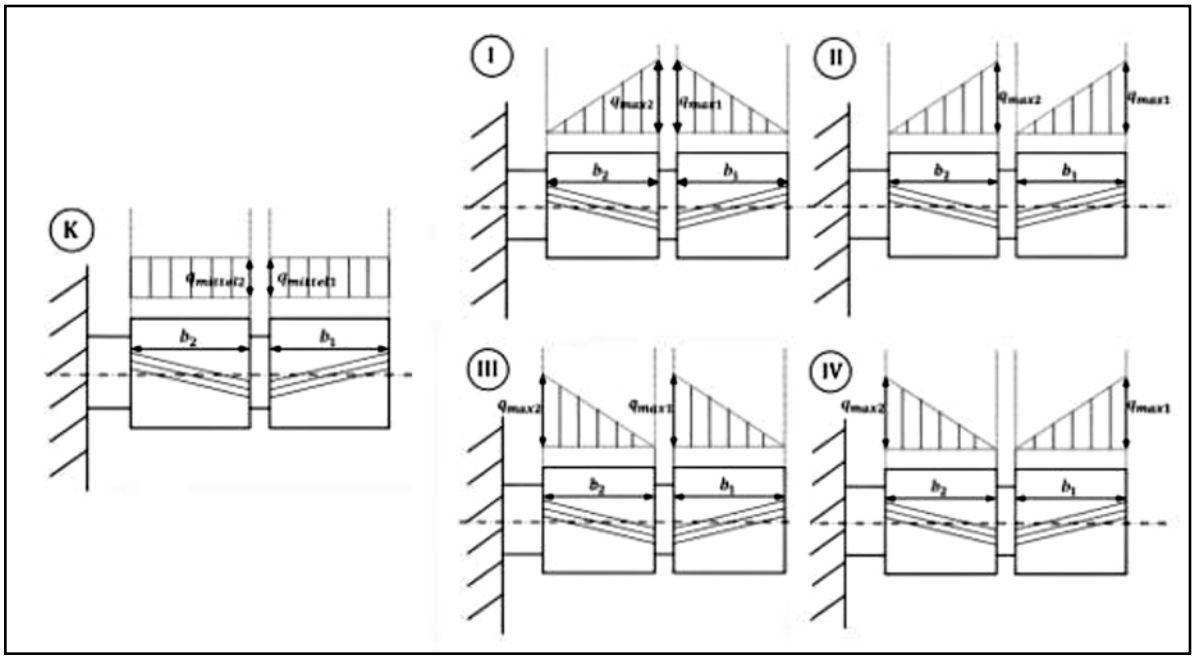

Figure 10 Adapted load cases for double helical gears.

process that covers the interactions between the elements and checks for changes in the system in terms of deformation changes, load distribution changes or even load changes. The calculation routine has to be repeated iteratively until all criteria are changing less than 1 percent. This computer-aided algorithm allows multiple calculations in a short period of time that can be used to improve the design itself or optimize the gearbox with the use of modifications in micro geometry. Especially for double helical gears, there is a need to separate the tooth contacts in terms of modifications since the deformations and the influence of the left and right tooth contact is significantly different to the system. At the point of this research project, there are no possibilities given yet for an automated load distribution calculation for double helical planetary gearboxes. Having this combination of qualified time-efficient analytical load distribution and precise time-optimized, automated finite element analyses offers a new possibility for the optimization in design, space and efficiency of double helical planetary gearboxes.

Optimization

Having the opportunity of multiple automated calculations, the optimization process is more effective. Parametric FE models can be used to analyze the influence of macro geometry and lead to different design goals in terms of weight, size, mass inertia, or stiffness to meet the given requirements. The optimization process should always focus on changes in design and macro geometry. For special agreements or fixed conditions of design space or manufacturing processes, final optimizations can be realized by using modified flank geometry. Especially the characteristics of double helical-geared planetary gearboxes require optimizations in micro geometry in most cases. The difference in deformation amongst the left and right tooth side and the changing helix angle could only be prevented by using very stiff components, resulting in unneeded oversized parts of the gearbox. For this reason, flank modifications in profile and lead direction can be calculated either as preset values for crowning, helix angle modifications, etc., or as a freely defined flank topology.

Summary

The present research project describes the algorithm to determine the load distribution of planetary gearboxes with double helical gears. The detailed calculation methods offer the possibility to use the actual assembly design for the necessary finite element analysis; results have shown that approximated models cannot be used to calculate the load distribution accurately. Additionally, analytical calculations for the bearing deformation are presented and implemented. As mentioned above, the process of combining the single information to a final result is of major importance. The interdependent elements of the assembly lead to nontrivial correlations, making multiple calculations inevitable. The research project also offers a structured approach for the iterative calculation process that allows to be transferred in a computer-aided calculation program. This solution enables the possibility of an effective and detailed calculation process for planetary gearboxes with double helical gears.

In comparison with spur and single helical planetary gearboxes, the advantages and disadvantages are shown in Fig. 12 and Table 1.

As shown in the results above, all gear designs have advantages and disadvantages. The design should be chosen by the goal that has to be realized. In terms of compensating high axial forces, double helical, as well as spur gears, are preferable, whereas double helical gears have better noise emission due to higher contact ratios. Another advan-

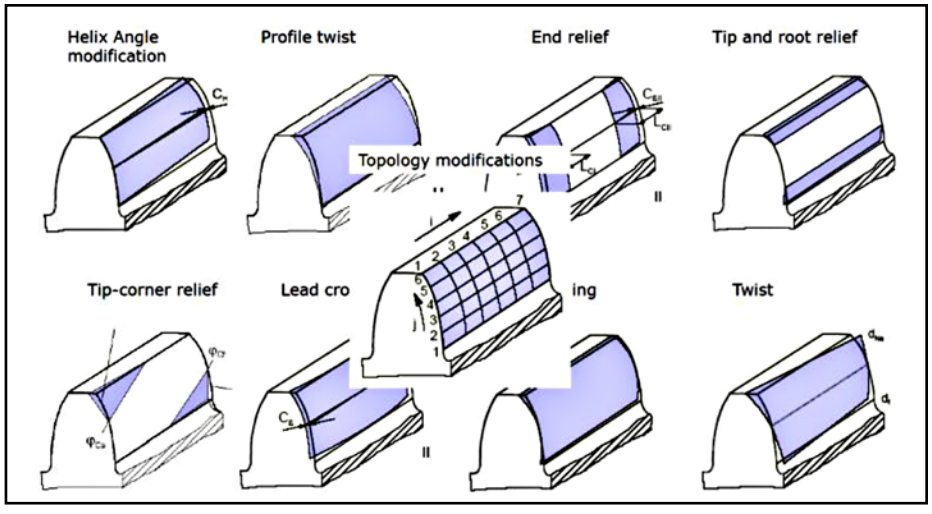

Figure 11 Modifications in lead and profile direction separately for both sides of double helical gears [Ref. 1].

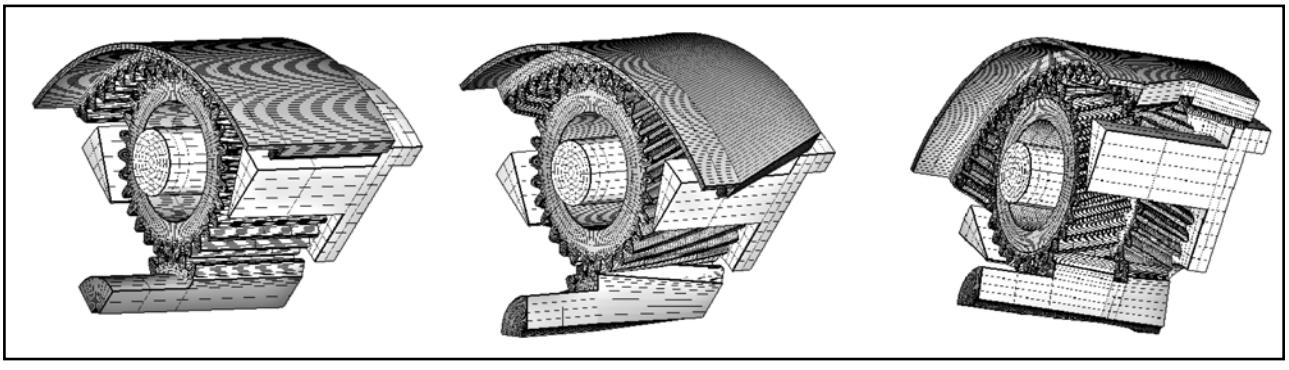

Figure 12 Comparison of gear designs.

Table 1 Comparison of gear designs (extract)

	Spur gear	Helical gear	Double helical gears
Power	35 MW		
Speed	2500 rpm		
Max. torque	550000 Nm		
$K_{H\beta}$ unmodified	SU/PL 1,3 PL/RG 1,2	SU/PL 1,4 PL/RG 1,5	SU/PL 1,1 | 1,5 PL/RG 1,2 | 1,6
Planet bearing deformation — misalignment	70 µm	75 µm	10 µm
Noise emission tooth contact	54 dB	31 dB	35 dB
Axial force	–	86000 N	–
Total contact ratio (effective tooth width equal for all designs)	SU/PL 1,5 PL/RG 1,67	SU/PL 3,7 PL/RG 3,8	SU/PL 2,6 | 2,6 PL/RG 2,78 | 2,78

tage of double helical gears is the equal load distribution from the planet gear to the bearings. Being almost independent from the actual tooth contact load distribution, double helical gears differ from spur and helical gears, whose bearing deformation highly depend on the tooth contact. A major disadvantage of double helical gears is the expensive production cost, furthermore as shown in Table 1 most of the time there will be a need of different modifications on the gear sides, which may lead to additional costs.

The results given in a detailed load distribution can be used for strength verifications, according to given standards such as ISO, DIN or AGMA. Comparisons and possible further development with AGMA 940, *Double Helical Epicyclic Gear Units*, are follow-up projects after realizing the current research project.

Whereas approximated calculations such as AGMA 927-A01, and the derived ISO 6336 Appendix E, can provide good results in terms of lead modifications and face load factors for standard spur gears, this research project and the developed software (Ref. 2) is able to regard modifications and their consequences in profile and lead directions as well as in the whole field of contact. Specific effects of double helical gears or deformations of the interacting elements in a planetary gearbox cannot be considered in approximated methods. An automated workflow and calculation routine combines different calculation methods such as analytical and numerical calculations and enables this complex calculation to be done by a single operator. Using parametric models and implementing strict check routines for the calculation, interpolation, iteration, and evaluation minimizes error susceptibility for users not having comprehensive expertise of every calculation method used in the project. Optimizing time efficiency, by using calculations with high computing time such as FE calculations only if no analytical algorithm could be investigated, the developed calculation algorithm can be automated and digitalized into a computer-aided calculation process and therefore is qualified for serial calculations and further research projects as well. **PTE**

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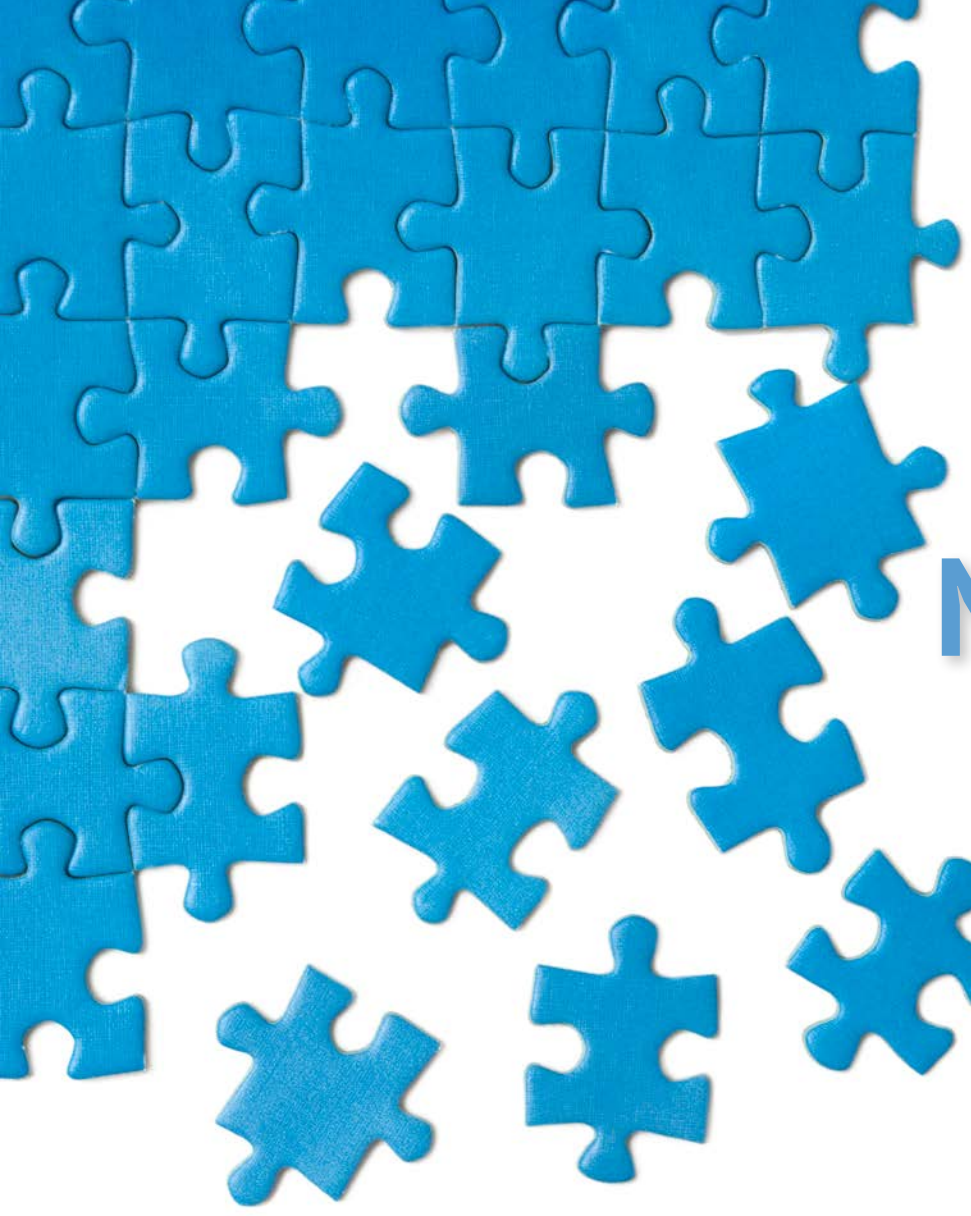

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Power Transmission Engineering

How to Select a DC Motor: Coreless and Iron Core Brushed DC Motors

George Hunt, Applications Engineer, Micromo

DC Motors

DC motors possess linear relationships that allow for very predictable operation. For instance, if enough voltage is applied across the terminals of a DC motor, the output shaft will spin at a rate proportional to that applied voltage. You can take the ratio of the applied voltage over the rated voltage and multiply that number by the no load speed and get the running speed. Also, if you decide to measure and plot the current and torque, you will have a simple straight line indicating yet another directly proportional relationship. When torque demands increase, so does the current. Plotting the torque and speed together, you will find that only two points of data are needed. Those are the no load speed and the stall torque. The entire motion control world, including manufacturers and designers, depend greatly on the premise that all these linear relationships will hold true. And they do because the laws of physics do not change! However despite their simplicity, selecting a DC motor for an application can still be a daunting task. There are many other variables that must be taken into account including dimensions, load, duty cycle, environment, feedback considerations, etc. Perhaps decoding some of the mysteries of motor operation will shed some light on the selection process.

Going for simplicity with brushed motors. If your application demands a reliable, time-tested, low cost motor, then brushed DC motor technology may be what you're looking for. The key here is simplicity. A brushed motor is designed to run off of straight-line DC voltage and can even be connected directly to a properly sized battery. When a DC voltage is applied across the terminals of a brushed motor, a potential difference is achieved and current is induced into the windings on the rotor. The brushes allow this current to flow through a rotating mechanical switch called a commutator. The rotor windings act as electromagnets and while powered form 2 poles that terminate at the commutator segments. This entire assembly is known as an armature. While rotating the commutator allows the direction of the current to reverse two times per cycle. This permits the current to flow through the armature and the poles of the electromagnets attracting and repelling the permanent magnets that encompass the motor's inner housing. As the energized windings of the armature pass the permanent magnets, the polarity of the energized windings reverses at the commutator. This process is called mechanical commutation and only found in brushed motors. During the instant of switching polarity, inertia keeps the rotor going in the proper direction and allows the motor to continue turning. The result is power in its mechanical form measured in watts. Mechanical power is the product of torque multiplied by the rotational distance per unit time (or speed). Torque is the force vector component that rotates a load about an axis and is inversely proportional to speed (Eq. 1):

$$P_{Mechanical} = M\omega \quad (1)$$

Where,

P = Mechanical Power; M = Torque; ω = angular velocity

From the equation above, we see there is a price to pay for how much power a motor can deliver. The amount of current that flows through the windings, directly affects to the torque the motor can produce. Adjusting the supply voltage will force a proportional change in the motor's speed so the output shaft's angular velocity (speed) will have to be sacrificed as torque demands increase. There are also other factors that come into play such as losses. For example, static friction is defined as the friction torque a motor must overcome in order for the shaft to begin turning. Then there are brush contact losses caused by the friction of the brushes upon the commutator. Also, copper losses in the form of heat sometimes referred to as I^2R losses play a role. Electrical power is represented in Eq. 2.

$$P_{electrical} = I^2R \quad (2)$$

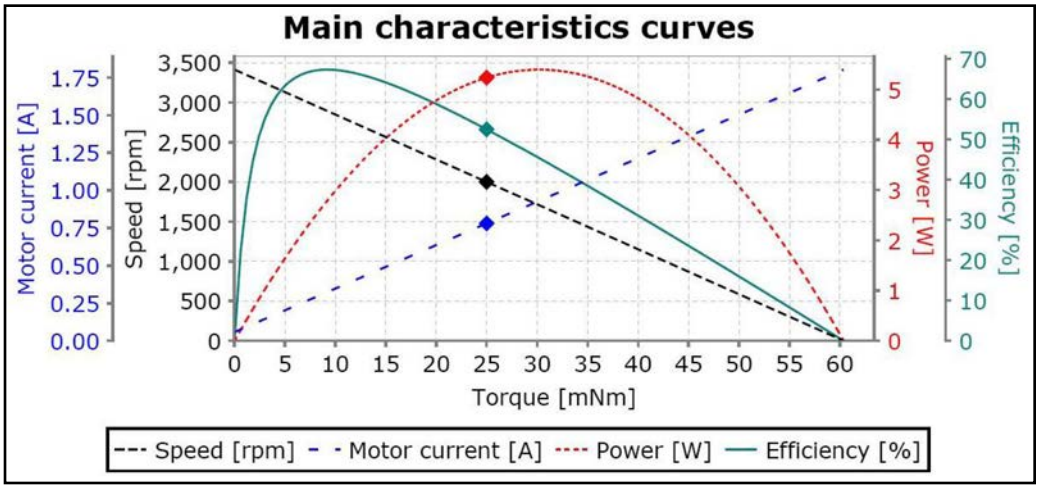

Figure 1 Plotted curve from Faulhaber coreless DC motor; note linearity of torque/speed component.

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Where,

P = Electric Power; I = Current; R = Resistance

Although, when torque and speed are measured empirically, the resulting graph may not be perfectly linear in all cases. From Equation 1, however, we can see that both torque and speed are inversely proportional and that a linear relationship exists. Because of this, feedback may not always be necessary. Feedback is usually provided by an encoder, tachometer or resolver. It tells the servo system where the motor is and at what speed the shaft is turning. Taking all this into account, we can establish that a properly designed, closed loop servo system will have a predictable response to a controlled input. And with this directly linear relationship a servo can easily compensate for any unwanted changes introduced into the system; see Figure 1 for a plotted curve from a Faulhaber coreless DC motor; note specifically the linearity of the torque / speed component.

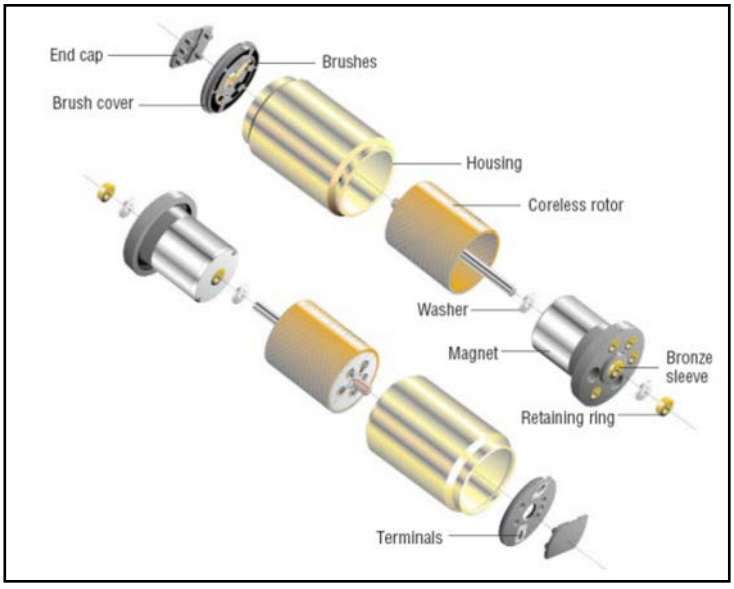

Figure 2 Faulhaber-designed coreless DC micro-motor.

Iron core brushed DC motors. Traditionally, the motion control industry has relied on iron core brushed DC motors for demanding applications. They are capable of achieving a very high torque due in part to their iron core construction. The rotor is usually a rigid design that not only provides a sturdy support for the windings, but also allows for excellent heat dissipation. That is the reason more current can be pushed through the windings when torque demands increase — it acts as a heat sink. Their low cost is yet another plus when project funding is limited. There are, however, some disadvantages to the iron core construction. For example, due to its heavy armature, overcoming the inertia can reduce a motor's acceleration capability. Higher rotor inertia limits the dynamic characteristics such as the motor's acceleration and stopping time. Another problem with the iron core rotor design is increased inductance. When running at high speeds the brushes will pass over the commutator's segments and imperfections. At each commutation point, when the brush breaks contact with a commutator segment, the energy stored in the motor winding as a magnetic field causes an arc or voltage spike between the brush and the commutator segment. This occurs not only during normal commutation but also in situations where the brushes "bounce" on the rotating commutator. At higher speeds, this effect can result in faster brush wear and electro-erosion. One solution is to utilize a precious metal commutator system. This type of system allows for motors to be manufactured much smaller, as a carbon graphite commutation system takes up much more space. The commutation signal will usually be cleaner as well. Since the voltage drop between brushes and commutator is generally small in precious metal systems, motors can be made to operate at lower voltages. However, due to a precious metal system's inability to self-lubricate, precious metal commutation can experience a long-term effect called "micro-welding." This effect can wear down the commutator's surface over time.

Coreless DC motors. The answer to some of the problems with iron core technology was addressed in the 1940s by Dr. Fritz Faulhaber with the invention of the coreless DC micromotor (Fig. 2). This design opened up a whole new multitude of possibilities for space-constrained applications requiring high precision. These motors have a self-supporting, progressive, skew-wound, ironless rotor coil that has demonstrated incredible efficiency when compared to iron core motors. For the first time, DC motors did not require the use of iron laminations in the armature. Thanks to this construction the rotor is extremely light, yielding a low moment of inertia. This in effect allowed for faster acceleration, resulting in a much smaller mechanical time constant. Another benefit to coreless DC motors is that they can be manufactured in very compact sizes; which is why they excel in space- constrained applications. The rotor also rotates smoothly without cogging and the coreless DC motor's windings have very low inductance. All of these characteristics help reduce brush wear and prevent electro-erosion — thus increasing the motor's lifespan.

Unfortunately, however, with no iron laminations coreless motors are somewhat prone to overheating. In some instances a heat sink can be used to alleviate this problem. Also, cost would have to be factored into most applications as the high precision and repeatability of coreless DC motors comes at a bit of a price. These motors are designed for specific applications and would not be the best choice to use in most consumer products. The most common applications are large OEMs in industries requiring very high precision, primarily for medical, aerospace, military, robotics and automation. Some example products are aesthetic lasers, diabetic insulin pumps, collision avoidance scanners, and unmanned aerial vehicle (UAV) applications. These applications have demanding micro-positioning needs, dimensional constraints, and sometimes vacuum compatibility needs. Coreless DC motors seem to excel in situations where reliability, precision, longevity and repeatability are of the upmost importance. **PTE**

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Vibration Analysis Goes Mainstream

John Bernet

Using vibration analysis to evaluate machine health has many benefits, and with advances in sensor, recording, and analysis technology, vibration analysis is now within the reach of even small organizations.

- Measuring the vibrations of motors, pumps, and other common machines can reveal valuable information about machine health—or impending failures.
- Vibration analysis can reveal four of the most common mechanical faults: imbalance, misalignment, wear, and looseness.
- Easier measurement procedures combined with automated vibration analysis enables personnel with minimal training and experience to use vibration to evaluate machine health and determine required maintenance.

Most machines have rotating parts, and rotating parts vibrate. Measuring how and how much those parts vibrate can tell you a lot about the health of a machine. Whether it's the rumble of worn bearings or the shaking, shimmying, or thumping of loose, misaligned, or unbalanced parts, machines have a tale to tell to those who are willing and able to listen.

Vibration analysis — the art and science of measuring and interpreting those telltale rumbles and shakes — has been around for decades, but mostly in the domain of specialists operating exotic instruments for corporations and government agencies with mission-critical equipment and very deep pockets. For everyone else, "vibration analysis" was typically performed by a mechanic using a makeshift stethoscope fashioned from a screwdriver — the tip held to the machine, the handle held to the ear—or, more often, not done at all. Recent developments in vibration sensor, data acquisition, and analysis technologies, however, are making vibration analysis cheaper, easier, and more widely available.

What Can Vibration Analysis Tell You?

Among the most important mechanical faults that vibration analysis can reveal are the following:

Imbalance. A "heavy spot" in a rotating component causes vibration when the unbalanced weight rotates around the machine's axis, creating a centrifugal force. As machine speed increases the effects of imbalance become greater. Imbalance can severely reduce bearing life as well as cause undue machine vibration.

Misalignment/shaft runout. Vibration can result when machine shafts are out of line. Angular misalignment occurs when the axes of (for example) a motor and pump are not parallel. When the axes are parallel but not exactly aligned, the condition is known as "parallel misalignment." Misalignment may happen during assembly or develop over time, due to thermal expansion, components shifting, or improper reassembly after maintenance. The resulting vibrations may be in the direction of the rotation, along the shaft axis, or both.

Wear. As components such as bearings, drive belts, or gears become wear, they may cause vibration. When a roller bearing race becomes pitted, for instance, the bearing rollers will cause a vibration each time they travel over the damaged area. A gear tooth that is heavily chipped or worn, or a drive belt that is breaking down, can also produce vibration.

Looseness. Vibration that might otherwise go unnoticed may become obvious and destructive if the component that is vibrating has loose bearings or is loosely attached to its mounts. Such looseness may or may not be caused by the underlying vibration. Whatever its cause, looseness can allow any vibration present to cause damage, such as further bearing wear, or wear and fatigue in equipment mounts and other components.

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How Do You Measure Vibration?

Vibration sensors have advanced far beyond the mechanic's screwdriver. There are a variety of sensor types, but the accelerometer is the most common. To take a measurement, a small metal sensor is attached to the appropriate location on the equipment to be tested. The attachment, which can be permanent for continuous monitoring or temporary for machines that are evaluated only periodically, must be at a position on the machine that reveals the best information about the vibration that is being investigated (at the bearings of a motor, for example, or close to a rotating shaft).

Inside the sensor an array of tiny electronic accelerometers convert movement along any of the three axes (up-and-down, back-and-forth, side-to-side) into an electrical signal that is fed to a recording device. Recorded vibration data can be analyzed at the test site for an immediate diagnosis, and can also be saved for later analysis or comparison with earlier recordings to monitor trends in machine health.

Studies conducted by the U.S. Navy (Ref. 1) found that many vibration analysis programs were not collecting all of the data that was needed to make an accurate diagnosis. The studies concluded that to diagnose machine condition accurately, data was needed from all three axes of a rotating shaft. When only two axes of data were used, diagnostic accuracy dropped to 80%. When data from only a single axis was analyzed, diagnosis accuracy dropped to 46%.

Automating the analyst. Collecting and storing vibration data from a sensor is only the beginning. To be useful, vibration data must be analyzed and interpreted. A vibration graph can reveal a lot to a trained and experienced vibration analyst, but hiring (or training and then retaining) a vibration analyst is such an expensive proposition that only large, well-funded organizations have been able afford to keep analysts on staff. Everyone else has had to hire vibration consultants only when need justified and budget allowed.

Making vibration analysis available and affordable for everyone who could benefit from it would require not just affordable equipment but also "automating the analyst;" automated diagnostic programs were needed that could analyze raw vibration data and give useful, simple, "actionable" recommendations for non-experts. The key to automating vibration analysis, as it turned out, was to compare the vibration data in question with data from a similar, "healthy," "known to be good" machine. Although the concept of comparing the data from the machine in question with "baseline" data from a similar, known-good machine is simple, the implementation is complicated. A vibration analysis program performs a sophisticated analysis, comparing hundreds of data points with the "fault patterns" of similar machines to give a simple, understandable, diagnosis that makes clear how healthy the machine is and whether maintenance is needed. The resulting diagnostic report should give the operator or maintenance technician a clear picture of machine condition and action required.

What Are The Benefits Of Vibration Analysis?

Predictability. Studies have shown (Fig. 2) that vibration analysis can provide early warnings of impending machine failure, giving maintenance staff time to schedule required repairs and acquire needed parts.

Safety. Having information about machine health enables operators to take faulty equipment offline before a

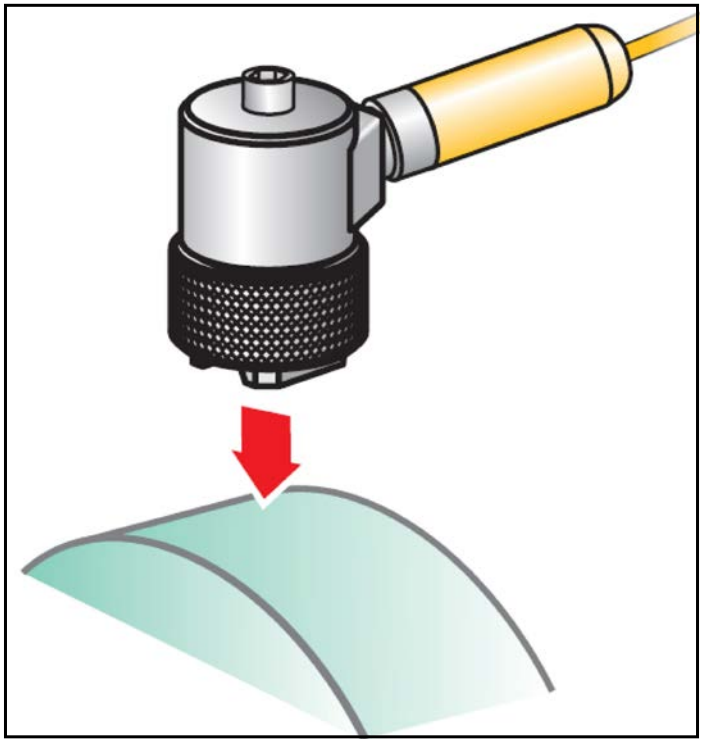

Figure 1 Attaching a vibration sensor with a magnetic mount.

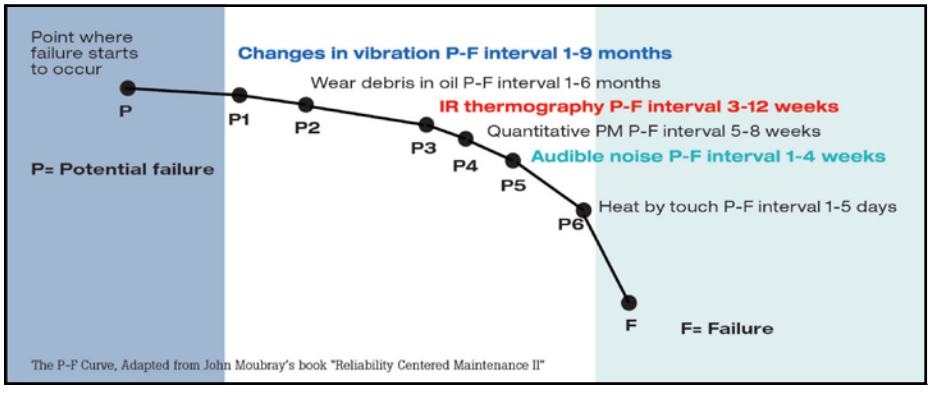

Figure 2 Potential failure curve over a nine month interval.

hazardous condition occurs.

Revenue. Well-maintained machines have fewer unexpected and serious failures, helping to prevent production stoppages that cut into the bottom line.

Increased maintenance intervals. When machine health is being tracked, maintenance can be scheduled by need — not just by accumulated hours of operation.

Reliability. Monitored machinery has fewer unexpected or catastrophic failures.

Cost savings. Running machinery until failure often results in more expensive repairs, overtime, and forced purchases. Twenty-five years of documented savings show a 20:1 benefit-to-cost ratio for vibration analysis programs (Ref. 2).

Peace of mind. A better understanding of machine health builds confidence in maintenance schedules, budgeting, and productivity estimates.

Why Add Vibration Analysis to a Maintenance Program?

"Run to fail" maintenance programs, while simple, often have costlier repairs, loss of revenue from production stoppage, and expensive overtime. Preventive maintenance programs, in which machinery is serviced after a certain number of hours of operation, can result in unnecessary work being performed, and unmonitored machinery can still fail before the maintenance interval elapses. When vibration analysis is incorporated into a maintenance program, however, the condition of monitored machines is known. Thus unnecessary maintenance work is avoided and required work can be scheduled for convenient times and when parts are available. Maintenance staff knows which machines are good enough to run, which need repairs scheduled soon, and which need to be shut down before they fail.

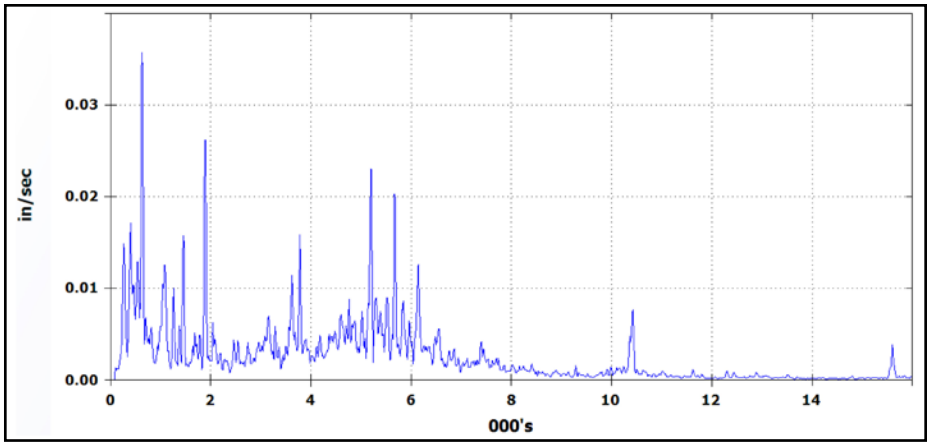

Figure 3 Vibration intensity and frequency of a rotating shaft.

How to Get Started With a Vibration Analysis Program

The U.S. Navy determined 30 years ago that it wanted the benefits of vibration analysis, but could not afford to have a vibration expert on every ship. What are the roadblocks to implementing a program?

- Training staff, and then retaining staff with the extensive vibration analysis skills, is expensive
- Results achieved may not justify the cost in equipment, training, labor, etc.
- Company priorities change, so a vibration program is scrapped

Recent advances in vibration analysis, however, have enabled programs that can diagnose common machine faults without the need for prohibitively expensive equipment and expert operators.

The suggestions below can help any organization in its efforts to implement a vibration analysis program.

Start small and grow. Don't try to monitor 500 machines in a plant all at once. Instead, choose 25 to 50 machines to start with, then add additional machines as priorities, time and budget allow. Organizations that already have a reliability group can increase the scope of their maintenance program to include vibration analysis.

Focus on problem machines. If you have machines that have a history of failure or a few machines that can take down half the plant — start with them. Even small machines that aren't deemed big enough for a reliability group to monitor may be important to the maintenance and operations groups, because they are the ones that require the most attention.

Focus on the common machine faults. Imbalance, misalignment, looseness, and bearing failures account for 80–90% of machine faults.

Use automation and proven measurement methodology. Obtaining

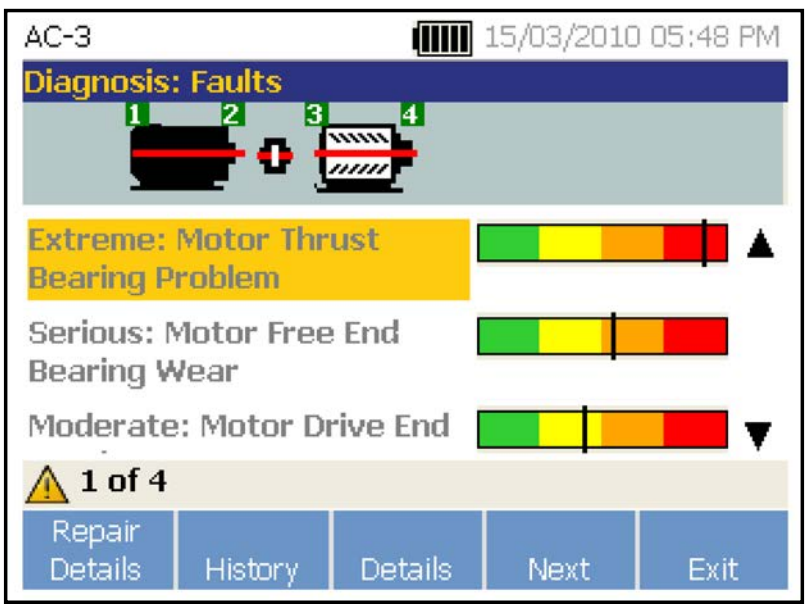

Figure 4 Automated vibration analysis can report on machine health in terms that are understandable and actionable by technicians without vibration analysis experience.

Figure 5 Technician using a handheld vibration analyzer.

complete picture of the machine's entire powertrain is critical. Maintenance technicians and operators don't have time to look over reams of data — they have a plant to run. A system that screens the data and provides answers about what is wrong with a machine — and what to do to fix it — should be the goal.

Summary

Advances in vibration sensor, data acquisition, and analysis technologies have enabled the introduction of powerful, portable, affordable, easy-to-use vibration measurement and analysis tools that enable even smaller organizations with limited training and hardware budgets to enjoy the considerable benefits of vibration analysis. **PTE**

John Bernet *is a vibration application specialist at Fluke Corporation and a Category II-certified vibration analyst. He has over 20 years of vibration analysis experience in industry and the U.S. Navy. John can be reached at* John.Bernet@fluke.com.

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Siemens

PRESENTS ARENA OF DIGITALIZATION IN ELECTRIC MOTOR PLANT

Electric motors for industrial use have been manufactured at the Siemens site in Bad Neustadt an der Saale for 80 years. Digitalization is playing an increasingly important role at this site. For this reason, the plant is going to be developed as a showcase factory for digitalization in metalworking. In the new "Arena of Digitalization" covering an area of more than 800 square meters, Siemens is now showing customers and partners how digitalization is used in metalworking and motor production and what results can be achieved with it. In addition, using its own development and the way production has grown over many years as an example, the showcase factory demonstrates how digitalization already offers advantages in terms of productivity and efficiency for the discrete manufacturing industry.

The "Arena of Digitalization" was opened by Klaus Helmrich, member of the managing board of Siemens AG, Jan Mrosik, CEO of Siemens' digital factory division, Wolfgang Heuring, CEO of Siemens' motion control business unit, and Peter Deml, head of the electric motor plant in Bad Neustadt an der Saale.

"In the light of advancing digitalization and the associated requirements resulting from it, industry faces entirely new opportunities and possibilities," said Helmrich. "These all center on a more and more growing individualization of products as well as of quality, efficiency, speed and flexibility. Companies in the manufacturing sector are having to respond to increasingly differentiated customer requirements and are therefore reliant on flexible production right down to a batch size of one."

As a response to these challenges, Siemens is offering its customers from the manufacturing sector a comprehensive portfolio of products and solutions under the digital enterprise umbrella. Mrosik explains: "Our solutions cover the entire value chain, from product design, production planning and production engineering to production execution and services. Spanning all these are Teamcenter, a database that is accessible to all parties involved, and MindSphere, a platform for life-cycle and data analytics. If this production process is integrated and digitalized from end to end, a company can achieve substantial overall optimization outcomes."

At the electric motor plant in Bad Neustadt an der Saale, Siemens uses six specific topic areas to show how products and solutions from its own portfolio can be implemented step by step in a production process that is already up and running.

"Frequent innovations, individually tailored products, and the resulting high degree of product diversity: these are the challenges which the production process at the electric motor plant in Bad Neustadt has to rise to today," said Heuring. "Digitalization is helping us to tackle these challenges successfully. We plan to use the 'Arena of Digitalization' and the example of our own manufacturing to demonstrate to our customers — machine builders as well as machine operators — the advantages that using Siemens digitalization technologies provides. Digitalization solutions will also help us considerably in continuing to maintain a leading position among our global competitors in future and, last but not least, to secure jobs in the region in this way. We want to share our knowledge and experience of digitalization here at this location with our customers from the machine tool industry. That is our goal."

"Digitalization of the processes in the plant is a process of continuous development. Initially, we focused on using digitalization in manufacturing to create consistency throughout the CAD-CAM/CNC chain, including tool and NC program management. Systems that had previously functioned separately were synchronized and fitted with digital interfaces. In addition, we implemented new tools, optimized our NC programs and made various design adjustments," said Deml.

As a result, the electric motor plant in Bad Neustadt an der Saale has so far successfully achieved 40 percent faster throughput times where processes have been modified, shortened correction loops by 50 per cent and increased ramp-up times for new machines by 60 percent. (*www.siemens.com*)

Dana Incorporated

ANNOUNCES MULTIPLE OEM SUPPLIER AWARDS

Dana Incorporated recently announced that the company earned major supplier awards from Manitou Group, John Deere, Hyster-Yale, and AGCO, recognizing the company's commitment to excellence and continuous improvement. Together, these four original-equipment manufacturers represent 16 brands across the construction, agriculture, forestry, and material-handling markets.

"Dana's strategic commitment to growing our business through customer centricity is evident in our highly-valued relationships with vehicle and equipment manufacturers," said Aziz Aghili, president of Dana Off-Highway Drive and Motion Technologies. "These awards are proof that Dana truly collaborates with global companies that share our mission to lead the industry with innovative technology that improves vehicle performance and buyer satisfaction."

Manitou Group

During the company's yearly supplier meeting in Nantes, France, Manitou Group recognized Dana as the "Best Supplier of 2016" out of more than 1,600 companies that supply components to the off-highway vehicle manufacturer. This award acknowledges Dana's product quality, timely-delivery, extended warranty services, global supply chain support, and close engineering relationship.

"We have worked with Dana on product developments for the past five years, and we have built a truly collaborative and efficient relationship," said Laurent Gobinet, vice presidents sourcing for Manitou Group. "Dana's performance as a supplier fully aligns with the Manitou Group's vision, values, and expectations. Together, we are now in a position to share strategic approaches in order to create more value for our customers, and we look forward to partnering with Dana into the future."

John Deere

At John Deere Supplier Day events, Dana facilities in Crescentino, Italy, and Gravatai, Brazil, were awarded "Partner-Level Supplier for 2016" in the John Deere Achieving Excellence Program. This recognition signifies the company's highest supplier rating, indicating that the plants go above and beyond performance standards, reach world-class lev-

els, and demonstrate a measurable effect on customer satisfaction. Dana's Crescentino facility supplies driveshafts for the construction and forestry divisions of John Deere, while Dana's Gravatai plant produces modular axles for agriculture equipment.

Hyster-Yale

Hyster-Yale recognized Dana with the company's "Continuous Improvement Award," which recognizes suppliers who are actively engaged in quality improvement, have shown a significant or sustained improvement during the past year, and are committed to prevention of recurrence. In 2016, Dana delivered zero defective parts per million, a significant achievement given the complexity of the products supplied.

AGCO

At AGCO's recent European Supplier Day, Dana was recognized for "Logistics Performance," acknowledging the company's commitment, flexibility, and proactive approach in the region. Dana supplies axles and driveshafts to AGCO for agricultural equipment produced under the Challenger, Fendt, GSI, Massey Ferguson, and Valtra brands. (*www.dana.com*)

Varvel

OPENS U.S. SUBSIDIARY IN GEORGIA

Varvel has now inaugurated a new subsidiary in the United States. Varvel USA LLCconfirms the group's interest in the flourishing North American market as well as its commitment to internationalization, a constant characteristic of its business strategies. Varvel inaugurated its first subsidiary outside Europe in 2011, when it formed the MGM-Varvel joint-venture in Chennai, India, a major step towards integrating and developing the group's business in an exceptionally interesting market.

Varvel USA LLC is located in Peachtree Corners, Norcross, near Atlanta in Georgia, an extremely important logistic center for North America. The 4,500 square meter plant includes dedicated office space for the company's administration, sales and management. The new Atlanta plant is linked to 27 warehouses and logistic centers around the country and maintains a generous stock of Varvel products. The new subsidiary will handle all after-sales activities for customers in the United States, from technical assistance to consulting on the design of custom solutions for specific applications. Varvel USA LLC can also count on an extensive sales and distribution network. To complement the service already offered to U.S. customers, Varvel has also signed a partnership agreement with one of the most innovative and dynamic electric motor distributors in the country. This new arrangement will allow Varvel to supply complete gearmotors with the best possible service backup.

Francesco Berselli, president of the Varvel Group explains. "Our new subsidiary in the United States consolidates our standing on the international market and rewards the efforts of the whole Varvel team. This is an important milestone for us and a springboard for future development."

"While we are focusing more and more on exports, we must not forget that our Italian identity is one of our key strengths. We believe firmly in Italian manufacturing, but are well aware that Italian quality has to be promoted abroad too," said Mauro Cominoli, Varvel's general manager. "As we did in India six years ago, today we are determined to create a bigger name for ourselves in the United States, a market that is both new and full of opportunity for us." (*www.varvelusa.com*)

ANCA

CONFIRMS GRAEME BILLINGS AS BOARD CHAIRMAN

ANCA has announced its board has confirmed the appointment of an independent, non-executive chairman for the ANCA group board.

Pat Boland, joint co-founder said: "After a rigorous interview process, with several high-quality applicants, the board has appointed Graeme Billings to this role."

"Graeme comes from an impressive business background as both a senior manager, independent director and chairman for several of Australia's best companies," he concluded.

After his appointment, Billings said: "The ANCA Group is a great success story. I look forward to working with the board and management in pursuit of the company's long term growth strategy."

Formally a senior partner at PricewaterhouseCoopers, as well as leading the firm's Global Industrial Products sector, Graeme has extensive experience in assurance, transaction and consulting services with multinational and Australian companies in the automotive, construction and general manufacturing industries, spanning a 34-year period.

Billings also draws on his experience with acquisitions, mergers and other business investigation areas, including succession planning. In addition, he was a regular media commentator on the industrial products sector.

Billings lives in Melbourne with his wife and they have three children. He is a passionate sports fan and particularly enjoys AFL, cricket and golf.

This position is effective immediately. (*www.anca.com*)

AGMA

WELCOMES NEW BOARD MEMBERS

The American Gear Manufacturers Association (AGMA) recently announced the election of Jim Bregi, president of Doppler Gear as the new AGMA chairman of the board, at the AGMA Annual Meeting held March 30–April 1 in Palm Springs, California.

(Left) Jim Bregi, Doppler Gear and Dean Burrows, Gear Motions, Inc.

Other changes to the board include a new chairman emeritus, treasurer, business management executive committee (BMEC) chairman and technical division executive committee (TDEC) chairman.

The new AGMA executive committee is: Jim Bregi, chairman, and president of Doppler Gear; John Cross, treasurer, and president, ASI Technologies, Inc.; Todd Praneis, TDEC chairman, and director of product development, Cotta Transmission; John Grazia, BMEC chairman, and president, GearTec, Inc. and Dean Burrows, chairman emeritus, and president of Gear Motions, Inc.

Additionally, AGMA welcomes four new members to its board of directors. These directors will serve a three-year term (2017–2020), effective April 3, 2017. The new board members were elected by AGMA corporate members in the first quarter of 2017, and announced during the AGMA Annual Meeting.

The newly elected board members are: Michael Engesser, president, Reishauer USA; Mike McKernin, president, Circle Gear and Machine Company; Cory Ooyen, president, Global Gear and Machining, LLC; and Greg Schulte, president, Bonfiglioli USA.

"AGMA is a member driven organization and these industry leaders will join our dynamic board at an exciting time in its history," noted Matthew E. Croson, president of AGMA. "I look forward to working closely with them as we execute on our strategic plan and add value into the second century of AGMA's history." (*www.agma.org*)

Bonfiglioli

DISCUSSES EXPANSION, DIGITIZATION AND MARKET GROWTH

Bonfiglioli is one of the worldwide leaders in the manufacturing of gearboxes, gearmotors and drive systems. In the construction industry and the wind industry, the company holds a market share of 15 percent and more than 35 percent respectively. CEO Fausto Carboni recently discussed some of the latest innovations and projects during Hannover Messe in Germany.

Over the past three years, Asia and the Americas have become the company's fastest growing regions with more than 20 percent growth with four major countries standing out - Brazil, China, India, and Russia. However, the EMEA region still represents the most important market for Bonfiglioli with almost 57 percent of total turnover. The rest of the turnover is split between the Americas, representing 20 percent, and the APAC region, with 23 percent and annual growth of 15 percent.

Strongly convinced that the factories are the starting point of the solution that brings value to its customers, the company is largely investing in its products portfolio and production facilities. Bonfiglioli is reinforcing its worldwide presence and capacities through the expansion of R&D centers, production lines and facilities such as the one in Forlì, Italy, focusing on mobile and wind dedicated solutions, as well as the opening of new factories such as the plant in Pune, India, entirely dedicated to gearboxes for industrial applications. These investments, along with the already announced EVO project, give Bonfiglioli the ability to respond efficiently to the market needs with complete integrated solutions to match a wide range of industrial, mobile, marine and wind applications.

The family owned company, also started its digital journey basing tomorrow's innovation on today's victories. From a product perspective, Bonfiglioli can already count on the monitoring of several existing product ranges providing a detailed condition monitoring of the drives in operation and thus, giving the opportunity to operate preventive maintenance, anticipate machine break-down and analyze a large set of drive operating data.

In order to make the customer relationship more efficient and effective, the company also started to improve its online services with the launch of the new Mosaico e-business platform. In fact, Mosaico guides customers, distributors and sales engineers through the process of selecting the right product for specific needs, providing support in the design activities and allowing them to track orders.

For the 2017 financial year, the Italian drive specialist predicts continuous positive growth despite the general market uncertainties.

In addition, Bonfiglioli USA, a subsidiary of Bonfiglioli Riduttori S.p.A., recently announced the election of President Greg Schulte to the board of directors for the American Gear Manufacturers Association (AGMA). Schulte was elected to a three-year term by AGMA corporate members, effective April 3, 2017.

Schulte joined Bonfiglioli in 2002 as sales manager of the Mobile Solutions Division North America prior to becoming vice president of sales. He surpassed the company's aggressive growth strategy and sales grew by over 1,000 percent, giving the company a dominating presences in the U.S. and leading the way to further development and expansion.

In 2008, Schulte became president of Bonfiglioli USA. Under his leadership, the company has seen consistent year over year growth and has become one of the top performing branches within Bonfiglioli Group worldwide. Both he and the Company have been recognized for leadership and growth during his tenure, including Greg's nomination as Ernst & Young Entrepreneur of the Year (2009) and the company's numerous awards and nominations for growth including Inc. 5000 (2014 nominee), Fast 55, Emerging 30, Tri-State Success Award, Thoroughbred Award, MANNY Award and Green Energy Award. Schulte has been an active member of the AGMA and served on the AGMA Foundation board of trustees. He is an active volunteer with other local non-profit organizations as well. He resides with his wife, Julie, and family in Union, KY. (*www.bonfiglioli.com*)

B&R

RECEIVES VISIT FROM CANADIAN AMBASSADOR

Canadian Ambassador to Austria Mark Bailey recently visited industrial automation provider Bernecker + Rainer (B&R) in Eggelsberg. Meeting with Managing Director Hans Wimmer, Bailey learned about the company's latest products and other factors that have contributed to its rapid growth around the world — including in Canada.

B&R is a key strategic partner for Canadian machine builders in industries ranging from packaging and plastics to special-purpose machinery.

"Our highly qualified team of support, development and sales engineers accompany our customers through every step — from conceptual design to software implementation and even intelligent service concepts," says Christian Kastinger, who oversees B&R's sales activities in North America. "With our offices in Toronto and Montreal, we are close to our customers in the hotbeds of Canadian machine building."

Wimmer and Kastinger led the ambassador on a tour of B&R›s own smart manufacturing operations.

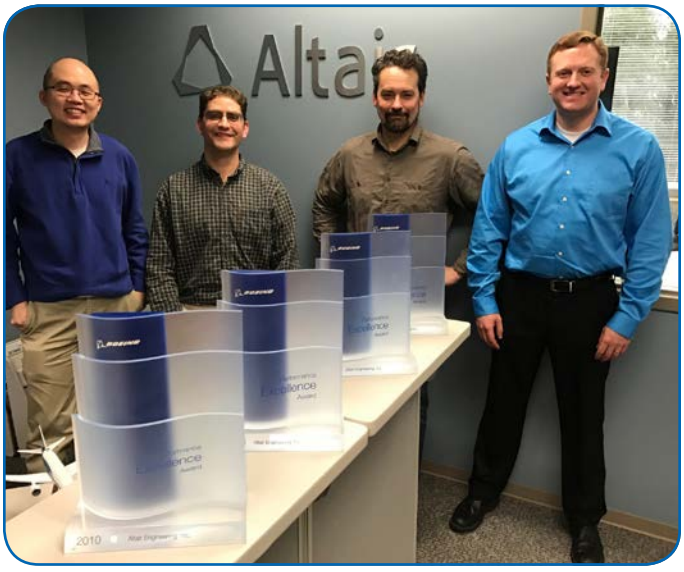
"What I've seen here at B&R has been very impressive. Industry 4.0 and Industrial IoT are the talk of global industry, and here in these ultra-modern facilities you can experience them in action," said Bailey. (*www.br-automation.com*)

(Left to right) Embassy Counselor Simon-Pierre Rhéaume, Managing Director Hans Wimmer, Canadian Ambassador Mark Bailey and Sales Manager Christian Kastinger.

Altair

WINS 2016 BOEING PERFORMANCE EXCELLENCE AWARD

Altair's product development services division Altair ProductDesign is honored to receive a 2016 Boeing Performance Excellence Award. The Boeing Company issues the award annually to recognize suppliers who have achieved superior performance. To qualify for the award, Altair maintained a silver composite performance rating for each month of the 12-month performance period, from Oct. 1, 2015, to Sept. 30, 2016. Altair has received this award for outstanding achievement for the fourth year in a row and for the fifth time in the last seven years.



"Altair ProductDesign is honored to receive this award for a fifth time," said Mak Gilbert, program manager at Altair ProductDesign. "We truly value Boeing's appreciation and recognition of the consistently smart, hard work our engineers conduct daily to support their design of lightweight, high performing aircraft," he said.

The Altair ProductDesign approach to aerospace design includes an aggressive application of simulation technologies upfront in the development process. This 'Simulation Driven Innovation' philosophy allows the company to find the optimal balance between weight, performance and cost for products being developed and results in a program with reduced risk and shorter cycle times to deliver an aircraft, helicopter or spacecraft that meets functional attributes and mass targets on time.

"We are delighted to have been chosen once again by Boeing. We strive to help Boeing produce great products that are engineered for performance, efficiency, and safety. This award is an outstanding recognition of the exceptional Altair engineers that support Boeing engineering goals and objectives," said Brett Chouinard, chief operating officer, Altair. (*www.altair.com*)

Cone Drive

EUROPEAN EXPANSION RESULTS IN GROWTH OPPORTUNITIES

Cone Drive expanded its global footprint in early 2016 by establishing a sales office in Europe. The move has proven to be a resounding success with strong interest in Cone Drive's precision motion control and high torque dense power transmission solutions. Cone Drive appointed Mike Page, an industry veteran offering 25 years of experience in the industrial mechanical and power transmission industry, as director of European sales and his focused attention on the European manufacturing community has resulted in mounting growth opportunities for Cone Drive.

"Cone Drive, the Global Precision Motion Control experts, have brought together an impressive package of Precision Motion Control and High Torque Dense Power Transmission solutions for the European market. From our proprietary double-enveloping worm gear driven Servo Speed Reducers, our H-Fang Slew Bearings and Drives to our latest range of Harmonic Solutions, we are able to support precise positional accuracy and higher torque demands where performance in a quiet, compact package is required," Page said.

(*www.conedrive.com*)

C&U Americas

RECEIVES VALUE IMPROVEMENT AWARD

C&U Americas recently received the 2016 Value Improvement Award from Hitachi Automotive Systems in recognition of outstanding value improvement and performance achievement. This award follows a previous citation in 2016 for the Hitachi Quality Award and is the second Value Improvement Award presented to C&U Americas since 2014. Matt Unsworth, director of sales and Rich Peterson, director of engineering, accepted the award on behalf of C&U Americas at the 6th Annual Hitachi Automotive Systems Supplier Awards held at the EKU Center for the Arts in Richmond, KY on April 25, 2017. (*cubearing.com*)

Schaeffler

CELEBRATES FORT MILL EXPANSION

Schaeffler Group USA Inc., a global manufacturer of precision components for the industrial and automotive sectors whose South Carolina roots stretch back to the 1960s, recently celebrated the grand opening of its expanded manufacturing plant and new administrative building in Fort Mill, S.C. The project resulted in the creation of over 100 South Carolina jobs. For almost 50 years, Schaeffler has demonstrated its strong commitment to the Palmetto State through dramatic investments and expansion projects totaling over $1 billion and counting.

The grand opening celebration featured over 100 invited guests and dignitaries, including The Honorable Henry McMaster, Governor of South Carolina; H.E. Dr. Peter Wittig, Germany's Ambassador to the United States; the owners of the Schaeffler Group, Maria-Elisabeth Schaeffler-Thumann and Georg F. W. Schaeffler, as well as Klaus Rosenfeld, CEO of Schaeffler AG.

"Schaeffler is excited to celebrate another milestone in our five-decade partnership with the State of South Carolina," said Schaeffler America CEO Bruce Warmbold. "The increased production capacity in our Fort Mill 1 plant enables our company to offer more job opportunities for residents of the Palmetto State as well as more high-tech solutions to our automotive and industrial customers. Schaeffler is grateful to Governor Henry McMaster and the State of South Carolina for their continuing support of Schaeffler's operations as we work to help shape Mobility for tomorrow."

"South Carolina's manufacturing industry is one of the fastest growing in the world, and we have fantastic companies like Schaeffer to thank for that," said Governor McMaster. "Each time a company like this one commits to our state and invests in our people, it shows that our State is a great place to be doing business. Today's celebration is just one of many that we know the partnership between Schaeffer and South Carolina will produce in the years to come."

Schaeffler Group USA Inc.'s latest $36.5 million capital investment, which generated approximately 105 additional jobs, resulted in the construction of a new administrative office building, the expansion of one of two factories located on the company's Fort Mill campus, and a reworked plant entrance to accommodate the growth and increase in traffic.

The factory expansion, which creates almost 35,000 sq. ft. of additional manufacturing space in the company's Fort Mill 1 Plant, increases capacity in stamping, heat treatment and assembly for thrust bearings used in 8-, 9- and 10--speed automatic transmissions. Meanwhile, the brand-new administrative building encompasses over 64,000 sq. ft. of office space, including state-of-the-art workstations, a multimedia conference center for regional meetings, and a full-service employee cafeteria.

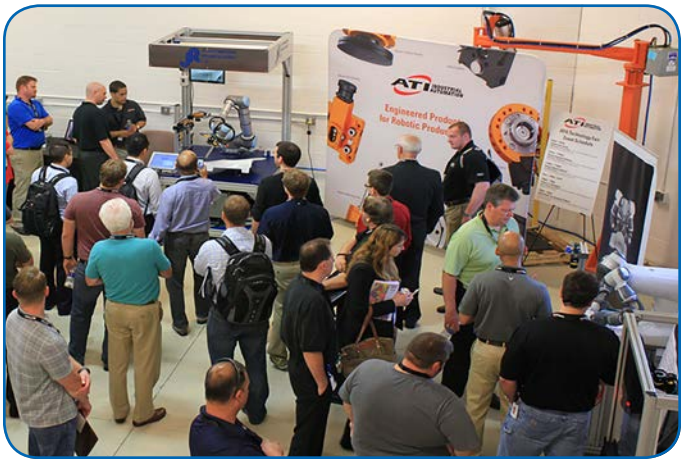
The York County expansion is part of a $164 million capital investment in Schaeffler's South Carolina operations – which include facilities in Spartanburg County and Chesterfield County – that was announced back in January 2015. Collectively, the investments are expected to create more than 440 new jobs in the Palmetto State. (*www.schaeffler.us*)

ATI Industrial Automation

SETS DATE FOR TECHNOLOGY FAIR

ATI Industrial Automation will hold its Annual Technology Fair on August 10, 2017 at its Orion Township, Michigan facility. The one-day educational event will focus on "Applications Advancing Automation," providing attendees the opportunity to learn more about ATI's products and hear from the industry-leading experts that use them every day. The event will feature educational seminars hosted by ATI's distinguished customers, as well as live robotic demonstrations of ATI's Tool Changers, Multi-Axis Force/Torque Sensors, Robotic Collision Sensors and Robotic Deburring Tools.
Attendees will have the opportunity to discuss their specific automation challenges and possible solutions with ATI account managers, engineers and personnel from automation partner companies who will also be on hand.

ATI's passion is helping to solve unique automation challenges and elevate processes. The Technology Fair is designed to benefit both those considering an initial foray into robotic automation, as well as those looking to upgrade or enhance their existing robotic lines.
The event takes place August 10th. Lunch will be served; special guests and a detailed schedule will be announced soon. The event will run from 8:00 am to 4:00 pm. (*www.ati-ia.com/TechFair*)



Force Control

RELEASES NEW POSIDYNE CLUTCH BRAKES CATALOG

A new 16-page, full color catalog from Force Control Industries details the Posidyne line of clutch brakes featuring Oil Shear Technology for long service life with no maintenance or adjustment. Ideal for high cycle count applications (up to 250+ CPM), from 240 to over 78,500 lb/in torque ratings, they are available with air or hydraulic actuation. Totally enclosed sealed housings allow them to operate in severe environments. Various cooing options include fan, water, oil-to-air and forced lubrication. Washdown, Marine Duty, severe and hazardous duty options are available. This new literature is available in print by request, or can be downloaded at the website. (*www.forcecontrol.com*)

June 27–29—Power-Gen Europe 2017

Cologne, Germany. Power-Gen Europe and co-located Renewable Energy World Europe, is where a rapidly-evolving power industry meets to gather information and compare views on shared opportunities and challenges. Attracting a worldwide audience, it is a key event for advancing Europe's energy future. Featuring the leading suppliers, sub-suppliers, service providers and end-users across the entire power generation value chain, the trade show encapsulates all aspects of today's centralized and distributed power generation sector. Together they combine strategic and technical presentations with the largest trade show exhibition of power equipment and services in Europe. Conference topics include renewable energy, energy storage, plant management, digital tools, and strategies for change. For more information, visit *www.powergeneurope.com*.

July 5–6—International VDI Congress-Drivetrain for Vehicles

Bonn, Germany. The electrification of the powertrain implies one of the mega trends in transmission development. This technical advancement has impacted the entire automotive industry and affects everyone from the manufacturers, the suppliers and subcontractors up to the drivers themselves. This conference examines the predicted impact and influence of the new electric and hybrid vehicles on the market in terms of suitability for mass production. Here the focus is placed on the requirements that electrified drive systems have to fulfill and how they inspire manufacturers and suppliers in engineering and mechatronics to propel innovative developments to new heights. One of the highlights in Bonn is the accompanying trade show, which over the years has grown to become a major marketplace. More than 100 organizations from around the world present their solutions covering all aspects of the automotive transmission and its components. For more information, visit *www.transmission-congress.com*.

July 31–August 3—CAR Management Briefing Seminars

Grand Traverse Resort, Traverse City, Michigan. Initiated by the University of Michigan in 1965, the first Center for Automotive Research Management Briefing Seminars (CAR MBS) hosted only 30 people. When the industry was at its highest number of employment, the event grew to attract more than 1,400 attendees annually from more than 35 states and 15 countries–representing industry, academia, media and the government. CAR MBS leads the industry in providing a context for auto industry stakeholders to discuss critical issues and emerging trends while fostering new industry relationships in daily networking sessions. Seminars include targeted sessions on manufacturing strategy, vehicle lightweighting, connected and automated vehicles, advanced powertrain, supply chain, sales forecasting, purchasing, talent and designing for technology. For more information, visit *www.cargroup.org*.

August 10—The Changing Landscape of Additive Manufacturing Materials

Youngstown, Ohio. SME and America Makes come together to bring you this one-of-a-kind seminar. 3D Printing has significantly grown in recent years and is expected to quickly grow over the next few years. Discover which materials and filaments are most durable, what types of machines to use, certification/qualification standards as well as how to reduce cost, and increase profitability. Participating companies include GE, the U.S. Army, Northrop Grumman, and more. Topics include new materials, aerospace production, material implementation, expanding design space and the future of additive manufacturing. For more information, visit *smartmanufacturingseries.com*.

August 21–22—Design and Production Engineering 2017

Birmingham, U.K. The Design & Production 2017 Conference brings together experts, researchers, scholars and students from all areas of mechanical engineering including design engineering, manufacture engineering, production engineering, vehicle engineering and other related areas such as mechatronics, bio-inspired robotics, prosthetic design and bio-inspired design. This conference offers an opportunity to attend the presentations delivered by eminent scientists, researchers, experts from all over the world. Topics include reshoring, manufacturing innovations, material science, aerospace, maintenance and more. For more information, visit *www.design-production.conferenceseries.com*.

September 6–8—AGMA 2017 Bevel Gear System Design

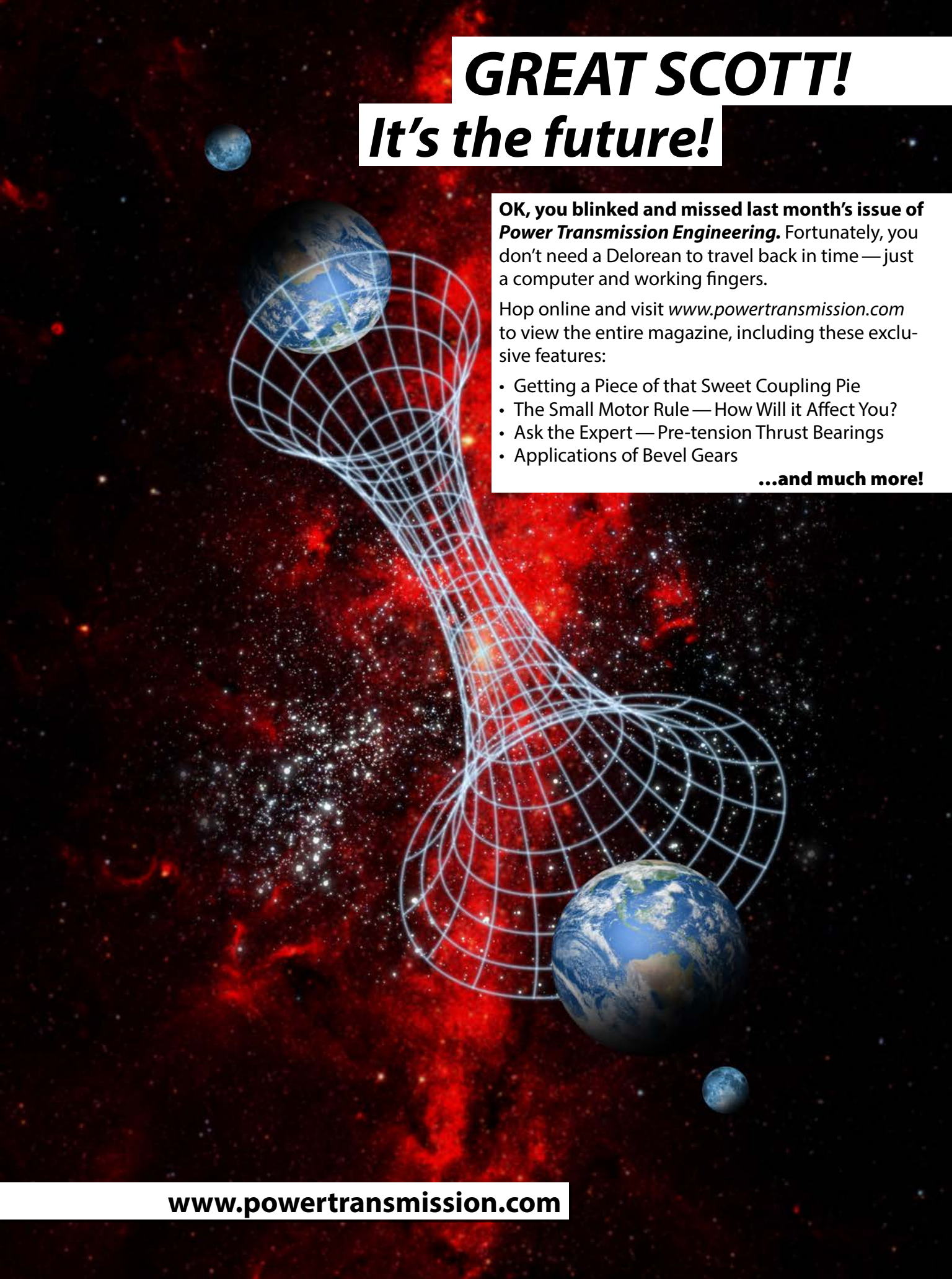
San Diego, CA. Learn how to design and apply bevel gears systems from the initial concept through manufacturing and quality control and on to assembly, installation and maintenance. Engage in a practical hands-on guide to the bevel gear design, manufacture, quality control, assembly, installation rating, lubrication and, most especially, application. Engineers, technicians, and others involved in the selection, application and/or design of bevel gear systems should attend. Ray Drago is the instructor. For more information, visit *www.agma.org*.

September 18–22—AGMA 2017 Basic Training for Gear Manufacturers

Oak Lawn, Illinois. Learn the fundamentals of gear manufacturing in this hands-on course. Gain an understanding of gearing and nomenclature, principles of inspection, gear manufacturing methods, and hobbing and shaping. Utilizing manual machines, develop a deeper breadth of perspective and understanding of the process and physics of making a gear as well as the ability to apply this knowledge in working with CNC equipment commonly in use. This course is taught at Daley College. A shuttle bus is available each day to transport students to and from the hotel. Although the Basic Course is designed primarily for newer employees with at least six months' experience in setup or machine operation, it has proved beneficial to quality control managers, sales representatives, management, and executives. Course instructors are Dwight Smith, Allen Bird and Peter Grossi. For more information, visit *www.agma.org*.

September 19–22—Process Expo 2017

McCormick Place, Chicago, Illinois. Process Expo represents the pinnacle of food technology bringing together the world's most successful food and beverage processors, equipment manufacturers and leaders in the field of academia. It is owned and organized by the Food Processing Suppliers Association (FPSA), a global trade association serving suppliers in the food and beverage industries. Nearly 600 food processing and packaging exhibitors will display machines, products and services specific to food and beverage processing. For more information, visit *www.myprocessexpo.com*.



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

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Al-Jazari — Mechanical Genius

Salim Al-Hassani

The following is a very brief overview on the life, work and achievements of Al-Jazari — the most famous mechanical engineer of his time. Now well more than 1,000 years ago, Al-Jazari brought Islamic technology to a culminant point.

Al-Jazari was the most outstanding mechanical engineer of his time (1136–1206). His full name was Badi' al-Zaman Abu-'l-'Izz Ibn Isma'il Ibn al-Razzaz al-Jazari — but he became better known as Al-Jazari. He was born in Jazira, the area lying between the Tigris and the Euphrates in Mesopotamia. Like his father before him, he served the Artuqid kings of Diyar-Bakir for several decades as a mechanical engineer. In 1206 after the year of his death, he completed an outstanding book on engineering entitled, Al-Jami' bayn al-'ilm wa-'l-'amal al-nafi' fi sinat'at al-hiyal (*The Book of Knowledge of Ingenious Mechanical Devices;* also known as *A Compendium on the Theory and Useful Practice of the Mechanical Arts*). It was a compendium of theoretical and practical mechanics. George Sarton (*Belgian-American chemist and historian, considered the founder of the discipline of history of science.*) wrote: "This treatise is the most elaborate of its kind and may be considered the climax of this line of Muslim achievement."(*Introduction to the History of Science*, 1927, Vol. 2, Pg. 510).

Al-Jazari described fifty mechanical devices in the book, in six different categories, including water clocks, hand washing device (wudhu' machine) and machines for raising water, etc. Following the World of Islam Festival, held in the United Kingdom in 1976, a tribute was paid to Al-Jazari when the London Science Museum showed a successfully reconstructed working model of his famous Water Clock."

Al-Jazari's book is distinctive in its practical aspect because the author was both competent engineer and skilled craftsman. The book describes various devices in minute detail, providing an invaluable contribution in the history of engineering. British charter engineer and historian of Islamic technology Donald R. Hill, who held a special interest in Al-Jazari's achievements, wrote:

> **"It is impossible to over-emphasize the importance of Al-Jazari's work in the history of engineering; it provides a wealth of instructions for design, manufacture and assembly of machines."**

Donald R. Hill translated into English Al-Jazari's book in 1974 — seven centuries and 68 years after it was completed by its author. Al-Jazari's encyclopedic treatise includes six main categories of machines and devices. Several of the machines, mechanisms and techniques first appear in this treatise, later entering the vocabulary of European mechanical engineering. Among these innovations, we mention the double acting pumps with suction pipes, the use of a crank shaft in a machine, accurate calibration of orifices, lamination of timber to reduce warping, static balancing of wheels, use of paper models to establish a design, casting of metals in closed mold boxes with green sand, etc. Al-Jazari also describes methods of construction and assembly in scrupulous detail of the fifty machines to enable future craftsmen to reconstruct them.

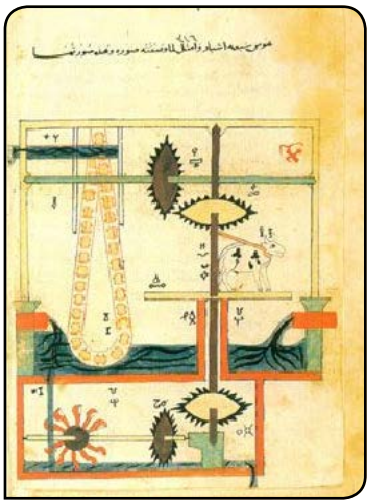

Illustration of Al-Jazari's hydropowered saqiya chain pump device, from his 1206 book — *The Book of Knowledge of Ingenious Mechanical Devices.*

And he was successful in that, for many of his devices were constructed following his instructions. The work by Al-Jazari is also unique in the way that other writers often fail to give sufficient details, because — amongst other factors — they were not craftsmen themselves, or if they were craftsmen, they could have been illiterate. Al-Jazari in this respect was unique, and this gives his work immense value. His book, Hill states, "is an absolute wealth of Islamic mechanical engineering."

In their paper on "Mechanical Engineering during the Early Islamic Period" (published in I. Mech. E, The Chartered Mechanical Engineer, 1978, pp. 79–83), C. G. Ludlow and A. S. Bahrani have raised the important point that it is more than likely that there is more on the subject in some of the thousands of Arabic manuscripts in the world libraries which have not yet been inspected closely, and obviously require looking into.

Hill, too, constantly raises the two major issues with respect to the history of engineering in general, and that of fine technology in particular. He first states the fact that the field, which is absolutely immense, is yet largely unexplored.

One of his concluding points states, "It is hoped that as research proceeds, firmer evidence for the transmission of Islamic fine technology into Europe can be provided." Hill also offers some hints for such transmission. The most likely route was Spain. Such fine technology could have followed the same route as the astrolabe (itself part of this fine technology.) Apart from Spain, there were other possible lands of transfer, e.g. — Sicily, Southern France, Italy, Byzantium and Syria during the Crusades. Hill is also right on a further point, i.e. — that what will be seen in this work is just a fraction of the whole process which, as with much else, has hardly been explored. (**Salim Al-Hassani** is *Emeritus Professor at the University of Manchester and Chairman of The Foundation for Science, Technology and Civilization, Manchester, UK.*) **PTE**

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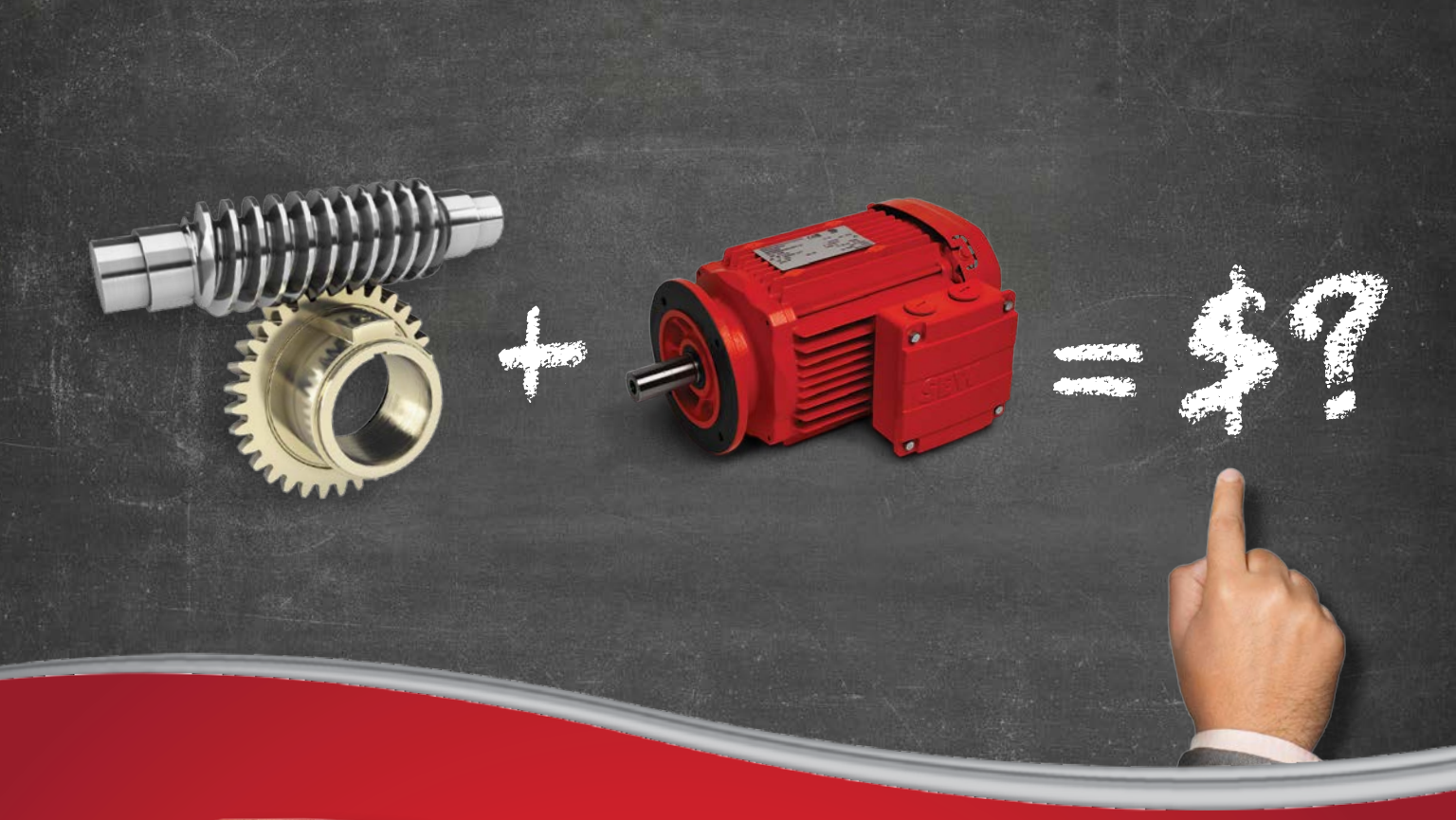

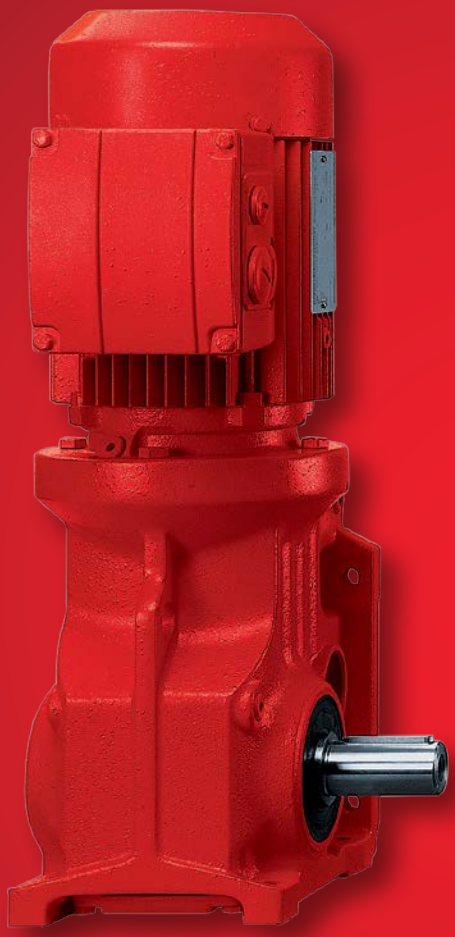

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