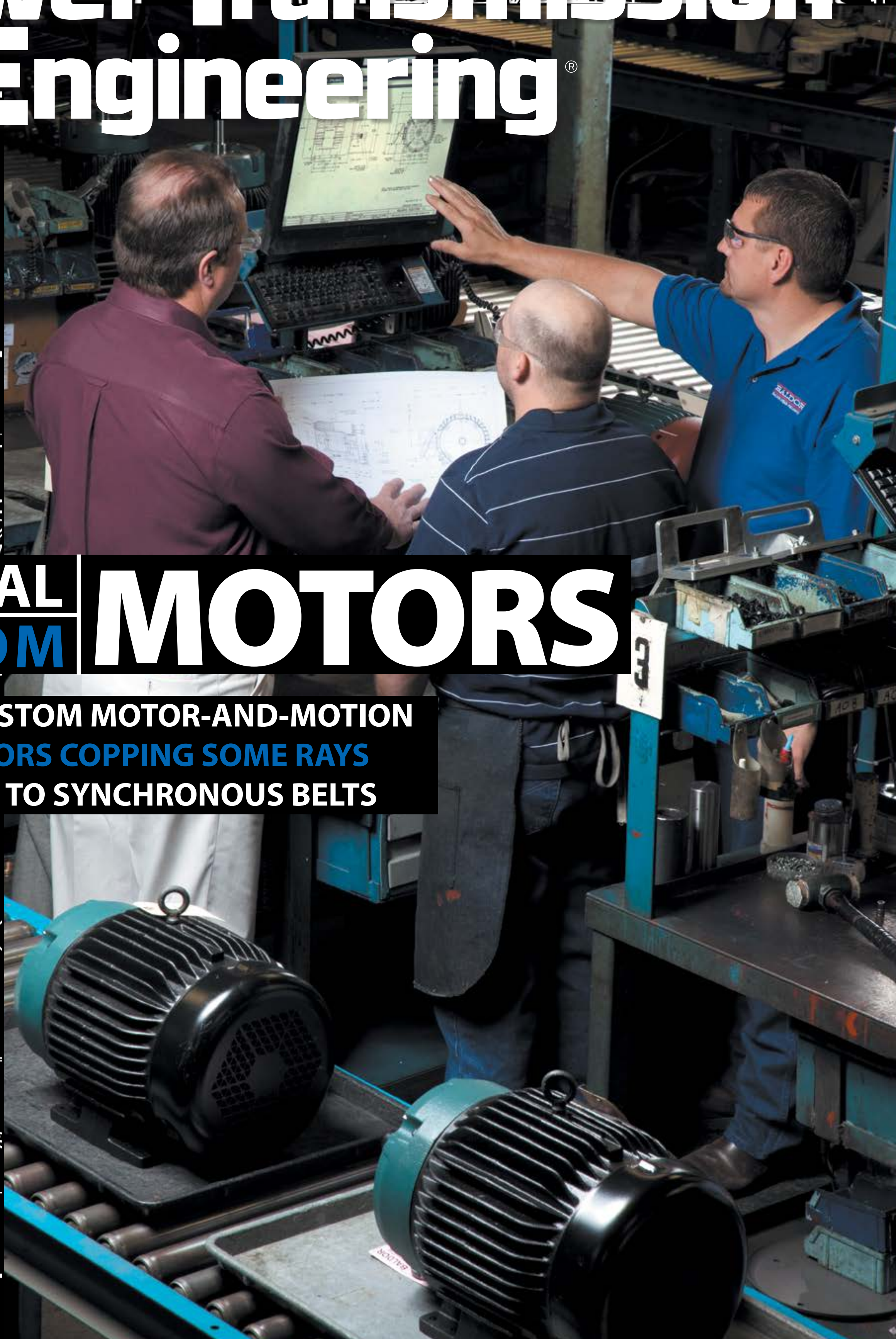
Power Transmission Engineering®

JUNE 2016



GENERAL CUSTOM MOTORS

DEFINING CUSTOM MOTOR-AND-MOTION

MAXON MOTORS COPPING SOME RAYS

GATES GUIDE TO SYNCHRONOUS BELTS

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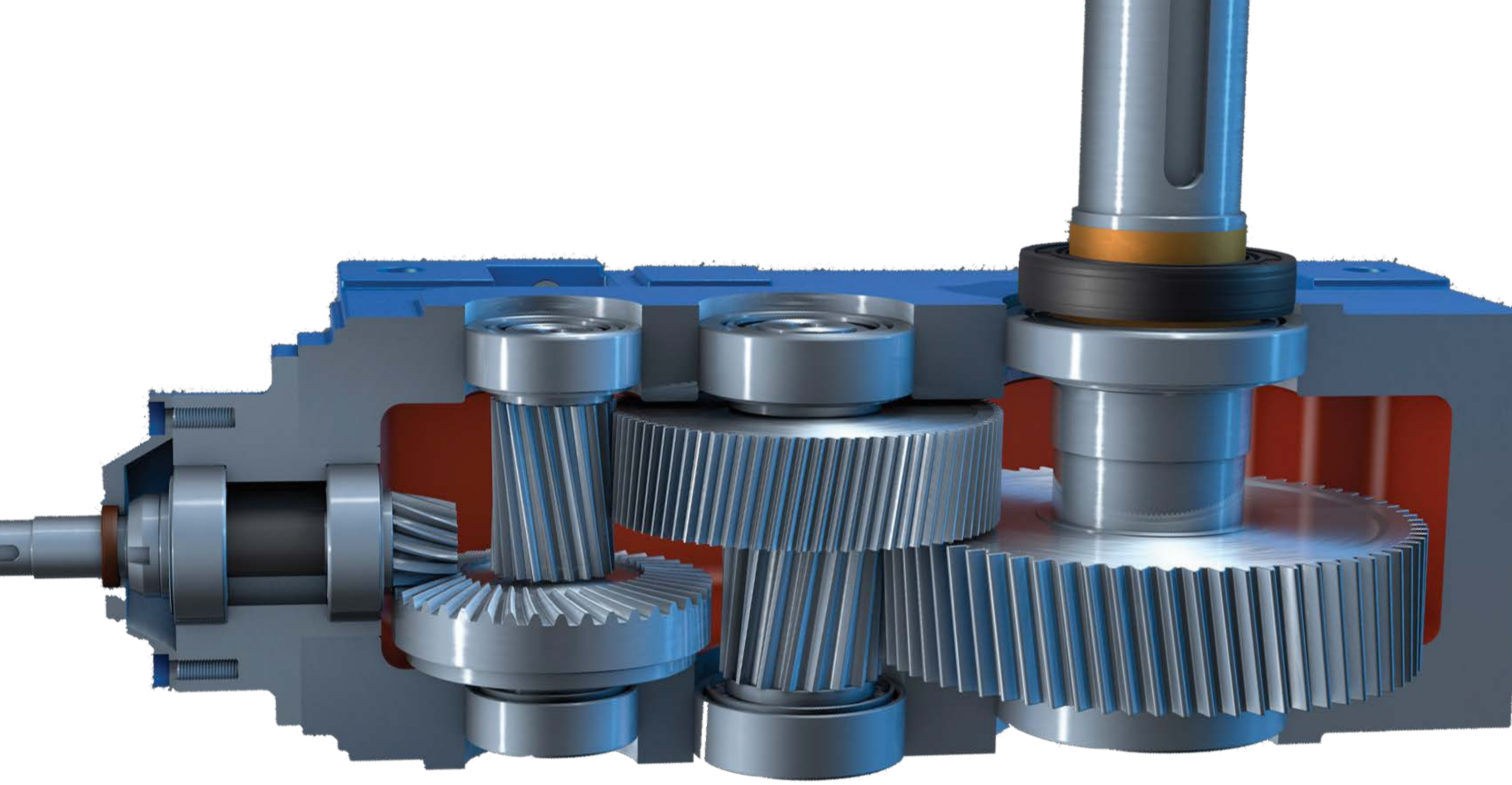

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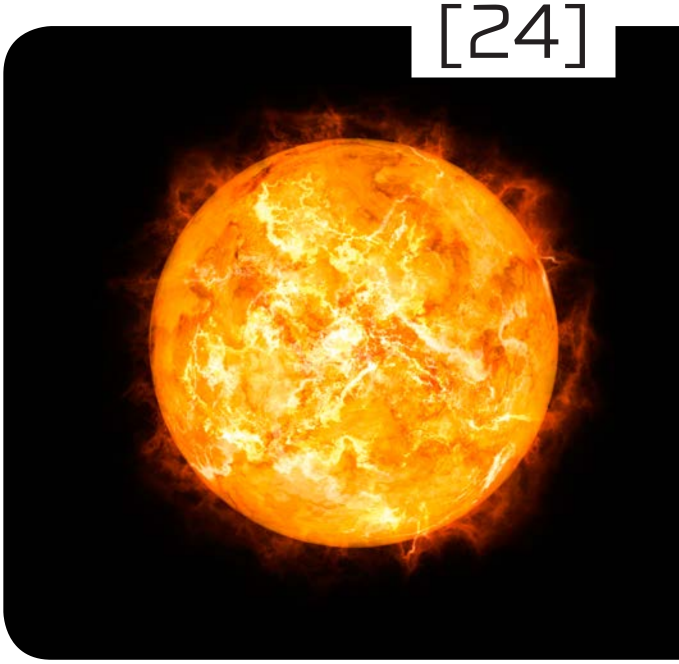

FEATURE ARTICLES

TECHNICAL ARTICLES

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Power Transmission Engineering

VOL. 10, NO. 4

Photo courtesy of Baldor

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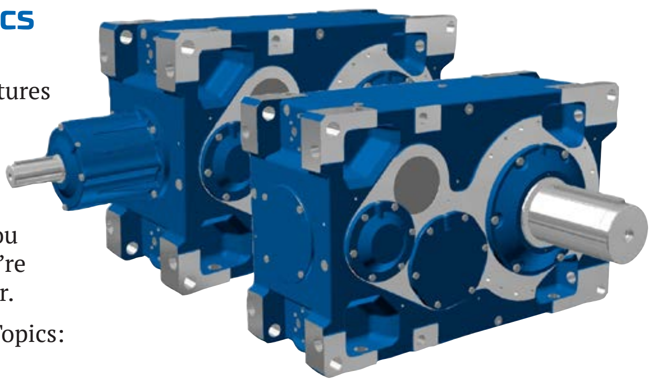
PTE Featured Topics



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

This Month's Highlighted Topics:
Bearings
Gear Drives

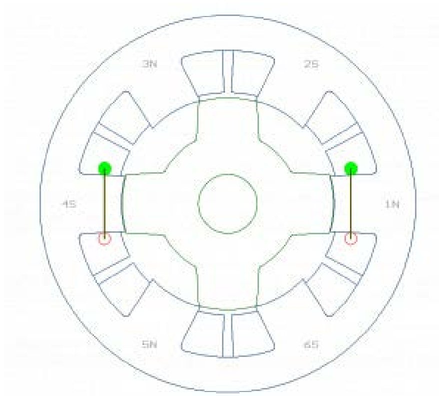
Social Media

Have you browsed our Twitter page recently? We've added the latest PT news and product information from companies like Nord, Schaeffler, Hash Mobile, Lapp Group and more. Check out these and other PT manufacturing topics here: *https://twitter.com/PowerTransMag*

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

Motors Blog

George Holling, technical director at Rocky Mountain Technologies, Inc. regularly contributes articles on the *PTE* website regarding motors, power quality, power factor, efficiency and other relevant PT topics. Visit *www.powertransmission.com/blog* for more details.



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Schmidt Offset Couplings can be mounted to shaft hubs or directly to existing machine flanges. They are available for shaft displacements of 0.156 inches to 17.29 inches and torque capacities from 55 to 459,000 inch-pounds. Many design configurations are available including specials.

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ZERO-MAX®

Randy Stott, Managing Editor

Motors and More

Electric motors are often considered a mature industry—one whose basic technology was invented more than a century ago and whose fundamental concepts haven't changed much since. But new applications continue to demand change. Engineers want greater efficiency, more precise control and improved reliability.

Over the years we've seen a number of advances that have greatly increased the range of applications for motors. Thanks to the proliferation of and improvement in electronics, we have servos, variable frequency drives and other ways to control motion.

These topics and more are covered this issue, as we focus on motors. Senior Editor Jack McGuinn's article (beginning on page 18) delves into the decision-making process regarding custom-designed motor and motion control solutions. In the article, experts weigh in on the relative merits of choosing a stock solution versus developing one from scratch.

We also check in on the cutting edge with our case study from Maxon about the motors being used in the European Space Agency's Solar Orbiter, planned for launch in 2018. These motors must withstand both extremely high and low temperatures, radiation bombardment and the vacuum of space. Plus, they have to be super lightweight, efficient and reliable. Read the article beginning on page 24 to see how engineers are meeting this challenge.

Finally, we have a technical article from ABB on the acoustic analysis of electrical motors in a noisy industrial environment. The authors have successfully demonstrated the use of acoustic signals to perform condition monitoring of electric motors, even in a noisy environment. Their solution involves the use of a 48-microphone acoustic camera, which helps localize the sounds generated by the equipment and isolate problems from the background noise.

In addition to these articles, there's a lot more information on motors on our website, including the "Motor Matters" blog written by our motor expert, George Holling. Holling's most recent piece deals with some of the basics of V/F drives, including what they do and why we need them. You can read these web-exclusive articles by visiting *www.powertransmission.com/blog*.

But that's not all. If motors aren't your thing, we also have a wide variety of content this issue on other power transmission topics. The BSA has provided this issue's *Bearing Briefs* column (p.26), which focuses on the various bearing requirements in a poultry processing facility. We also cover bearing installation in a fan application with this issue's *Field Notes* column (p.34).

News Editor Alex Cannella explores the new MedAccred standard, which brings the same kind of accreditation to suppliers of the medical devices industry that Nadcap has provided for aerospace. If you're involved with medical equipment, this important and timely article can be found on page 36.

To top things off, we also have articles on synchronous belt selection and replacement (p. 30), high ratio epicyclic gear drives (p. 40), alternative gear steels (p. 42), and leaky shaft seals (p. 52).

If you can't find what you're looking for, check in at *powertransmission.com*. Just type what you're looking for into the search bar, and happy exploring!

As always, thanks for reading!

Bosch Rexroth Frequency Converters

OFFER SCALABILITY AND FUNCTIONALITY

All over the world, industrial end-users are demanding energy-efficient machines and equipment to significantly reduce operating costs and reduce their carbon footprint (CO_2 emissions). By using demand oriented electromechanical energy, users are able to take vital steps in the right direction achieving those goals. Speed-controlled induction motors in variable speed pump drives, for example, can reduce electricity consumption by up to 80 percent in comparison to fixed-displacement drive applications. The EFC 3610 and EFC 5610 frequency converters from Rexroth address these potentials simply and economically. Scalable in performance and functionality features, the drives can be integrated into a wide range of automation environments with simple commissioning and open interfaces.

The intelligent frequency converters control speed as demanded, thus significantly reducing the energy consumption of pumps, compressors and fans. The frequency converters commonly known as variable frequency drives (VFD), AC drives or variable speed drives (VSD) can be integrated into many types of applications and machines as compact units for speed and torque control. Together with permanent magnet motors, the frequency converters increase energy efficiency and the adaptive pulse adjustment of the PWM frequency, minimizes motor noise at the same time. Integrated energy counters measure actual consumption and capture valuable information for the energy usage optimization of machines and systems.

Commissioning without a PC

With the integrated control panel, commissioning can be done easily without external programming devices or a PC. From there, the user can start auto-tuning and enter, change or backup parameters. With switchover options between parameter sets and integrated PID control to increase flexibility as well as extensive connectivity options like Multi-Ethernet interface option (Sercos, EtherNet/IP, PROFINET, EtherCAT and Modbus/TCP), designated fieldbus options (Profibus DP and CANopen) and additional I/O options, the devices are suitable for most machine applications.

The removable LED operator display panel shows all operating variables and has an integrated copy function. This accelerates the commissioning of several frequency converters with the same or similar parameter set and reduces the work required when exchanging equipment or in series production.

PC-based commissioning and diagnoses

The integrated mini-USB programming interface in conjunction with the free downloadable *Rexroth IndraWorks Ds* software tool, is used for easy commissioning via start-up wizard, monitoring and diagnoses or simple back-up, archive and restore parameters with any PC.

The drives have analog inputs and outputs, which can be configured as voltage or current interfaces. Digital inputs/outputs make simple direct coupling with a PLC possible. The assembly work required is significantly reduced by the integrated brake chopper and mains filter as well as time-saving installation technology using plug-in terminals and an attachment option on standard DIN rail.

Open interfaces for universal application

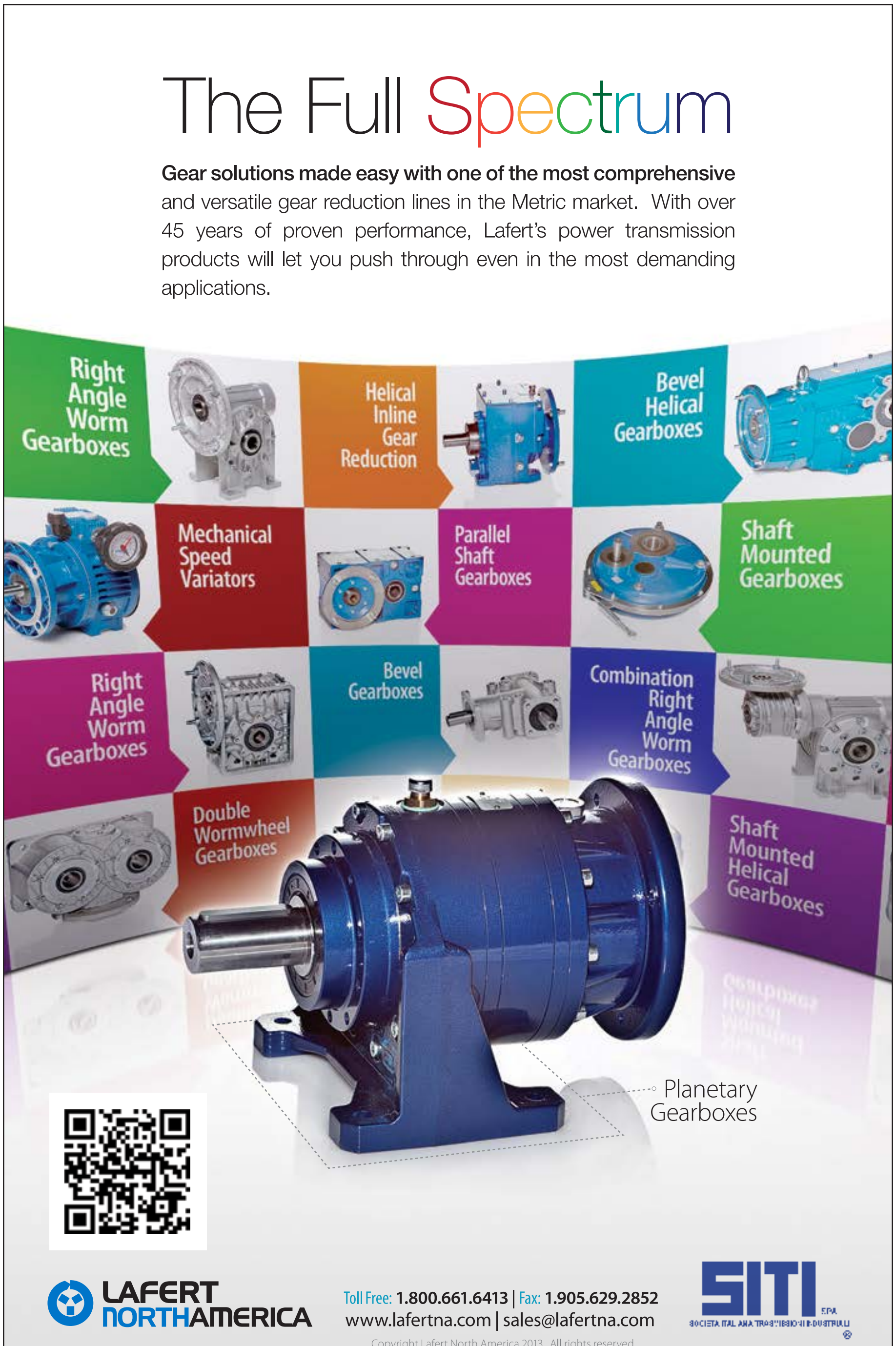
The EFC 3610 / 5610 frequency converters from Rexroth can be easily integrated into an automation network via Sercos, available through the optional Multi-Ethernet interface or other resident protocols like EtherNet/IP, PROFINET, EtherCAT, and Modbus/TCP. Modbus RTU interface is included as standard on the devices. Other fieldbus options available are Profibus DP and CANopen. With the integrated sequence control with 16 levels, inde-

pendent sequences can be parameterized. The protection function for pump operation and motor temperature monitoring protects the system during critical process conditions.

The new EFC3610 frequency converter series cover the power range from 0.4 to 22 kW or 0.5 to 30 hp, while the EFC5610 provides an expanded range up to 90 kW or 125 hp and safe torque off (STO). In addition to the freely definable V/f (V/Hz) operation, the EFC 5610 also offers vector control for an optimal torque curve. In heavy duty mode, the overload capacity can be maintained at up to 150 percent for 60 seconds. The high-torque EFC 5610 frequency converter also offers an optimal start torque of 200 percent at 0.5 Hz.

For more information:

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



Nord Drivesystems

POWER SURFACE COATING FACILITY

At the Nord Drivesystems headquarters in Bargteheide, Germany, the power, functionality and intelligence of Nord products are used to the company's own advantage across the factory floor, with geared motors and drive electronics handling various applications. Notably, this includes a recently established surface coating facility, where Nord systems drive overhead conveyors, fans and hoists.

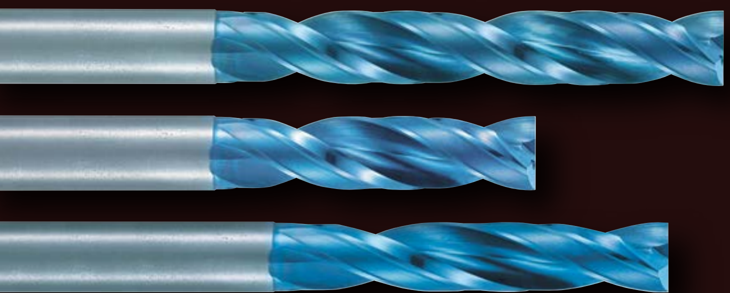
The new surface coating facility at the Nord headquarters has twice the size of the previous paint shop. New paint booths, an automated high-bay warehouse for paint cure, and packing stations together occupy 1,400 m^2. An intelligent control system has, on average, halved the lead times for paint jobs. Any drive can be painted and shipped within two hours after assembly.

Paint line with a fast lane

Nord configures each drive system to order, drawing almost exclusively on components manufactured in-house. Application-specific coatings are part of this process. Fast processing of urgent orders has now become much easier. Previously, geared motors were routinely returned to the end of the queue once the first coat had been applied. The new conveyor system enables completely flexible routing: after curing, high-priority products can jump the queue and immediately get their next paint coat. Intelligent sorting algorithms also ensure that paint jobs with equal priority are optimally grouped by coating systems and shades. This has reduced wastage and setup times. In addition, state-of-the-art filter systems in the paint booths limit pollution to a minimum. The packing stations also draw on the smart sorting capabilities of the conveying systems: each packing station can be designated to handle a particular mode of shipment.

NACHi

Superior Quality



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IMTS2016

The right drive for each and every task

More than 100 drives take over various tasks in the new facility – Nord drive technology powers conveyors, hoists, exhaust ventilation and cooling fan systems. Drawing on its own modular drive program, Nord has configured optimal solutions for each of the various requirements. Both highly efficient helical bevel gear units and worm gearboxes with very high gear ratios are used. Depending on the performance and function requirements, the motors are controlled by different frequency inverter models.

Ventilation systems

Four fans with a 22,000 m^3/h circulation capacity ensure proper air exchange in the paint booths. The fan drives are equipped with 22 kW distributed drives from the SK 200E frequency inverter series. The control solution enables standby mode and ensures adequate compensation of filter pollution by regulating the motor speed based on the measured air flow rate. Like all Nord inverters, these drives provide smart energy saving functionality. They automatically detect partial load and reduce the energy consumption of the motor accordingly. Since the inverters are installed on the roof along with the ventilation units, they are designed for IP66 ingress protection.

Overhead conveyor

The Nord motors and gear units passing through this facility often weigh several hundred kilograms. Robust hardware is therefore required. The overhead conveyor is operated at a maximum speed of 10 m/min. It is equipped with over 100 smooth-running worm geared motors. Some parts of the facility are classified hazardous areas (Ex zone 2). The 14 drives installed within them are controlled by SK 500E series cabinet-installed inverters. All other drives feature a motor-mounted SK 180E type inverter. Designed to achieve a great price/performance ratio while offering a full complement of efficiency functions, the SK 180E supports motor outputs from 0.25 to 2.2 kW to address all simple handling tasks in horizontal applications. A technology box installed with the inverter adds a Profibus in-

terface as well as various sensor and pneumatic interfaces for transmission of position data and controlling switches. The integrated drive configuration capability as well as the consistent use of plug connectors was instrumental in minimizing the drive installation effort in the extensive facility. The AC vector drives have a separate 24 V control voltage supply and can therefore be accessed via Profibus even when the 400 V power supply is switched off.

Hoist technology

The facility includes a high-bay storage as a drying room. An automated storage and retrieval unit enables flexible access to all drive components. Each drive unit can be retrieved via its individual designation and automatically transported to a paint booth with the overhead conveyor. The automated storage and retrieval unit is equipped with powerful helical bevel geared motors for hoisting and driving. The telescopic jib that picks up the payload is extended by means of a light-weight, compact aluminum helical inline geared motor. Nord has implemented position control loops for the hoisting and driving axes. That is, type SK 545E frequency inverters simultaneously process absolute position data and the signal of an incremental motor encoder. They then autonomously adjust the position according to the set value specified by the automated storage and retrieval unit's PLC and report back the reached position to the PLC. The drive electronics control speed and gentle acceleration and braking (S ramps). In this application, Profinet interfaces were integrated for communication with the PLC.

For more information:
Nord Drivesystems
Phone: (608) 849-7300
www.nord.com

NKE

INTRODUCES SINGLE ROW CYLINDRICAL ROLLER BEARINGS

Bearing manufacturer NKE Austria GmbH presents its series of single row cylindrical roller bearings – a bearing type on which many customers in different industries rely. The salient feature of this series is the wide range of variants it comprises: more than 3,000 types are made to order in NKE's assembly plant in Steyr, Austria. In addition to being exceptionally flexible, the modular production facility enables very short lead times on all products. The applications of this type of bearing are as numerous as its variants: they are used in pumps and compressors, mechanical presses, electric motors, gearboxes, traction motors and axle bearings for railway vehicles, in steelworks and in many other industrial applications.

The bearings are available in 164 sizes in design variants NU, NJ and NUP. The bearing cages are available in roller-guided and outer ring-guided versions and are made from brass and polyamide, with pressed steel versions available, too. In addition to radial clearance group CN (C0) as standard, group C3 models are also available. Special versions, for example traction motor bearings (SQ1) and electrically insulated bearings (SQ77) are available at short lead times.

To maximize their lifespan cylindrical roller bearings are made from clean bearing steel. The superior surface finish of the raceways further helps reduce friction as well as lowering the operating temperature. The optimized geometries of raceways and rolling elements increase the loading capacity, while a modified cage design improves the formation of lubricant film. Thanks to the improved design of bearing guiding flanges of the NJ and NUP variants, the bearings can take up higher axial loads. Misalignments can be compensated through a modified contact geometry and crowned inner raceways. Tighter tolerances for the roller sorting ensure a uniform load distribution.

In addition to these numerous technical benefits, cylindrical roller bearings feature optimum operational reliability and maximum cost effectiveness. All NKE bearings are subject to stringent quality procedures and are tested using state-of-the-art procedures and equipment. The Steyr site is certified to ISO 9001:2000 (design, development, production and distribution of bearings) and ISO 14001. In recognition of the exceptional quality of NKE's products, the company was awarded the prestigious Austria Quality Seal last year.

For more information:

NKE Austria GmbH (Ritbearing)
Phone: (800) 431-1980
www.ritbearing.com

Lenze

INTRODUCES THREE-PHASE AC MOTOR FOR EFFICIENCY GAINS

Lenze Americas recently introduced the m550-P three-phase AC motor designed to achieve IE3 efficiency class in accordance with IEC60034-30 during Modex 2016. Compared with IE2 class motors, the new Lenze motor range reduces energy lost and cost by up to 20 percent.

"International energy directives have turned their focus to universal three-phase AC motors, with a number of countries even mandating minimum efficiency levels," said Joel Thomas, intralogistics industry manager, Lenze. "Bigger is not always better when it comes to efficiency. The m550-P motor delivers premium IE3 efficiency with minimal jumps in size when compared with IE2 efficiency motors."

Designed for demanding variable motion duty, the Lenze m550-P three-phase AC motor provides a power range of 1 to 60 hp (0.75 kW to 45 kW) with a variety of voltages for simple mains operation with fixed speeds. Optimized for use with frequency inverters, the m550-P motors pair seamlessly with high efficiency Lenze g500 gearboxes.

Lenze's m550-P four-pole motors feature an IP55-rated enclosure with an integrated fan and temperature monitoring. The new motor ranges are equipped with precisely coordinated electrical interfaces. Options for the m550-P motor include terminal box, HAN plug and ICN plug connections, in addition to brakes, encoders and blowers. Featuring the same axis height measurements as IE2 motors, both new motor ranges simplify the transition to IE3 efficiency and, in most cases, eliminate the need for construction changes. Available with certification from UL, CSA and CCC, and IE3 efficiency class, Lenze m550-P motors can be deployed virtually anywhere in the world.

"Customer investments in Lenze's economical drive technology show immediate returns in efficiency and energy savings—and can entirely pay for themselves within the first two years," said Thomas.

For more information:
Lenze Americas
Phone: (508) 278-9100
www.lenze.com

Zero-Max Shaft Locking Bushings

PROVIDE SOLUTIONS FOR STATIC LOCKING APPLICATIONS

Every setup operator's goal when preparing a tool setup is to load, locate, lock and operate the setup in seconds without problems. The challenges are basically the same whether setting up a machining center or power transmission system. A static application can have the same demands as dynamic. The setup steps for both must be simple – the fewer components, the better. And the locating and locking process must be very precise and equally repeatable so the system startup is flawless from the get-go.

Enter ETP Express Bushings, the clever setup and shaft locking device that is an ideal solution for both dynamic and static applications. It's no secret that a jig that facilitates tool and fixture changes saves time and money. The challenge is to find the right way to do it. The extremely simple, yet versatile ETP is adept at handling both dynamic and static applications while saving time, trouble and money in the process. In today's ever-changing manufacturing industries where more is demanded of less, reducing setup time at the front-end of a production job is the best place to start. ETP provides that front-end improvement.

The ETP is essentially a precision bushing that will accurately expand both the ID and OD at the same time when the single actuation screw is tightened. Since the expansion is caused by the self-contained hydraulic pressure, the resulting force is even along all surfaces. The bushing aligns precisely without axial movement as it is tightened. It positions very accurately in seconds.

Another key ETP feature is that it can be actuated thousands of times with repeatable accuracy and without any axial movement. An Allen wrench is all that is required to mount and lock these bushings into place. They have sealed, clean lines that resist debris collection and clean easily without any special maintenance.

ETP is available in several models to fit the application. The ETP Express and Techno models both feature a single actuation screw. The Express handles a torque range from 40 to 6400 ft. lbs. while the Techno handles a torque range from 28,000 to 32,000 ft. lbs. Sizes available handle 15 mm through 100 mm shafts with both operating well in temperature ranges from –22° to +180°F.

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

Ringfeder Power Transmission

FRICTION SPRINGS ABSORB SEISMIC SHOCKWAVES

Extensive experience in the field of damping technology is just one of the reasons Ringfeder Power Transmission can offer solutions when it comes to securing critical infrastructure projects. Friction springs made by Ringfeder are designed to absorb seismic shockwaves. Depending on the desired damping stroke and the forces likely to occur, the outer and inner precision rings made by the German manufacturer can be adjusted to one another. The springs are a maintenance-free solution, proved and tested in an earthquake, measuring at 6.5 on the Moment Magnitude Scale (MMS), thus making them suitable for use in power infrastructure facilities, ranging from high voltage switchgear to capacitor platforms.

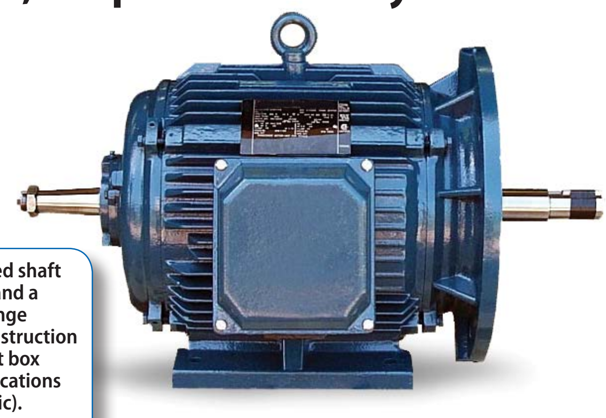
For more information:

Ringfeder Power Transmission
Phone: +(49) 6078-9385-0
www.ringfeder.com

Can You Develop Your Own Custom Motor-and-Motion System?

Some of the ins-and-outs, ups-and-downs, of special-needs systems.

Jack McGuinn, Senior Editor



This motor has a special tapered shaft on the back end of the motor and a stepped down shaft on the flange mounted side. All cast iron construction including the base and conduit box to be used in severe duty applications (Photo courtesy Leeson Electric).

In this century's complex, ever-changing world of manufacturing, such capabilities as hardware and software expertise, effective location and distribution, business savvy and yes, even luck, are some of the cardinal requirements for running a successful business.

But another stands out, in a sense encompassing them all: how best to spend precious time—especially in a product's time-to-market context—and company resources.

This last "maxim" applies with great certitude for a company or a business that is tasked with a blank-paper assignment of designing, developing and manufacturing a custom electric motor-and-motion system—either for its own in-house operational needs or those of an OEM or end-user. It is often said you get what you pay for—but you know that is not always true. Indeed—when it comes to custom ***anything***, the buyer should not only beware; he should run like hell if, for example, he senses that he is being over-sold a package that is far beyond or below what in fact he truly wants or requires.

If you are looking to manufacture or self-install a custom electric motor-and-motion system, you ***are*** going to pay more. Basically, there exist four major types of electric motors—DC, AC synchronous, AC single-phase induction and AC three-phase induction—and each one can be customized to suit a special requirement.

OEM making tile saws has the motor manufacturer add on-off switches and power cords so they do not need to do this assembly (Photo courtesy Baldor Electric).

But stop and ask yourself—what exactly does "custom" mean—beyond higher price? Is it primarily design-based? Hardware-based? Both? Is it truly "unique" in its design or execution? And what precipitates the need for a custom-designed system? Don Labriola (P.E.), president of QuickSilver Controls, Inc., a custom design motion and control shop that works closely with like-minded motor builders, explains.

"Sometimes a custom design is needed to design around other constraints in a system that are pre-established; sometimes they are not as firm as they first appear, given the *costs/risks* of having to go custom. Other times, a key feature that is required that may be added to an existing design via software; i.e.—if the vendor is willing to customize. We have had a significant number of design-ins via flexible software and the ability to quickly add features."

Time to market and lost opportunity are costs often overlooked by design engineers. An internal design may save unit cost, but may add significant design costs that must be spread out over the unit cost, and a schedule slip may cause the product to completely miss their market. So time, resources—and especially risk—must be managed. Underestimating the challenge of a full custom design can (needlessly) sink a project.

From there it gets a bit trickier.

George Holling, chief technical officer for Rocky Mountain Technologies, points out, for instance, that customization is often *not* application-driven, as might be typically assumed.

"A manufacturer may want to promote a new technology that they conceive may give them an edge, i.e. — less heat, more reliable, less cost, etc.," he says. "Or they may want to get around patents by using something different or they may simply want to develop a new supply chain or in-house manufacturing."

And Mark Baake, director of sales at Leeson Electric, says **"**There are times when motors also need to meet specific efficiencies, national or international specifications and/or compliance to standards. Generally, the application dictates the majority of the motor features — space, power, torque, etc."

Just for good measure, Jesse Henson, Baldor Electric Company (ABB Group) director of motor sales and product management informs that there are "custom motors" existing in name only — especially in the OEM markets.

"Custom motors are often specified when special performance, features or mounting are required by the OEM. Such a motor does not necessarily mean it is a custom motor, as many special- and definite-purpose motors are stocked by motor manufacturers. Certain product families were specifically designed for OEM custom applications, but have moved into a stock product to address the need for similar motors from multiple OEMs and MRO business."

Having determined what requirements differentiate "custom" from "in-house," companies with a "blank sheet" project in front of them then need to decide if they are capable of doing the job alone or if they need outside help. It's a big "if" — one that could prove costly if not dealt with wisely or if bad choices are made.

"A big item in any engineering project is picking which areas you can easily buy and which ones are your core competencies," says Labriola. "Your core competencies are those that differentiate you from your competitors, and that you are willing to staff with sufficient depth to avoid losing the competency if a single key player were to no longer be available.

"The second item with core competencies is that they should be developed prior to needing to use them. Designing parachutes after leaving the plane is to be avoided, as are developing key technologies underpinning a product while trying to keep to a tight schedule. A prior manager referred to this as trying to schedule breakthroughs. "

"This (optimizing in-house resources) is very true across many companies," says Baake, adding, "Resources over the years have been reduced and functions combined so you need to spend time on what is really needed."

Or, says Henson, "A custom motor could be optimized for the application in terms of performance, mounting, features and product life. For example, an OEM making tile saws has the motor manufacturer add on-off switches and power cords so they do not need to do this assembly in their plant. It is really about providing more value to the OEM."

Of course, given that 21st century motor/controller development requires a fair range of skills, e.g. — regulatory for emissions and safety circuit design; control algorithms; communications; HW/SW interfaces; test benches for testing; and hard real-time software — why would generalist-type shops even think they can build a custom motor on their own? Well, they usually don't.

"With global efficiency regulations, capital investments required, and registration, an OEM would find it difficult to build their own motors,' says Henson. "They would need to use very few models with extremely high volume to justify the massive investment. To add the design of adjustable speed drives on top of motors, it would take significant investments for start-up and a wide range of design and production engineers. If one looks at the companies making motors and drives, there has been much global consolidation over the last decade and not too many new start-ups."

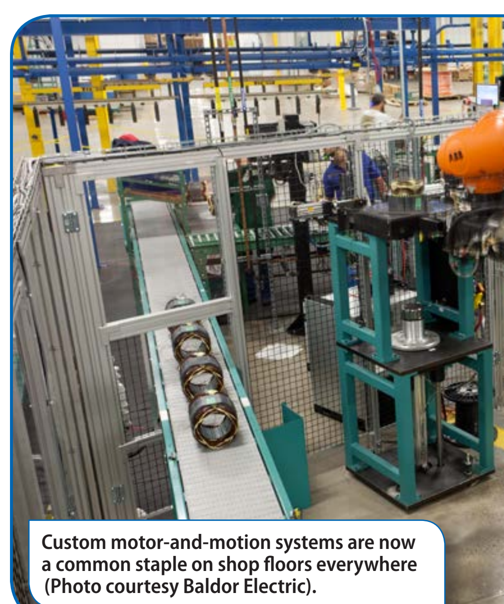
Indeed, Holling declares: "The good old days of trial and error are gone. (Our company) uses $50-$100k design tools, but some designers still simply scale and come up with sub-optimal solutions at best (too much cost), or designs that do not perform and then we often get involved. Vendors, especially in the chip industry, make it sound so simple to build a controller. The problem is they use PhDs (I have one of those — so I can say this) to design 'sample drives' that may work on a bench under very confined conditions. But some of those will not hold up in an industrial environment. A few succeed and many will give up."

"A well designed system looks simple," Labriola allows. "Component count makes it look like a "quick engineering project" could save on the total cost. The reality is that many man-years are invested in the algorithms and code. High-frequency, high-power circuitry in proximity to logic-level DSPs requires very careful design, with intuition gleaned from many iterations and sometimes significant experimentation. Simple, open loop steppers are fairly easy to implement; jumping into higher power, higher speeds, and well behaved motions is not the small step it may appear.

One wonders about scenarios where a shop has overestimated its skill, underestimated the degree of difficulty to complete the motor project, and had to bring in outside help to get things back on track. It happens more often than one might think — and even then there can still be problems if an unwise choice of an outside consultant has been made.

"Quite a few (occurrences) come to mind," says Holling. "Two recent cases where customers used outside consultants; in one case the consultant was an electronic trying to use a uP to switch a power device and things kept blowing up. They did not have the expertise or the equipment to analyze the failure. We successfully redesigned the controller and they are in production now (three years later). In another case the motor was a magnet graveyard (lack of magnetic design expertise or tools) with no torque, and that project is ongoing."

"Fortunately, (for us), yes!" says Labriola regarding customer fires that need quick extinguishing. "I have also seen others that got about 60% of the way there and then stalled and never made it. I usually quote that the first 90% of the project takes 90% of the time, and the next 10% of the project takes 90% of the time, thus projects are often late. Again, fortunately, we have


Custom motor-and-motion systems are now a common staple on shop floors everywhere (Photo courtesy Baldor Electric).

had a lot of shops that have started with our product for a prototype and just decided to keep it for the final design." Adds Baake, "We do see it occasionally and as long as the shop is a customer we help to provide them what is needed because in the end their customer is also ours."

Looking at it from a strictly OEM's perspective, Henson explains that "Most motor and drive manufacturers have previously supplied systems for the same or similar applications and have knowledge of what works and what doesn't. If it is new, the OEM should select a supplier with problem-solving engineering resources.

"Today many OEMs look at the entire power drive system consisting of motor, drive, mechanical power transmission devices (gearboxes, pulleys, etc.), as well as using the best practice for the driven load. There are only a few companies that can supply the complete package and service it in the end."

Earlier on we alluded to "unique" as a quality inherent in custom manufacture. Define unique as it pertains to custom motors and motion systems, you say? Let's let our experts handle that.

Cautions Holling: "Unique means there is only *one*, so most likely it will probably be a lie. But there would be some features that would single a motor out: a special magnetic design — i.e. transverse flux; a configuration with significantly reduced PM material; a special pole/slot/winding configuration; or special components such as soft magnetic composites, very high-temperature materials, etc.

Labriola adds that "We worked with our motor vendor to add a slot to a stator that enabled us to add a sensor coil strip that turned the motor into its own resolver (we call the combination a Mosolver). The PWM drive serves as the excitation and the rotor and stator as the magnetics. We are applying this to a couple of different motor types."

It is Baake's sense that "Many times the unique features are developed based on the 'voice of customer.' Unique features could be special shafts, bearings, machined or cast flanges or feet, but could also include special rotor/stator assemblies to develop custom power characteristics of the motor so it starts/operates as needed for a specific application."

As for Baldor's Henson, "Unique could be in terms of specialized mounting and shafts designed to be part of the OEM equipment. Motor performance, speed, torque and duty cycle can also be uniquely designed for the specific application.

"An example of this could be a totally enclosed air-over motor designed for a direct-drive, fan-on-shaft, HVAC application that is also cooled by the air over the motor as it drives the fan. In such an application lower starting torques are allowed and the OEM will want to minimize the use of active material in the motor. Testing of temperature rise and thermal protection performance on the application may take a few weeks."

So let us say the customer has reconsidered and has decided to call for "back-up" — enter the custom system consultant/supplier. (*FYI, the four companies included in this article are all hands-on producers and suppliers — not merely consultancies.*) What next? Does the customer typically know what they want and need, even if they *really* don't know how to build it?

"The customer generally has a benchmark design in mind," says Leeson's Baake. "But upon reviewing the specifications and asking additional questions in order to provide value-added benefit, motor designs or features can change significantly."

From Rocky Mountain Technologies' Holling's way of looking at it, there are the, shall we say less-than-informed customers and those customers that actually do their homework—which of course leads to choosing a custom house supplier.

"In many cases, (clients) just use a buzzword (e.g., brushless) because that is what everyone else uses. There is a lot of 'inertia' in the motion industry. Some of the more sophisticated customers will actually do an analysis of their needs and make a conscious technology choice that includes performance, price and marketing. These customers will also be the ones that will most rely on outside experts."

But in Labrilola's experience, it's mostly complex, application-driven—and about the customer knowing where to go for help. "Most of the customers I have worked with come from the application need side; e.g.—size, weight, torque and power. And even more commonly, what protocols does the controller support, ability to handle an application space (i.e., a winder that needed electronic gearing with seven places behind the decimal point in the gearing to cause the different self-supporting, bobbin winding configurations needed by their customers).

Again addressing a larger-scale manufacturing (OEM) base, Henson says "(Baldor customers) usually know the input voltage, speed, horsepower, enclosure and mounting needed. Technology selection is often pretty advanced to deviate from an AC induction motor. A special reason would be discussed."

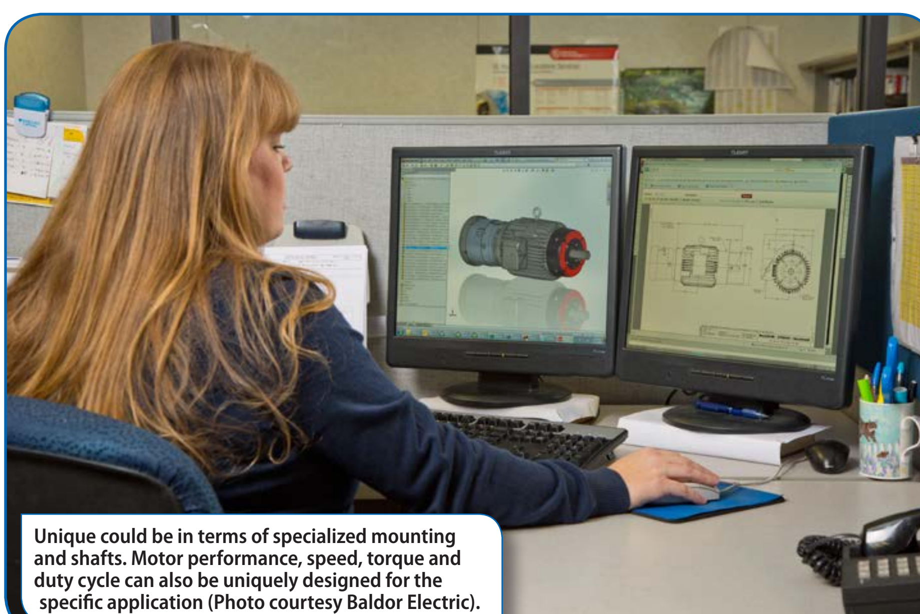
With all the parameters to be addressed and choices to be made, is there one most difficult type of custom motor system to design, build and deliver? Of course there is; and the difficulty presents in different ways.

"Time killers are those projects that really do not know what they need," Labriola says. "This shows up in motor power changing by a factor of up to 30 over the course of the project. If the package size or other requirements get set before the motion needs have been determined, it can put the whole project in peril."

Henson believes that "Some requirements from customers go outside the scope of a motor manufacturer's standard designs. When this occurs it's important to select the right motor manufacturer that can support the customer's designs with strong engineering expertise and flexible manufacturing capabilities."

Leeson's Baacke provides two examples:

"Two types of applications come to mind. First is a vibratory application which has high shock loads to the motor frame bolts and bearings. Second is a centrifuge application; in this application the motor may decide to begin rotating 380 seconds after the power is applied to the motor. Therefore, long



Unique could be in terms of specialized mounting and shafts. Motor performance, speed, torque and duty cycle can also be uniquely designed for the specific application (Photo courtesy Baldor Electric).

start-up/acceleration times, and large load inertias to move/rotate the motor (are required).

Holling points out that while "Industrial is typically easy, (it) may require very quick turnaround. (While) appliance has a focus on cost and automotive has impossible specs at no cost. Military is often the most difficult, but at least cost is a secondary issue. The new motor design needed to meet high torque requirements, yet maintain low running amps to allow for use in household applications. The motor also required a unique metric mounting flange."

Given how manufacturing economic reports are all over the map (literally) these days, a final question begged asking — Is it a good time to be in the custom motor-and-motion industry today?

"We currently enjoy a nice mix," says Labriola. "Some DoD, some medical, multiple smaller OEMs; keeps one area going down from being a disaster."

But at Rocky Mountain Technologies, "Right now is probably not a great time," Holling says. "Our consulting business is doing well (not saying we turn down orders but we are probably upper price end) so we are probably siding towards a recession. DoD is the toughest place — very hard to make money. We have a sister company that does all of our government business. If we tried DoD in a commercial company we would go broke on government contracts.

"Large OEMs are easier to work with but harder to sign up than smaller ones that are typically higher maintenance and have often unrealistic budget expectation but they will find the funds required if they are in a bind and then they want everything done overnight, which is not always possible as everything takes time."

Meanwhile, at Leeson, "The motor business as a whole is a strong market," Baake enthuses. "The sweet spot would be Distribution, Integrators, Assemblers, OEM's and end-users. Large motors can quickly support a business once they have been spec'd in (qualified) at the OEM or end user. This helps gain more of a foothold into the business and opens the doors for other motor sales that are not easily obtained." **PTE**

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Closer to the Sun

Maxon Precision Motors

The Solar Orbiter will change its trajectory and swing by Earth and Venus to reduce its distance from the sun to only 45 million kilometers. Temperatures rise up to 520 °C under the ceaseless pounding by solar radiation. All other sides are surrounded by the eternal cold of outer space making for an incredibly challenging environment (photo credit 2016 ESA – C. Carreau).

Without the sun, there would be no Earth and no life. However, our knowledge about our home star is still very limited. This is about to change. In 2018, the European Space Agency (ESA) will send its Solar Orbiter into space, equipped with a thick heat shield.

It is a cautious approach. Step by step, the Solar Orbiter will change its trajectory and swing by Earth and Venus to reduce its distance from the sun to only 45 million kilometers. No other human-made object was ever this close. The way back to Earth would be three times as long.

Not a pleasant place for the Solar Orbiter: At the front, temperatures rise up to 520°C under the ceaseless pounding by solar radiation. All other sides are surrounded by the eternal cold of outer space. This combination makes for an incredibly challenging environment.

The secret of solar eruptions

Solar Orbiter is a joint project of the ESA and NASA. It is going to be an important milestone in the exploration of the sun. Even though the sun is responsible for the development of the planets in our solar system, and even though it influences the weather as well as life in general, we know far too little about it. For example, what causes the solar winds? Or solar eruptions? What forces are behind the formation of the heliosphere, the cloud of charged particles that extends past the outer reaches of our solar system?

It is going to take a while until scientists will have answers to these questions. In 2018, an American rocket will take the probe into space. It will travel for three years until it can begin its work. Solar Orbiter is going to provide a new perspective of the sun, its surface and the polar caps. For this purpose it is equipped with around a dozen cameras and measuring instruments. Some of these systems and subsystems are being developed and built in Lausanne, Switzerland. The company Almatech (*Editor's Note: see sidebar page 25*) is involved in the development of STIX, an X-ray telescope for the observation of solar eruptions. It is expected to provide new insights into the acceleration of electrons and their projection into the depths of outer space.

Sunglasses for instruments

Just like people should not look directly at the sun, measuring instruments also need protection. After all, the intensity of the radiation on board the Solar Orbiter is 13 times higher than on Earth. The primary means of protection is a state-of-the-art heat shield that remains directed at the sun at all times. A few holes can be opened for measurements. However, the instruments need to be protected too. In the case of STIX, this is provided by permanent beryllium protective filters and the use of an aluminium grid during solar eruptions. This grid can be placed in front of the 32 X-Ray detectors by means of two Maxon RE 13 motors. The brushed DC motors are wired in parallel, enabling them to be used together or individually. This ensures a service life of ten years – the planned duration of the mission.

The Solar Orbiter's heat shield has apertures that briefly let the instruments look at the sun (2016 ESA).

At Almatech, four engineers are continuously working on the detector system, which is called STIX-DEM. "It's a challenge to develop a device that has never been built before and to test it to prove that it is going to function reliably," said Fabrice Rottmeier, senior project manager. "At the same time, it's a great experience and very motivating to be part of a scientific research program that investigates questions about the origin of the universe and the origin of life."

Lightweight drives as an advantage

Weight is a critical factor for space projects. Maxon motors come into their own here. Rottmeier: "With Maxon drives we were able to build a shield that weighs less than 200 grams and survives vibrations without problems." The renowned reliability and high quality of Maxon motors were another selection criterion. He adds: "The support from their engineers is very flexible and all around great." **PTE**

For more information:

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Almatech
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Maxon's RE DC brushed motors are well-suited for space applications. The ironless winding and the high-quality magnet provide an efficiency well above 90 percent. The drive was customized for the Solar Orbiter project with special lubrication and cables (2016 Almatech).

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Company Spotlight: Almatech

Almatech is a Swiss private SME located in the Technology Parc (PSE) of the Swiss Federal Institute of Technology (EPFL). It was founded by a team of engineers. The company has experienced steady growth since its creation and offers fully integrated, project-oriented services, from the technical requirements to the delivery of hardware. Core competencies are project management, products assurance management, analysis and structure, design, manufacturing and assembly. Almatech has very strong knowhow in the design, analysis, manufacture, assembly and test of structures for space applications. Thanks to the long experience of its engineering team and to its efficient project-oriented organization, Almatech is able to propose three types of services:

Research & Development

Skills and equipment required for R&D project are very specific to the field of research and may change from one project to another. Therefore, Almatech works in close collaboration with EPFL and other research laboratories, and is a member of EPFL Space Center. Thanks to its location and the background of its engineering team, Almatech has privileged contacts with these institutions, and has access to Class 100 clean rooms. Almatech offers a global and multidisciplinary complete service, including: technical review, patent search, test planification, execution and analysis, pre- and post-test analysis, model correlation with test data and more.

Flight Hardware

Flight hardware structures are lightweight and highly reliable structures that are exposed to harsh environments. Several design iteration are often necessary to fulfill all requirements. Almatech provides an integrated service that includes 3D computer-aided design of complex assembly using *Catia*, elaboration of manufacturing plan, selection and follow up of highly specialized and competent sub-contractors, product assurance activities, validation by numerical simulations, including quasi-static, dynamic, modal and coupled thermo-mechanical calculations using *MSC. Nastran,* integration and assembly of the different parts and performance of acceptance and qualification tests.

Test Equipment

Almatech offers its clients a high-quality and innovative service. Almatech was selected in 2009 to complete the fabrication, assembly and integration of the Bepi Colombo Laser Altimeter Receiver Baffle Unit (ESA program). This project includes the FEM verification of the whole structure and its validation/qualification through dynamic tests. The validation by testing of flight hardware specific features or behavior often requires the development of ad hoc test equipment, e.g. a microgravity simulator or apparatus for application of qualification loads. Almatech offers the following services including the design of mechanical test equipment for flight hardware, cleanliness and contamination control, hazard analysis, structural verification by numerical simulation and tests and the manufacturing and assembly of the test equipment. For more information, visit *www.almatech.ch.* **PTE**

Analyzing the Poultry Process

Bearing Application and Production Considerations

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

We build relationships

Reception

The receiving operation is a largely automated process in most poultry plants. After being removed from cages, a conveyor is used to transport the birds to the live hang area. The broilers are hung on an overhead chain conveyor which is powered by a low speed offset parallel gear motor. This chain conveyor conveys the broiler through the initial stages of the poultry process. Bearing applications include non-washdown mounted ball and roller bearings. This application is subjected to shock loads which require rugged cast iron construction pillow block and four bolt flanged bearings. Corrosion resistant bearings are usually not required at this stage of the process.

Crate Washer

Corrosion resistant bearings should be considered here including the use of stainless steel where applicable.

Water Bath

Each bird is exposed to an electrical charge and conveyed to the slaughter area. The circular blade used for slaughter is powered by an electric or hydraulic washdown duty motor. Washdown or corrosion resistant bearings or stainless steel should be considered here. These bearings are subjected to high ambient temperatures and humidity and heavy chemical washdown cycles. Housing end covers and high performance synthetic grease are recommended.

Scalding Tank

Birds are scalded by immersion in a scald tank for 1.5 to 3.5 minutes. Scalding facilitates feather removal. After scalding, the birds are conveyed quickly to the de-feathering process. For this process mounted roller bearings, tapered or spherical bearings should be considered. Using a specialty lubricant may also want to be considered.

Picker

A key maintenance area where stainless steel raidal ball bearings work well with specialty lubricants replacing standard lubrication practices. Some bearing manufacturers are stocking replacement units for this application. Some poultry producers run this application to failure.

Cutting Processes

Correction resistant housings with stainless steel inserts are recommended and end caps are always important to safety in the head and trachea removal process.

Hoch Cutter

Very mechanized automated European equipment utilized to open up the bird. Bearing applications include stainless steel radial ball bearings ranging in sizes from 6202 to 6207. Specialty lubricants should be considered to replace standard greases in bearings. Consider the fact that there is a certain amount of "detergent creep" caused by the extreme temperature changes.

The receiving operation is a largely automated process where non-washdown mounted ball and roller bearings can be utilized.

The use of stainless steel radial ball bearings ranging in sizes from 6201 to 6205 can be utilized for the vent remover in the poultry process.

Vent Remover

This unit is used to remove the ventrical out of the bird. Bearing applications include the use of stainless steel radial ball bearings ranging in sizes from 6201 to 6205 sealed.

Eviscerator

This unit removes the viscera from the bird and the viscera is typically hanging outside the bird for inspection. Bearing applications are typically inch and metric radial ball bearings, a strong consideration may want to be given to stainless steel. This may be recognized as a high maintenance area suggesting the use of top quality bearing products.

Screw Chiller

This unit cools the bird following the Eviscerator process. Bearing applications include roller bearings for screw shaft support.

Giblet Chiller

Application is used to retrieve all saleable internal parts. Standard ball bearing housed units are utilized and corrosion resistant housings may want to be considered.

Breast Cap Cutter/Whole Wing Cutter

These machines are not considered to be high maintenance equipment. Stainless steel radial ball bearings are

Corrosion resistant bearings should be considered for the live bird crate washer.

Poultry Process Area & Solutions Matrix									
Plant Areas	Unmounted Ball & Roller Bearings	Mounted Ball & Roller Bearings	Corrosion Resistant Mounted Bearings	Corrosion Resistant Ball & Roller Bearings	Solid Lubrication	Seals	Automatic Lubricators	Alignment Tools	Condition Monitoring
Receiving									
Slaughter									
Scalding									
De-Feathering									
Evisceration									
Chilling									
Cutting									
Further Processing									
Packaging/Freezing									
Auxilary Equipment									
Pallet Jacks									

recommended for this area. These applications offer an opportunity to supply linear bearings. Stainless steel motors may want to considered.

Inside/Outside Bird Washer

Standard radial ball bearings in all areas; possibly consider stainless steel radial ball bearings in certain areas of the application. There is a high volume of water in this application. May want to consider a special grease that could be used in a very wet environment.

Extended Maintenance Intervals for Bearings in Chilled Poultry Conveyor

Hubs with deep groove ball bearings operated in a chilled (–15°C) environment. Due to frequent wash-downs and breathing in bearings during shut down, water ingress occurred shortening the service life. Sealed stainless-steel deep groove ball with food graded solid-oil (2RS1/W64F). Bearing life extended from one year to more two years maintenance-free operation. **PTE**

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Guide to Selecting and Replacing Synchronous Belts

Taylor Jung, Product Line Manager, Synchronous Drives, Gates Corporation

Just as we now consider rotary dial phones archaic, so are many installed synchronous belt drives. That they continue to operate is testimony to their durability. But that should not prevent you from taking advantage of newer synchronous belt drive technology that can improve both equipment design and field installations.

Synchronous belt technology has taken a quantum leap forward since the invention of the timing belt in the 1940s. Synchronous belts now rival roller chain, gears, and other forms of power transmission in almost any application. Research into new compounds, additives, blending processes, jackets, tensile cord materials, and tooth profiles yields further advances every day, resulting in belt drives that pack more power into an ever smaller space.

This article will review some basics about synchronous belt drives and highlight some of the technological advancements that might make you rethink that new drive design or replacement drive.

Belt Replacement

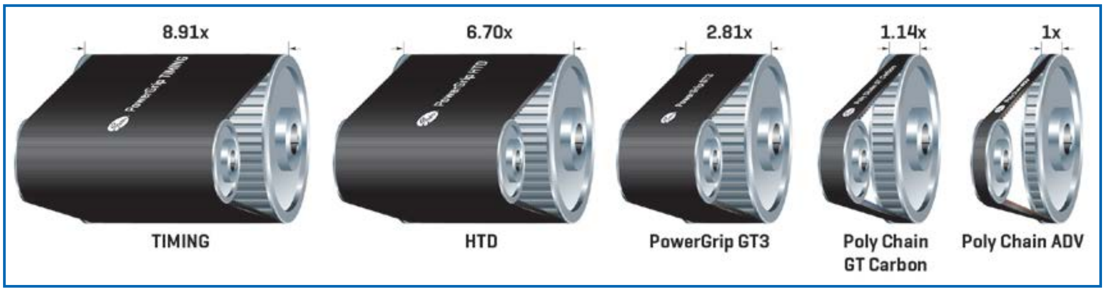
When replacing a synchronous belt on an existing drive, there's a natural tendency to simply swap out the belt for an identical new one. That could be a mistake for two reasons. The first is that belt wear might be the result of worn sprockets. A good rule of thumb is to replace sprockets after every third replacement belt has reached its maximum service life, or sooner if the sprockets show significant wear. Worn sprockets reduce belt life considerably.

However, there's a second and more compelling reason not just to swap out an old belt for a new one. Take a close look at the drive and the equipment on which it's installed. If you are running a traditional timing belt, for example, you have a range of other synchronous belt design options open to you. (See the image above and compare the size of the timing belt on the left to the latest synchronous drive on the right, which can outperform the timing belt.)

Decades ago it took wide belts and sprockets to handle load-carrying applications. The belt/sprocket width and weight of these drives, when attached to a speed reducer, often contributed to exceeding the specs for overhung load, placing a strain on bearings. Frequent bearing replacement and associated maintenance costs were the result.

Today's narrower, lighter synchronous drives can not only handle greater loads, but they also allow the sprockets to be placed on the shaft closer to the bearings, which reduces overhung load and extends bearing life.

What are some of the technological advancements that allow today's synchronous belt drives to become ever smaller and more powerful?



Each of the drives pictured has the same performance capabilities. The drive on the far right, however, uses the latest technology to greatly reduce size and weight.

Tooth Profiles

The first synchronous belts were designed with trapezoidal shaped teeth. The term "timing belt" is often applied to this tooth profile because it is used primarily for synchronizing, or timing, the movement between two shafts. Technological advancements in tooth design led to the curvilinear and modified curvilinear tooth profiles, each of which increased the load-carrying capacity of synchronous belts.

Today's modified curvilinear tooth profiles ensure smooth, quiet operation and precise registration for high precision positioning applications and high capacity power transmission drives.

Modified Curvilinear

Curvilinear

Timing

Belt Construction (Body Compounds and Jacketing Material)

Synchronous belts with the same tooth profile perform differently depending on their construction and who manufactures them. Engineering and design processes used to combine body compounds, jackets and tensile cord can vary greatly. Designers and users should be mindful of a belt's

performance characteristics before specifying or replacing a belt on a piece of equipment.

Tensile Cord

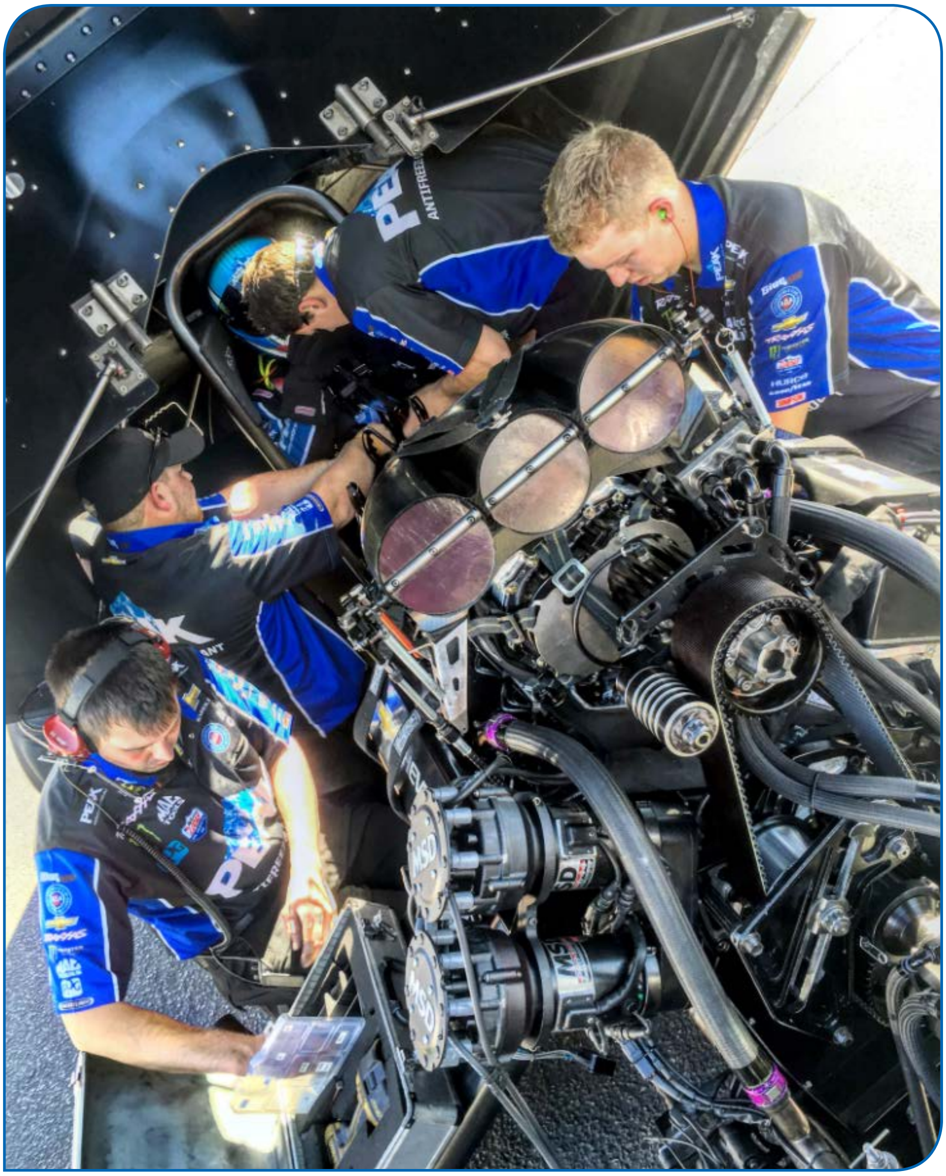
The tensile cord is the muscle of a synchronous belt, bearing most of the load for transmitting power. Steel was the first material used for tensile cords, replaced by fiberglass and aramid fibers, which offered additional strength and heat resistance. Today's newest, high-end belts use carbon fiber tensile cords, which offer the following characteristics and advantages:

- High power density for more compact drive designs
- High flex fatigue resistance
- High modulus (pitch stays constant regardless of load)
- High strength-to-weight ratio
- Superior environmental resistance (no degradation from water, oil and most contaminants)

Sprockets

Sprockets are a highly engineered component of synchronous belt drive designs. It takes both belt and sprockets working together in harmony to deliver a high performance belt drive system.

Considering that sprockets may operate at rim speeds up to 6,500 feet per minute and transmit loads as high as 1,200 hp, sprocket design and analysis is a critical component of drive performance and safety.



The blower on John Force's record-setting NHRA Funny Car is powered by a synchronous belt drive that helps the 8,000-horsepower dragster exceed 300 miles-per-hour in less than 4 seconds.

Application Criteria

Synchronous belt drives are well suited for applications with the following demands:

- Synchronizing power transmission between shafts
- High mechanical drive efficiency
- Compact drive layout
- Low maintenance
- Energy savings
- Clean running (no contamination from lubrication)
- High torque at both low and high speeds

Conclusion

When it comes time to replace a synchronous belt on an old drive, or design a new drive, stop a moment and consider the benefits of upgrading to the latest synchronous belt and sprocket technology. Today's narrower drive profiles offer high load-carrying capacity in a compact space while saving wear and tear on connected components. **PTE**

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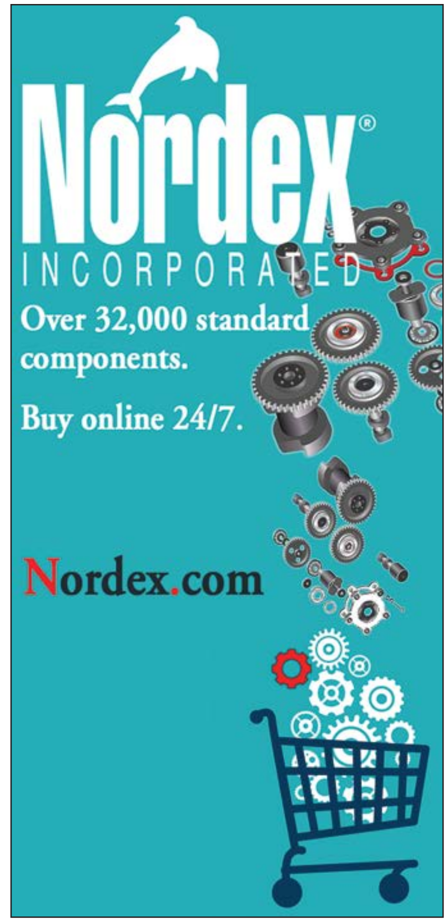

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Proper Bearing Installation

Certified Bearing Specialist (CBS) Takes on Expensive Fan Application

Gregory (Keith) Boutwell, CBS and executive account manager at B&D Technologies (a division of B&D Industrial), explains how he used his bearings expertise to save a customer thousands of dollars through correct bearing installation.

"A customer had a zone fan application with $2,000 worth of bearings being replaced every 4–6 weeks. I went to their location and looked at the application with a manufacturer's representative. The manufacturer representatives' solution was to change the grease as the bearing was running too hot. The customer had four of these fans and the investment in failures was adding up. The customer was pretty adamant that something was not being done right as he was sure that they were not getting that many bearing failures from the manufacturer.

I got the customer a price on grease and asked that when he replaced the next bearing to let me know so I could watch the installation. As I observed the maintenance man change out the bearing, I noticed that he took the stab ring and tossed it into his toolbox. I asked him about not using the stab ring and his answer was that it serves no purpose. He told me the stab ring was included just to take up space in the housing. I told him it indeed was for taking up space but it also would limit the expansion on his bearing, therefore giving him a fixed and floating bearing.

I asked him to install this one with the ring and we'd document the installation. We documented the installation and reported it to the maintenance manager. The maintenance man was insistent that adding the spacer ring would not make any difference in the operation of the bearing nor would it be the reason that the bearing was heating up. We took the old bearings to the shop and he broke it open and showed me a bearing housing full of sludge and dry matter that at one time was grease before being cooked out with the heat that was being produced. I also suggested that he install covers on the side of the bearing that was open to the elements. Fine particles of carbon black were present in all parts of the bearing.

I kept close tabs on the bearings that had been changed and asked about them about every other trip to the customer's plant. I was always told by the maintenance manager that they had not had any problems since I had gone over with them about how to correctly install the bearings. I was also given the chance to solve other bearing problems that they have been having. This cut into the sale of the bearings to this customer and I increased my sales of grease. But in end I developed the reputation of being a problem solver. And this brought many more opportunities.

As a result of the success I had in solving this customers problem I was able to gain his confidence and he allowed me and my supplier partners to perform training on lubrication, proper installation and preventative maintenance tips. The end result that I was hoping for has been achieved. I have gained confidence in the work I have done not only by the maintenance management but by the maintenance personnel. The maintenance man that was so adamant that I was incorrect has become a long time friend and he will call on me and present me with other problems that he has in the plant.

Even though I have been in the bearing and power transmission market for a long time, I have found out that training and refresher courses on everything from type of bearings to lubrication to causes of failures will always be beneficial. The Certified Bearing Specialist certification was an eye opener in that it encourages you to use catalogs and to find the answers to problems. Sometimes if you do not look at a problem head on and try to widen your base of knowledge you become complacent in what you are doing. The CBS program keeps you on your toes and helps to broaden your horizons by giving you an additional resource. **PTE**

Certified Bearing Specialist

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

For more information:

Bearing Specialists Association (BSA)
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Gregory (Keith) Boutwell has been in the bearing and power transmission business for 41 years. He has spent his entire career in the Columbus Georgia location of B&D Technologies. "No matter how long I am in this business I will always learn something new every day."

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Bringing Nadcap to the Medical Industry

MedAccred stands to plug a longstanding hole in medical industry standards, and it's growing in popularity.

Alex Cannella, News Editor

The medical device industry today has numerous standards and regulations to follow, most notable amongst them being ISO 9001 and ISO 13485. However, these requirements have a shared blind spot: critical processes (heat treating, sterilization, etc.). In the medical industry, all of the standards and audits suppliers need to adhere to focus on general system quality. If the critical processes aren't being looked at equipment can still fail because of poor craftsmanship.

"When you look at what the general auditing profile requirements have been in the industry, they have mostly focused on doing quality management system audits," Ravi Nabar, head of supplier quality assurance at Philips, said. "What those audits don't necessarily do, is actually probe deeply into the technical aspects of critical manufacturing processes that affect the quality of the product that's coming off of those manufacturing lines."

Matters are compounded by the fact that every OEM is responsible for auditing their suppliers, and there are so many different companies running audits that the regulation process can start getting in the way of production. Some suppliers do audits on such a regular basis that they have a team of staff whose sole job is to handle them.

"Right now, we can have several quality system audits from different medical facilities in any given month," Ed Engelhard, vice president of corporate quality at Solar Atmospheres, said. "They all cover the same exact ground. It's usually ISO 13485 or 9001 based. We're already registered to 9001, although we're not 13485. But the focus seems to be whatever the pet concern for that organization is, and we have to devote valuable resources to proving over and over again that we are essentially in compliance with requirements. And that's on top of already having a 9001 registration."

The situation is complicated and less than ideal for OEMs, as well. The medical device industry has seen a shift towards globalization and has numerous small suppliers applying their trade in the market. While OEMs can vet their first tier suppliers, it's much harder, if not impossible, for them to ensure the same level of quality is being maintained all the way down the supply line to third or fourth tier suppliers.

"We're in a place where there's a lot of outsourcing going on," Nabar said. "There's a lot of globalization, and yet the quality of what we actually put in the hands of our patients and customers is critical to the health of the public."

So the medical device industry's quality control infrastructure starts to look a bit like the wild west, with a hundred different sheriffs running around making sure their particular OEM's rules are upheld and their concerns handled, while some facets of the industry aren't scrutinized quite as closely as they should be. It's clear that some form of unifying requirements could go a long way towards minimizing these problems.

The answer that the industry is slowly starting to coalesce around is MedAccred, an accreditation for the medical industry designed to deal with this exact dilemma. Where other industry standards look at general quality across the entire facility, MedAccred zeroes in on very specific processes (e.g. heat treatment, sterilization, welding) and brings in experts in those fields to make sure suppliers know exactly what they're doing. The people behind MedAccred aren't looking to replace current standards such as ISO 9001, but instead, the program will exist alongside and further strengthn them, filling in the blind spots they don't reach. In fact, the regular quality systems requirements are a pre-requisite for accreditation from MedAccred. The comparison most used was that quality management systems audits are a mile wide, but only an inch deep on individual critical processes. MedAccred, on the other hand, is an inch wide, covering only one critical process per audit, but goes a mile deep into every nuance of that critical process.

MedAccred is being administered by the Performance Review Institute, the same not for profit trade association that administers Nadcap, the widely recognized accreditation that does for the aerospace industry what PRI wants to do with MedAccred, and does it well. The organization's almost three decades of experience with Nadcap has assisted in the process of developing MedAccred faster than its predecessor.

"The industry standards are not as developed for critical processes in the medical device industry as they are in the aerospace industry," Joe Pinto, executive vice president and COO of PRI, said. "So we learn from Nadcap that we need to focus on industry standards as well as look at the OEM-specific requirements, and that's what we're trying to do in the medical device industry. Trying to find process-specific experts from the industry, from the OEMs, as well as suppliers, who come together to write the audit criteria."

MedAccred is, effectively, an attempt to take the best practices and processes of Nadcap and translate them over to a new industry, and as such, the two programs bear many similarities. Both programs utilize audits performed by subject matter experts who are rigorously selected by industry representatives. Both use management councils composed of OEMs and suppliers alike to guide requirements and major decisions, with PRI acting as the administrator. The checklists for achieving accreditation are also similar. In fact, Nadcap's checklist was used as the starting point for some of MedAccred's own requirements.

"Nadcap has a lot of audit criteria, what the aerospace industry terms checklists, already developed," Pinto said. "So there was a very good base, and those audit criteria are intellectual properties owned by PRI. We were able to use a lot of those as the starting point for the medical device industry. And what we've done is taken those, and we have adopted them and added process validation requirements based on FDA guidelines to develop the medical device audit criteria."

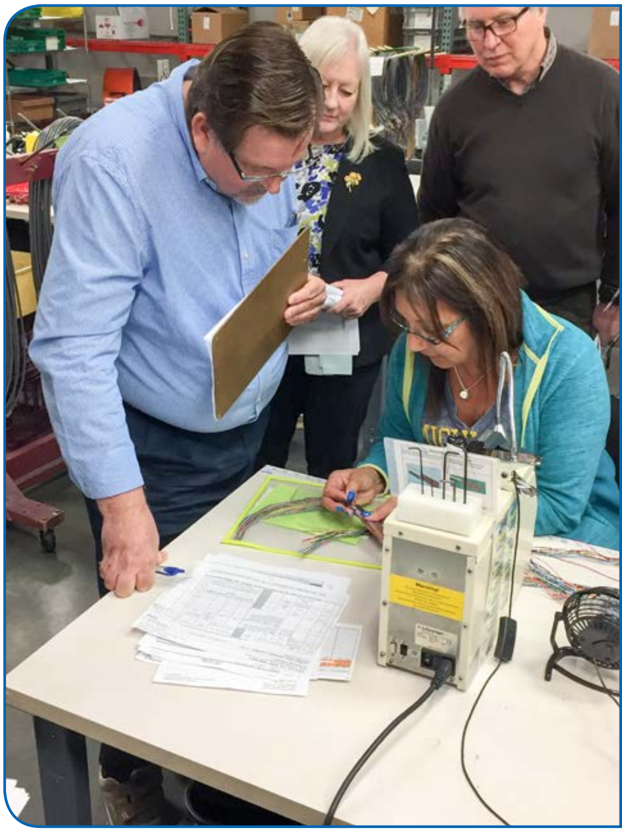
No matter which side of the OEM/supplier fence you fall on, there are multiple benefits to jumping onto the MedAccred bandwagon. For OEMs, the obvious benefit is an increase in the quality of parts they receive, but it also allows for improved supply chain oversight and compliance. MedAccred not only does an aligned set of requirements make it easier for OEMs to see the quality of their suppliers and their suppliers' suppliers, but is also a global program with audits scheduled across the world, meaning that an OEM wouldn't have to send an auditor halfway around the world to do business with a small supplier in China.

"Many times the OEMs do not always get to see and do not get to audit the critical process suppliers that are maybe in the third, fourth or fifth tier of the supply chain," Pinto said. "So, by having a program like MedAccred, they can mandate that 'anybody that is supplyig these critical processes for my products needs to be accredited,' so even if they don't know who's doing it because it's happening at the third, fourth tier level, they would have assurance that it is being done by an accredited supplier who has proven to have the capability to do the process."

"For us as an OEM, to have all the visibility down to the different tiers, along with aligned requirements and expectations all the way down, that's a very difficult thing, and MedAccred is fantastic for that," Scott Goolsbey, supplier controls manager at Stryker, said.

Suppliers also have plenty to gain from aligning expectations with MedAccred. With a consistent set of expectations, suppliers know exactly which set of standards they need to meet, and less time will have to be spent on redundant audits from different customers. As the program grows and more OEMs continue to join, more people will be looking for suppliers accredited to MedAccred, and some businesses are adopting early in the hopes of taking advantage of OEMs' growing interest.

Getting involved in the program can



give further benefits as well, mainly ensuring that your company's voice gets heard and can shape MedAccred's requirements. This is doubly true now, in the program's formative years, when there are still details to be ironed out. Both OEMs and suppliers are being welcomed by PRI to come together in MedAccred's Management Council and technical Task Groups.

For suppliers, the other way to get involved is obviously through getting audited for accreditation. If you're interested in an audit, the process is fairly straightforward. Once in contact with MedAccred, a supplier details their products and figures out what categories they should be applying for. Right now, your options are cable and wire harness, heat treatment, plastics, printed circuit board assembly, sterilization and welding. Once a supplier knows what category they should apply for, an audit is scheduled, and the supplier is given a copy of the audit criteria. It's strongly stressed by both PRI and Engelhard, whose company was the first in the world to achieve accreditation with MedAccred, and thus has experience with the audit process, that you prepare with an internal audit to make sure you meet all requirements before the actual audit.

"If you think you can have an auditor walk in without preparation, it's going to be a very long, difficult week for you," Engelhard said.

The audit process itself takes two to five days to complete, depending on the critical process and the scope of the facilities being audited. Once the auditor has inspected everything, they send their findings on to a PRI staff engineer, who approves the findings and analyzes if the supplier has completed the work to close them. The OEMs then review all the information and vote on the accreditation.

MedAccred is still a young program. The first roundtable meeting to develop it was held in December of 2012, and the first accreditation was awarded last spring to Solar Atmospheres. It'll be a long time before the program carries the same clout as Nadcap.

But despite its age and size, MedAccred's message is getting across and the program is gaining momentum. The program should complete more than 20 audits this year, and Pinto says they're aiming to do 200–300 audits a year as soon as 2019. PRI is also planning on expanding the accreditation to include more categories, such as one for batteries, as time goes on.

At the end of the day, however, the main reason MedAccred is speaking to some people is a purely humanitarian one: the betterment of patients through more reliable, potentially life-saving equipment.

"The medical field faces a lot of unique challenges that we can't necessarily address in MedAccred, but one of them should not be failures at the patient-doctor interface associated with the processes we do," Engelhard said. "That can't be allowed to happen. So to the degree that we can make a doctor's visit mundane and boring by controlling our processes, we should endeavor to do that. And that's why people should be involved in MedAccred." **PTE**

For more information:

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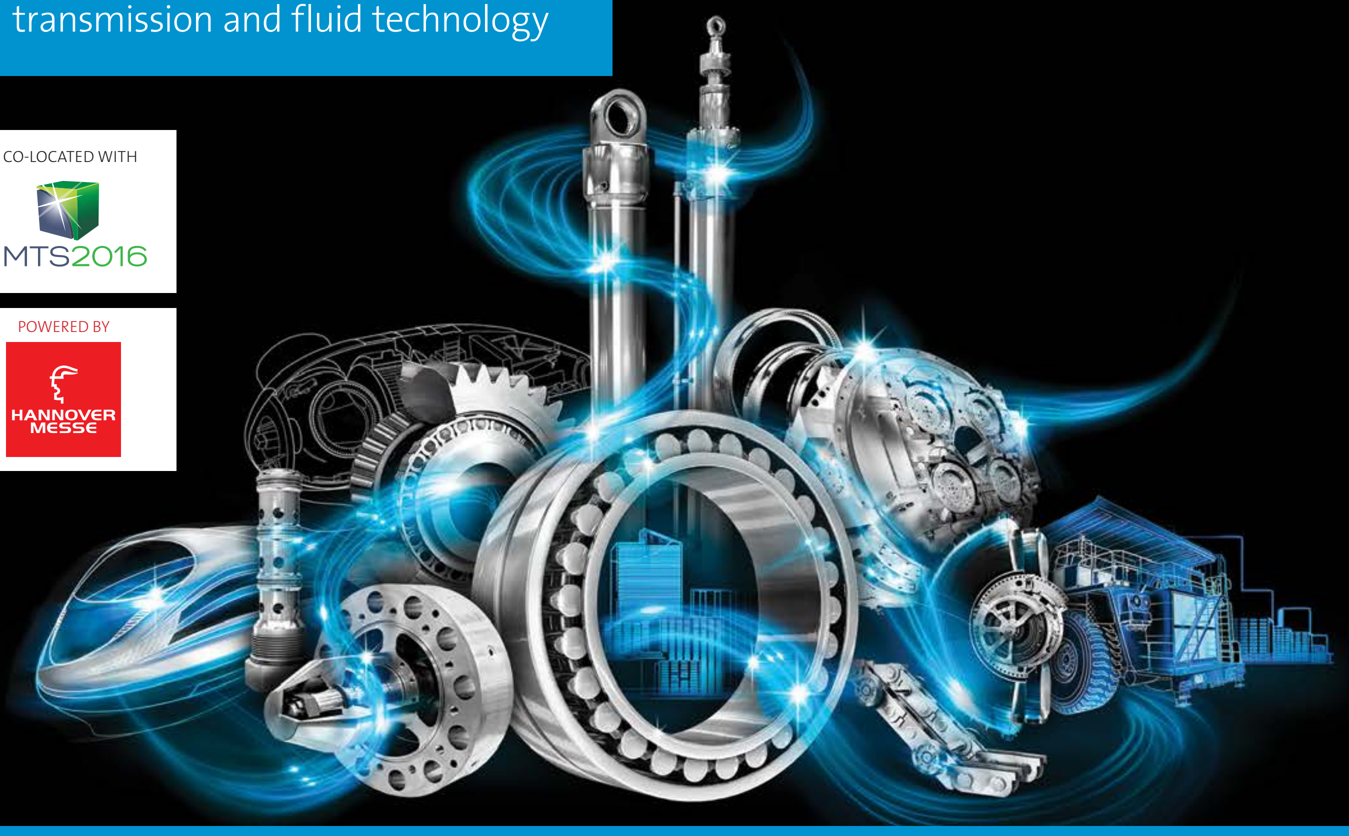

High Gear Ratio Epicyclic Drives

THE QUESTION

Referencing a June 2014 Article, "High Gear Ratio Epicyclic Drives Analysis," by Dr. Alex Kapelevich:

I have designed a small compound epicyclic gearbox with common planets.

Sun = 10 teeth

Planet = 14 teeth

Ring Gear stationary = 38 teeth

Ring gear output = 41 teeth profile shifted onto a 38 tooth pitch diameter.

Carriers are simply cages for the planet alignment and location.

According to your article, and according to my calculations and the prototype I have built, my input-to-output ratio is a reduction of 65.6:1. I am using a ~ VG1 viscosity grease and Nylatron materials for the gears and carriers.

I am driving the system with a small DC motor that is driven by 120 VAC with a full bridge rectifier. Max no-load motor speed of 18,000 ± 10%. Current at stall is 2.56 A, and output torque at stall is 1.82 in-lbs.

Ok. So that is all good. Now, since I am reducing output motor speed by 65.6:1, I should also get a torque increase of 65.6:1. Thus my output torque for the rotating 41T ring gear should be 119.392 in-lbs (in a perfect world). Assuming losses in the system, this number will of course be lower.

However, I am not getting even close to that output torque level. More like 40–45 in-lbs — I cannot figure it out. I have reduced sliding friction as much as possible (I am not using rolling bearings however). I have improved gear tooth surface finish as much as possible (50–100 RMS likely).

Any direction would be appreciated. Or even directed to a person who could help would be great!

I am testing output torque by using a dual compression spring assembly. I connect my output to one side of a large fine thread bolt. When I energize my motor my output begins to screw down the bolt, which then engages with the spring assembly until it eventually stalls the motor. I then use a digital torque wrench to measure how much torque I need to further tighten the bolt, as well as loosen the bolt.

I have used this "torque tester" method on other parallel axis systems and the results are as I expect and calculate — at least that's to say they are approximately in the range of what I calculate for the expected output torque.

Expert Answer Provided by Dr. Alex Kapelevich:

In this case, the low gear efficiency does not have much to do with the gear tooth surface finish. A reason for low gear drive efficiency (33–38%) is the Nylatron planet cage.

In the article you reference I wrote:

"In differential-planetary arrangements, tangent forces applied to the planet gear teeth from the stationary and rotating ring gears are unbalanced, as they lie on different parallel planes and have opposite directions. A *sturdy planet cage is required* to avoid severe planet gear mesh misalignment."

The Nylatron planet cage is not sturdy enough to avoid planet gear mesh misalignment; it creates an angular tooth contact and increases friction. It could be aggravated if the planet cage is not supported on its own bearings (or bushings) and is wobbling. This results in low efficiency. I would suggest considering the machined aluminum cage supported by the ball bearings. The gaps between the planet gears and their steel pins should be minimized as much as possible.

Besides, plastic gears have naturally lower efficiency because of increased tooth deflections under the load in comparison to metal gears. However, the 60–70% efficiency should be achieved with plastic gears.

Please contact me with more questions.

Best regards,
Alex Kapelevich

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Alternative to Ni-Bearing Carburizing Steels

Mathilde Millot-Méheux and Thomas Sourmail

Standard carburizing steel 18CrNiMo7-6 is often used when high hardenability is required, but due to its highly fluctuating price, there has always been an incentive to develop Ni-free steel grades. The 23MnCrMo5-5-2—or Jomasco 23mod—has been developed for this purpose. But to ensure smooth substitution within existing production lines, a number of points must be addressed: first, checking the response to carburizing treatments; and second, having similar mechanical properties with identical tooth root bending performance on gears. The latter is the purpose of this paper.

Introduction

The mechanical industry uses large carburized parts, made out of the 18CrNiMo7-6 steel grade. Their carburizing depth can reach several millimeters and requires long heat treatment before the finishing operations of the hard surface. The deformations that can occur during this process should be minimized to ensure the best use. The choice between several steel alloys dedicated to these uses is also oriented by the carburizing response, especially concerning the stability of austenite grain size and the resistance to intergranular oxidation. The length of this manufacturing process raises interests in cost reduction sources.

In the automotive industry the 18CrNiMo7-6 is used to make some gearbox parts for commercial vehicles and also differential gear parts. This area is well known as being a leader in cost saving.

The replacement of this Ni steel must meet the two following requirements: 1) the new alloy must exhibit similar response to the carburizing treatment and 2) also to similar mechanical properties.

The 23MnCrMo5-5-2 has been developed (Ref. 1) in this context. The comparison with the 18CrNiMo7-6 (named as reference grade in the following) in terms of carburizing depth, retained austenite content, austenite grain stability and intergranular oxidation depth and mechanical properties has been previously published (Ref. 2). The chemical composition of both grades is illustrated in Table 1. The authors have demonstrated in (Ref. 2) that the 23MnCrMo5-5-2 can replace the reference grade without any modification of the carburizing process for moderate conventional carburizing depths (lower than 2.5 mm).

The results suggest that to reach high conventional carburizing depth, the carburizing time could in some cases be reduced by 10%.

This work focuses on the FZG tests that were performed to assess the comparison between the reference grade and the 23MnCrMo5-5-2 on carburized gears.

Gear Manufacturing

Gear geometry. Two gear geometries were used; their characteristics are shown in Table 2. Three separate sets of gears were made. Their manufacture consisted of hobbing, carburizing and hardening with carburizing processes. The first set of gears (with module 5, Gear 1), was tested as carburized. Surface strengthening was performed after the carburizing treatment for two sets of gears with module 10 (geometry Gear 2). A series has been mechanically cleaned; the other has been submitted to shot peening.

Since the actual tooth root geometry has a strong influence on the load/tooth-root- stress conversion factors, one tooth with two neighbor flanks of each test series was scanned, and the effective geometrical data of the analyzed gears were determined. Figure 1 shows the scan of the actual gear geometry of the module 5 gears with the corresponding geometrical data. Figure 2 shows the scan of both the module 10 gears series as well as the theoretical geometry. It can be observed that, due to the grinding process, an undercut can be seen near the 30° tangent of the tooth root fillet of both shot peened gears. This undercut will certainly increase the tooth root stress. In interaction with the residual stresses due to the performed shot peening after the grinding process, the negative effect of the undercut should be reduced. The interaction of both effects (undercut and shot peening) cannot be

Table 1 Chemical composition in wt% of reference 18CrNiMo7-6 and designed 23MnCrMo5-5-2 grade, as obtained using optical emission spectrometry and LECO analysis for carbon content (*)

Steel grade	C*	Si	Mn	Ni	Cr	Mo
18CrNiMo7-6	0.18	0.21	0.52	1.55	1.67	0.30
23MnCrMo5-5-2	0.21	0.26	1.35	0.24	1.28	0.23

Table 2 Gear data for bending tests

Parameter	Symbol	Gear 1	Gear 2	Unit
Normal module	mn	5	10	mm
Number of teeth	z	24	24	-
Pressure angle	α	20	20	°
Helix angle	β	0	0	°
Face width	b	30	30	mm
Add. Mod. Factor	x	2.43	4.15	mm
Tip diameter	d_a	134	268	mm

This paper was originally presented at the 2014 International Gear Conference, Lyon Villeurbanne, France and is republished here with the authors' permission.

calculated exactly according to the current state of the art. An estimation of the influence of the undercut is proposed later on. For both grades the measured geometry as well as the undercut is comparable.

Residual stress evaluation. X-ray diffraction allows the assessment of the difference between the three series of gears. X-rays are produced by a tube with a chromium anode; displacement of the alpha {211} peak is studied.

After 25 μm etching the residual stresses were evaluated for one gear of each type; the uncertainty is evaluated to ± 40 MPa. Both grades have similar levels of residual stresses; results are shown in Table 3. As carburized, the surface exhibits compressive residual stresses of roughly 200 MPa. After the mechanical cleaning process, the level of compressive residual stresses has been doubled compared with the as-carburized state and multiplied by a factor 4 to reach –850 MPa on the shot peened gears.

Metallurgical characterization. All fatigue tests were done by FZG in Munich. Both hardness measurements and microstructure investigations were performed after the tooth bending tests on a tooth failed by tooth root breakage. Figure 3 locates the measurement of the carburizing depth in the tooth root fillet.

Retained austenite content has been evaluated in CREAS (Colloquium on the Resolution of Equations in Algebraic Structures) using X-ray diffraction on a cut tooth. Therefore a diffractometer with a chromium anode tube was used. The intensity of the three gamma peaks — 111, 200 and 220 — and the alpha peaks 110 and 200 — were used.

In Tables 4–6 the main results of the metallurgical features are summarized and shown for both grades, respectively — i.e., for the non-peened module 5 gears, the mechanically cleaned module10 gears, and the shot peened module 10 gears.

According to (Ref. 4), the recommended carburizing depth (550HV, or referred to hereafter as "Eht") in order to avoid tooth root bending rupture should be in the range 0.1* mn and 0.2* mn.

For the non-peened gears, both microstructure and hardness profiles correspond to the state-of-the-art of case carburized gears; only small differences were found. Those were a slightly higher Eht and higher core hardness for the 23MnCrMo5-5-2 in comparison to the reference grade; also, the Eht of the 23MnCrMo5-5-2 slightly exceeded the recommended range (0.24*mn).

The mechanically cleaned gears are similar in terms of metallurgical features. Furthermore, the Eht respects the recommendations of (Ref. 4) with 0.13* mn.

Due to the undercut in the tooth root fillet of the shot peened gears, the Eht is lowered in comparison to the Eht after heat treatment. However, all Eht are within the limits, according to the recommendation of (Ref. 4), 0.13* mn.

Test Method

The gear teeth were clamped symmetrically and tested over four teeth between two jaws. The type of device used for the three gearsets is shown (Fig. 4). The load direction was tangential to the base circle. Flank angle deviations were compensated by means of a precision adjustment so that a uniform load distribution across the whole face width could be assumed. The test gear was friction-locked between both jaws, therefore a preload was needed. This preload is indicated in Table 7 for the three test rigs used.

The pulsating load was calculated as the difference between the maximum load and the minimum lorad ($F_{Pn} = \Delta F = F_{P\,max} - F_{Pmin}$). The ratio R between the maximum and the minimum

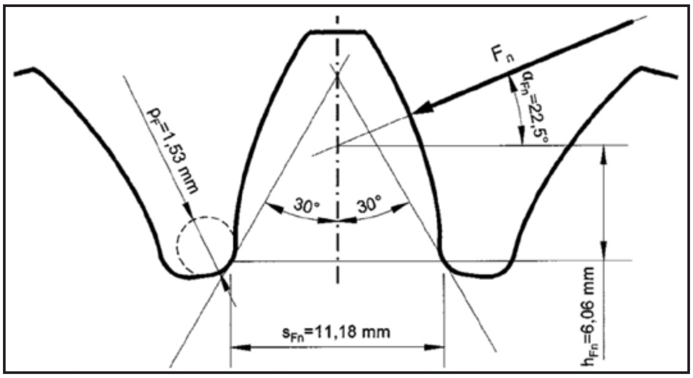


Figure 1 Evaluation of actual geometry and of the main geometrical data of module 5 gears.

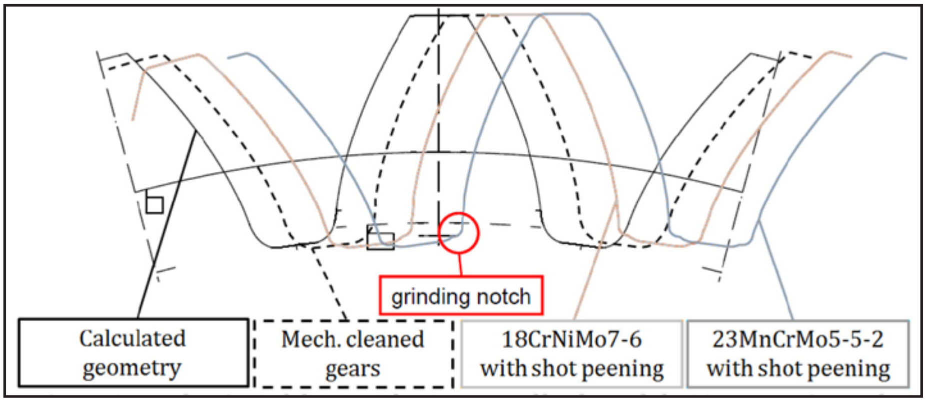


Figure 2 Evaluation of actual geometry of both module 10 gear series and comparison with calculated geometry.

Table 3 Residual stresses evaluated using X-ray diffraction after 25 µm etching

Steel grade	Unpeened	Mechanically cleaned	Shot-peened
18CrNiMo7-6	- 200 MPa	- 380 MPa	- 868 MPa
23MnCrMo5-5-2	- 162 MPa	- 456 MPa	- 834 MPa

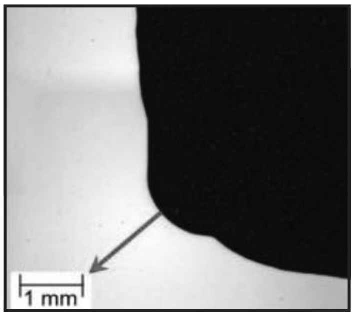


Figure 3 Schematic direction of measurement of CHD in tooth root fillet.

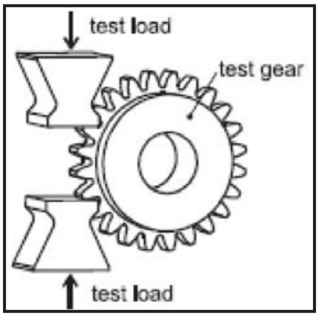


Figure 4 Clamping of test gear for bending test.

load ($R=F_{P/min}/F_{Pmax}$) was 0.1. The pulsating load characteristic was sinusoidal; each frequency used with each test rig is given in Table 7. An influence of the frequency on the test results has not been detected.

The endurance level was determined following the "staircase method," with 5 to 12 data-points-per-batch. The fatigue limit is assumed to be the fatigue strength at 6.106 cycles for 50% failure probability.

The endurance strength in bending is calculated according to the method explained in (Ref. 4).

Table 4 Metallurgical features of non-peened gears

Grade		18CrNiMo7-6	23MnCrMo5-5-2
Surface Hardness (HV1)	Flank	698	704
	Tooth root fillet	736	728
Eht 550 (mm)	Flank	1.13	1.28
	Tooth root fillet	0.96	1.22
Core hardness (HV1)		449	474
Intergranular oxidation (p.m)		10–12	12–14
Surface microstructure		Martensite and retained austenite	
Core microstructure		Martensite and bainite	
Retained austenite (%)		31	37

Table 5 Metallurgical features of mechanically cleaned gears

Grade		18CrNiMo7-6	23MnCrMo5-5-2
Surface Hardness (HV1)	Flank	663	664
	Tooth root fillet	669	677
Eht 550 (mm)	Flank	1.25	1.36
	Tooth root fillet	1.33	1.35
Core hardness (HV1)		419	404
Intergranular oxidation (m)		12–14	7–12
Surface microstructure		Martensite and retained austenite	
Core microstructure		Martensite and bainite	

Table 6 Metallurgical features of shot peened gears

Grade		18CrNiMo7-6	23MnCrMo5-5-2
Surface Hardness (HV1)	Flank	712	720
	Tooth root fillet	768	656
Eht 550 (mm)	Flank	1.78	1.76
	Tooth root fillet	1.49	1.37
Core hardness (HV1)		404	380
Intergranular oxidation (p.m)		15–19	17–32
Surface microstructure		Martensite and retained austenite	
Core microstructure		Martensite and bainite	Bainite
Retained austenite (%)		27	21

Table 7 Test conditions according to each device

Type of gear	Unpeened	Mechanical cleaned shot peened	shot peened
Type of pulsating rig	Hydraulic	Electro-magnetic	Mechanical
Underload	4 kN	7.5 to 10 kN	10 kN
Load step	1.5 to 3 kN	5 to 10 kN	10 kN
Tested teeth	12	5 to 7	7
Frequency	40 Hz	115 Hz	35 Hz

Test Results and Discussion

Gears, as carburized, and gears carburized and mechanically cleaned. Figures 5 and 6 show the nominal bending stress number that was determined for both materials on the basis of the nominal tooth root bending stress for endurance limit with a 50% failure probability for two states — as-carburized and carburized — and mechanically cleaned. On the basis of this parameter gears can be allocated in a defined quality range called ML, MQ and ME, and shown on both charts.

The 18CrNiMo7-6 gears and the 23MnCrMo5-5-2 tested in the as-carburized state show similar nominal bending stress numbers. The ML quality range is reached. When they are compared to previous data obtained by FZG, both grades show slightly better performances. These results are in good agreement with (Ref. 4). The following indication is given: "Values of MQ bending stress were achieved with adequate industrial cleaning techniques applied and therefore cannot necessarily be achieved after heat treatment alone." The results obtained for the gears that have been carburized and mechanically cleaned illustrate this citation nicely. Both the reference and the 23MnCrMo5-5-2 reach the MQ quality level. Once again, both grade performances are similar.

Test results on shot peened gears. For the carburized shot peened gears the tooth root stress is calculated first without considering the stress increase due to the undercut. The nominal bending stress number obtained for the 18CrNiMo7-6 is 474 N/mm², whereas it is evaluated to 485 N/mm² for the 23MnCrMo5-5-2. As the defect in the tooth root fillet was similar for both grades, the results can be directly compared. Once again, the gears made out of the 23MnCrMo5-5-2 have similar performances to the gears made out of the 18CrNiMo7-6.

The undercut certainly increases the real tooth root stress introduced during testing. Estimating the decreasing effect of the undercut according to (Ref. 5), the negative effect should be within a range of 10 to 20% in comparison with a non-grinded shot peened tooth root fillet. Using a finite element simulation (*Forge 2011* software), we have tried to evaluate this difference more precisely.

The Von Mises equivalent stress was evaluated using a 2-D model of the perfect theoretical gear geometry (elastic behavior). The mesh was refined in the tooth root region; the same calculation was done using the geometry with the undercut. The Von Mises equivalent stresses obtained for each geometry are compared according to the crack direction observed on gears after fatigue tests. It is illustrated in Figure 7 in grey for the standard geometry, and in white for the tooth root, including the defect. The evolution of the Von Mises equivalent stresses in both cases was plotted (Fig. 8). We con-

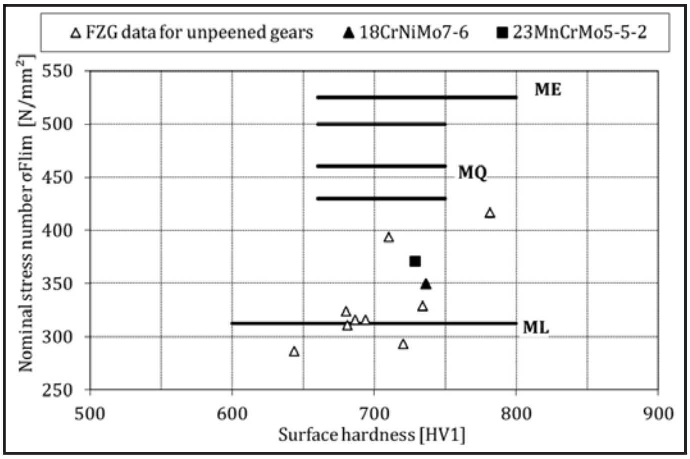


Figure 5 Comparison of nominal stress number obtained on un-peened gears made of 18CrNiMo7-6 and 23MncrMo5-5-2 with FZG data on similar samples and ISO6336-5 quality levels.

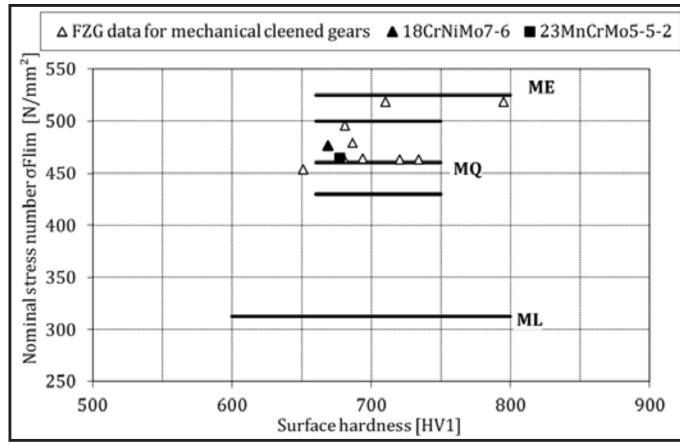


Figure 6 Comparison of nominal stress number obtained on mechanically cleaned gears made of 18CrNiMo7-6 and 23MnCrMo5-5-2 with FZG data on similar samples and ISO6336-5 quality levels.

sidered that the correct stress evolution begins above 250 μm from the surface. Using polynomial fit of these curves, the equivalent stress at the surface has been evaluated. An equivalent stress of 645 Mpa is estimated for the standard geometry. The undercut leads to an increase to 749 MPa. Supposing that the ratio of these equivalent stresses is identical to the ratio of the bending stresses, the undercut stresses are 16% greater than the standard geometry.

Figure 9 shows (white symbols) the results calculated by FZG without considering the geometry defect. A rise of 10% is shown by the lowest black symbols, a rise of 16% leads to the highest black symbols showing that the ME quality level could be reached by a carburized, shot peened gear made out of either 18CrNiMo7-6 or 23MnCrMo5-5-2 — with the correct geometry.

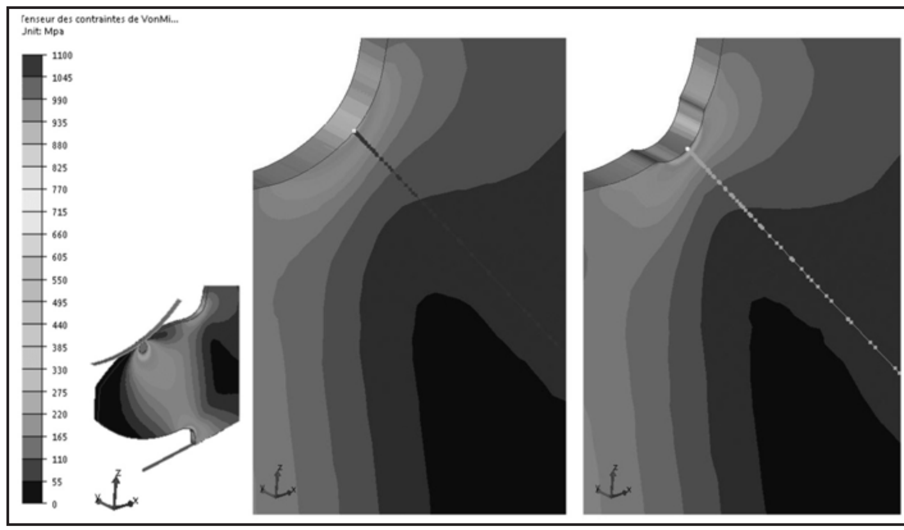


Figure 7 Von Mises stresses evaluated by FE method on gear with undercut (right image) and reference gear (left) submitted to same load.

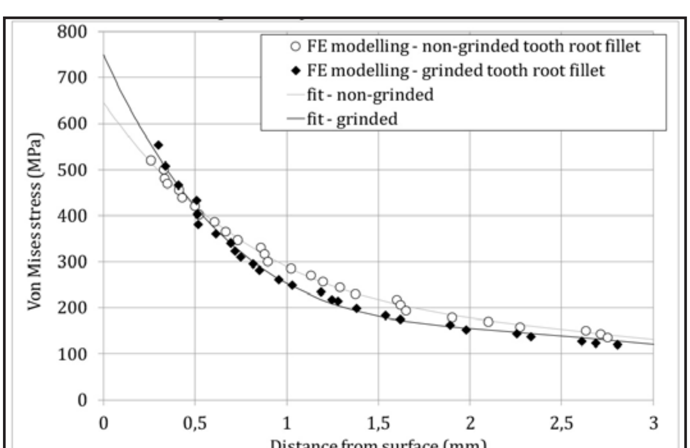


Figure 8 Evolution of Von Mises equivalent stress for standard geometry and grinded geometry.

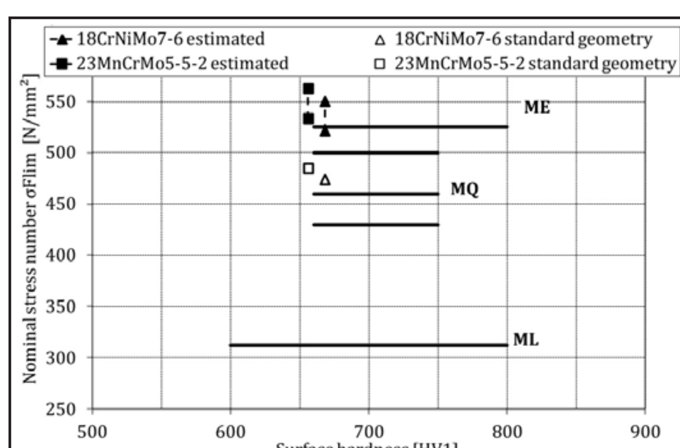


Figure 9 Comparison of nominal stress number obtained on shot peened gears made of 18CrNiMo7-6 and 23MncrMo5-5-2 with FZG data on similar samples and ISO6336-5 quality levels.

Conclusions

Thanks to an appropriate alloying choice, the 23MnCrMo5-5-2 is cheaper than the 18CrNiMo7-6.

The comparison with the 18CrNiMo7-6 (named as reference grade in the following) in terms of carburizing depth, retained austenite content, austenite grain stability and intergranular oxidation depth and mechanical properties has been previously published (Refs. 2–3). The Ni-free grade 23MnCrMo5-5-2 is virtually identical to the 18CrNiMo7-6 in terms of hardenability and mechanical properties in reference conditions. It was also shown that the reference grade can be replaced by the 23MncrMo5-5-2 without any adjustment to the carburizing parameters.

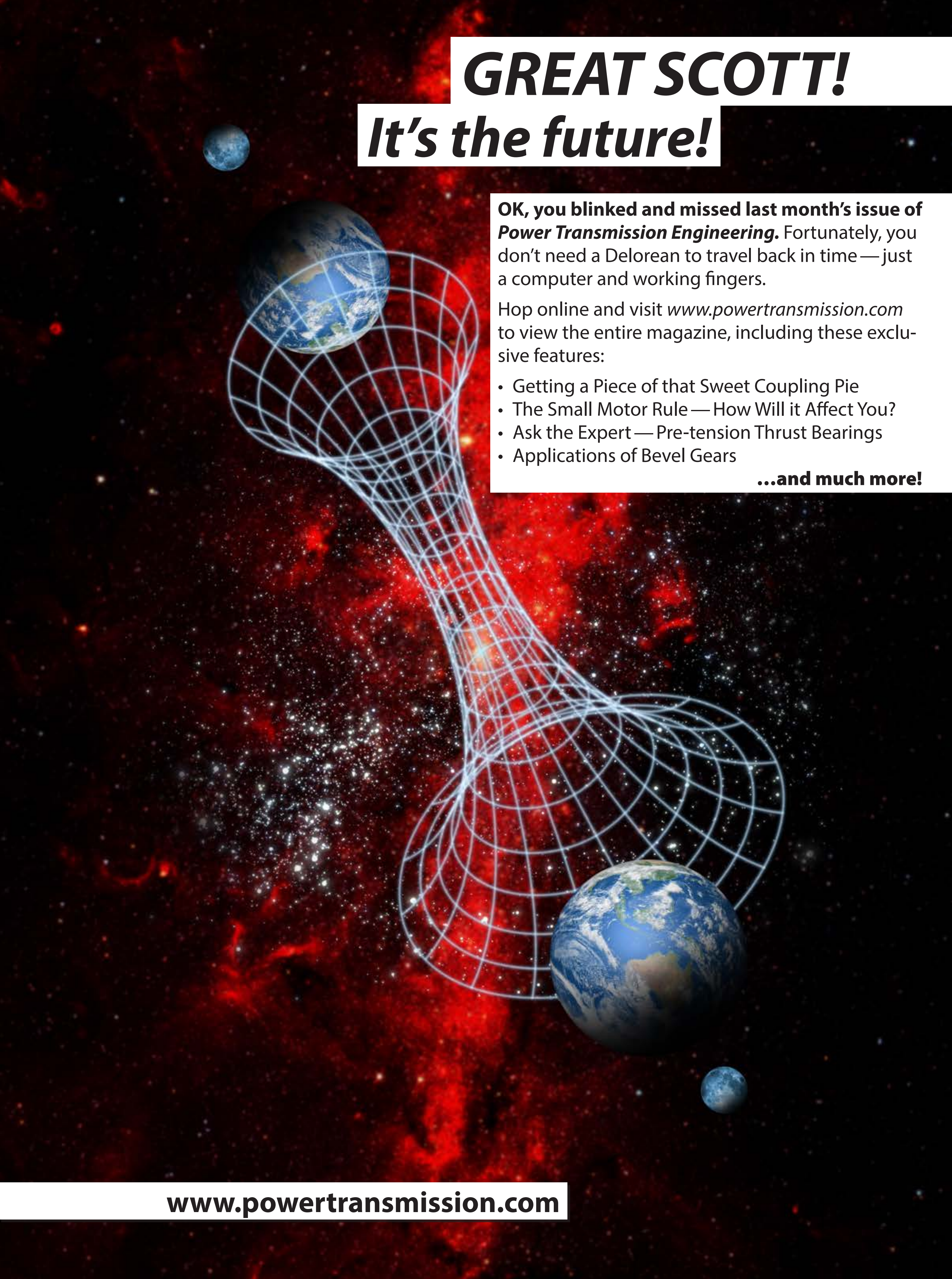
Three sets of gears were tested by FZG. Both grades were carburized in the same batch of heat treatment. X-ray diffraction measurements were performed to evaluate the residual stresses. The first set of gears was tested as-carburized. Both grades reached the ML quality level defined in (Ref. 4), with similar results. The second set experienced a mechanical cleaning after the carburizing treatment. These gears reached the MQ level of quality, once again with similar performances for both grades. Shot peening was performed on the third set, post-carburizing. Those gears achieved the ME level with similar results for the gears made out of 23MnCrMo5-5-2 and those made out of 18CrNiMo7-6. So, in addition to previously published work, the FZG test results that are detailed here demonstrate that the 23MnCrMo5-5-2 can replace the 18CrNiMo7-6 with no change in performance. **PTE**

References

1. Pichard, C. et al. "Process for Manufacturing of Articles from Carburized or Carbonitrided Steels and Steel for Manufacturing of Said Articles," EP 0 890 653 B1.
2. Frotey, M. et al. "Alternative to Ni Bearing Steels for Deep-Carburized Wind Turbine Gears," *Conference for Wind Power Drives*, Aachen, March 2013.
3. Sourmail, T. et al. "Alternative to Ni-bearing Carburizing Steels and New Grades for High-Temperature Carburizing," *Proceedings of SCT 2014*, Braunschweig.
4. ISO 6336. Calculation of Load Capacity of Spur and Helical Gears – Parts 1 to 5, June 1996/2003.
5. Niemann, G. and H. Winter. *Maschinelemente*, Band 2, 2, Auflage, Springer Verlag, Berlin.

Upon graduation (M. Engineering) in 2005 from INSA Lyon, **Mathilde Millot-Meheux** subsequently was awarded her PhD from Ecole Centrale de Lyon and INSA Lyon in 2009 — based upon the study of the influence of lubricant additives on tribofilm formation, friction coefficient and rolling contact fatigue life of rolling bearings. In that same year she began work as a research engineer in the Service Properties and Machinability research group at the R&D center of the French steel manufacturer Asco Industries. In that role Millot-Meheux's primary responsibility is the development of rolling bearing steels and gear steels.

Thomas Sourmail in 2006 was named manager of the Metallurgy research group for the Asco Industries R&D Center, located in the east of France. From 2002–2005, he worked as a research assistant at Cambridge, focusing on precipitation modeling in various systems, e.g. — FeCo, and super-alloys; from 2005–2006 he served as Project Leader for a group devoted to work on primarily ferritic materials. In his current managerial role, Sourmail oversees new product development for the various markets in the Asco Industries portfolio, including steels for the automotive and off-road industries — forging steels, carburizing steels, bearing steels, etc. — and also for O&G-type applications. Sourmail has been published in more than 40 peer-reviewed publications and journals and is the holder of a number of active patents.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Acoustic Analysis of Electric Motors in Noisy Industrial Environment

Maciej Orman and Cajetan T. Pinto

This paper presents a method for the acoustic analysis of electric motors in noisy industrial environments. Acoustic signals were measured via acoustic camera 48-microphone array, which has the capability to localize a sound (or sounds) source and, in turn, separate those sounds from intrusive background noise. These acoustic analysis results are then compared with vibration measurements; vibration monitoring is a well-known and established technique used in condition monitoring, and in this work vibration measurements were used as a reference signal for assessment of the value of the acoustic measurements. Vibration signals were measured by piezoelectric accelerometers. Two induction motor cases were examined — a healthy motor case, and a combination of static eccentricity with soft foot case. As shown, acoustic analysis appears to be a valuable technique for condition monitoring of electric motors — particularly in noisy industrial environments.

Introduction

Since any interruption in the manufacturing process can cause a serious financial loss for the company, it is very important to prevent unplanned shutdowns of electric machinery. Hence monitoring and diagnosing the health of electric motors is crucial, and continues receiving more and more attention. One of the possibilities for performing diagnostics of electric machines is by analyzing sound emitted by object of interests. The quality of acoustic monitoring is very much dependent on the background noise of the environment in which the machine is operated. Some attempts to create condition monitoring methods based on acoustic analysis were made in the past (Refs. 1–4). Recently, acoustic analysis has attracted more and more attention, and has been applied in many fields — speech recognition, for example. However, condition monitoring methods based on acoustic analysis are still considered difficult to implement in an industrial environment due to the background noise.

The easy availability today of data collectors and sensors as accelerometers or current probes drives the use of many condition monitoring systems based on those measurements. However, it is still very often the case that site engineers are asking for inspection of the machine when they notice abnormal sound. Instead of isolation of the sound and its analysis, a typical "solution" is to perform measurements of vibration, current, temperature or voltages that are not always indicative of the problem. Even though what was reported was abnormal sound, existing solutions are trying to detect the fault by various types of measurements, as opposed to showing that sound is emitted by a specific part in the first place. This, in turn, might limit the amount of possible diagnostic decisions, thus limiting the amount of required effort. For this reason, in many cases the first diagnostic attempt is made by highly experienced engineers who are able to initially detect and diagnose the problem by simply listening for the sound source. For many years, diagnostics in the industry were performed "by ear," with subsequent assessment of the emitted sound. Still, the influence of background noise can strongly affect the quality of such a judgment.

Today's trends in the job market lead to a situation where there is less and less people who are experienced enough to judge the condition of an object by listening to the sound it makes. It is the result of the fact that many people prefer to do office work rather than working in an industrial environment. As is shown in the Global Employment Trend document (Ref. 5), or in the list of the top 10 jobs forecast for next decade (Ref. 6), this situation will be even more prevalent in the future. However, there remains a necessity of doing the initial investigation of objects to localize the abnormal sound to perform immediate action.

A solution of the described problems might lie in the usage of acoustic analysis for objects-of-interest diagnostics. Thus far it has been relatively difficult to create a reliable, acoustic-based condition monitoring system due to the fact that sound measurements are always affected by background noise. However, recent technologies like acoustic cameras are able to successfully localize specific sound components and thus remove the influence of such noise (Refs. 7–8).

A variety of faults that can occur in induction machines have been extensively studied and many monitoring methods have been proposed to detect problems (Ref. 9). Most of those methods for condition monitoring of electric motors utilized vibration or motor current signature analysis (MCSA) (Refs.9–11). While vibration and current signature analysis-based monitoring techniques are well-known and well-accepted, acoustic measurements are not so popular in industrial application. This paper describes a diagnostic method for induction motors based on acoustic measurements, while vibration analysis is used as a reference for assessment of the value of acoustic measurements.

This work first appeared at the12th IMEKO TC10 Workshop on Technical Diagnostics, New Perspectives in Measurements, Tools and Techniques for Industrial Applications, June 6–7, 2013, Florence, Italy

Measurements Tools

Acoustic camera. The idea of the acoustic camera is to do sound source identification and quantification, and to create a picture of the acoustic environment through the processing of the multidimensional acoustic signals received via microphone array and to overlay that acoustic picture on the video picture (Ref. 7). Other possible acoustic camera applications include use as test equipment for non-destructive measurements for sound identification in vehicle interiors and exteriors (Refs. 7–8 and 12); trains and airplanes (Refs. 13–14); and for measurement in wind tunnels, etc. Additionally, some studies show the application of acoustic camera for unmanned underwater vehicles (Ref. 15), robots and robotized platforms, etc. It can also be used for passive acoustical sensing in battlefield environments (Ref.16).

In this work, a 48-microphone acoustic camera was used for sound measurements; parameters for the microphones are presented in Table 1.

Acoustic holography technique was used for analysis of the sound source. Acoustic holography technique is a method that is used to estimate the sound field near a source by measuring acoustic parameters away from the source via microphone array. This is a well-known technique and its description can be found in (Refs. 16–17).

Vibration measurements. Vibration measurements are one of the most popular methods for condition monitoring of electric motors. Typically, piezoelectric accelerometers are used for measurements of the vibration. For the purpose of the present work, vibration measurements were taken as a reference for the sound measurements. Vibrations were collected with ABB's *MACHsense-P* condition monitoring tool. *MACHsense-P* is a walk-around condition monitoring service tool provided by ABB that specifically focuses on electric motors.

Vibration signals were measured using 4 simultaneous data capture channels and analyzed for mechanical and electromagnetic defects. The frequency range used for analysis by *MACHsense-P* tool is from 0 Hz to 12,800 Hz. The vibration analysis presented in **this paper is embedded functionality in the *MACHsense-P* tool.**

Table 1 Microphone characteristic

Parameter	Value
Equivalent noise level:	27 dB(A)
Maximum equivalent sound level:	130 dB
Microphone Frequency response:	20 Hz–20 kHz

Table 2 Nameplate of motors

Parameter	Value
Active power [kW]	75
Nominal voltage [V]	690
Nominal current [A]	77.5
Nominal power factor [-]	0.86
Nominal speed [rpm]	1480
Winding connection [-]	Y
Number of poles per phase winding [-]	2
Nominal frequency [Hz]	50

Measurements Analysis and Comparison

All vibration and acoustic measurements where done in an industrial environment. Since induction motors are the most widely used machines in industry (Ref. 18), two of the same type three-phase induction motors were chosen. Nameplate details of the motors are presented in Table 2.

Both motors were located relatively close to each other, and both of them were driving centrifugal pumps of the same type through direct coupling. Both motors where operating at the same load level. Motor case 1 is considered to be healthy while motor case 2 is considered to have a combination of static eccentricity and soft foot. As soft foot typically results in static eccentricity, this combination of faults is very common.

Results based on vibration measurements. For both of the motor cases, vibration sensors were located horizontally on the center of the body of the motors. Figure 1A presents a vibration spectrum of the healthy motor case while Figure 1B presents a vibration spectrum of a combination of static eccentricity and soft foot motor case. Since static eccentricity can be typically visible in low-frequency range, both figures present frequencies from 0 Hz to 200 Hz.

You may notice that Figure 1B contains a high peak — at around 100 Hz. The value of this peak is above 0.12 gs, while in Figure 1A this peak is smaller than 0.02 gs. As presented in (Ref. 12), static eccentricity causes additional forces visible in vibration at frequency f_{ecc} — given by following equation:

$$f_{ecc} = 2 \cdot f_{line} \quad (1)$$

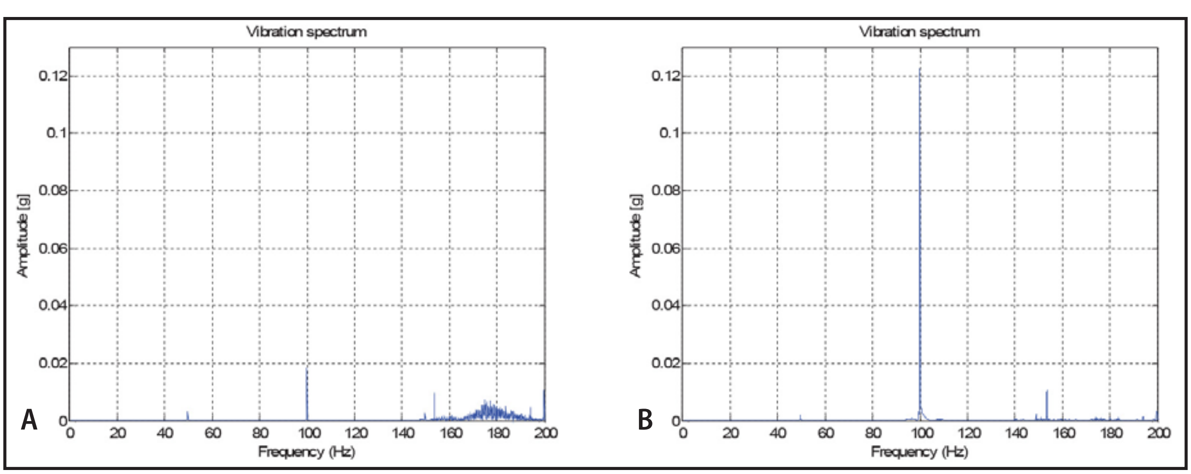


Figure 1 A) Vibration spectrum for healthy case; B) vibration spectrum for combination of static eccentricity and soft foot.

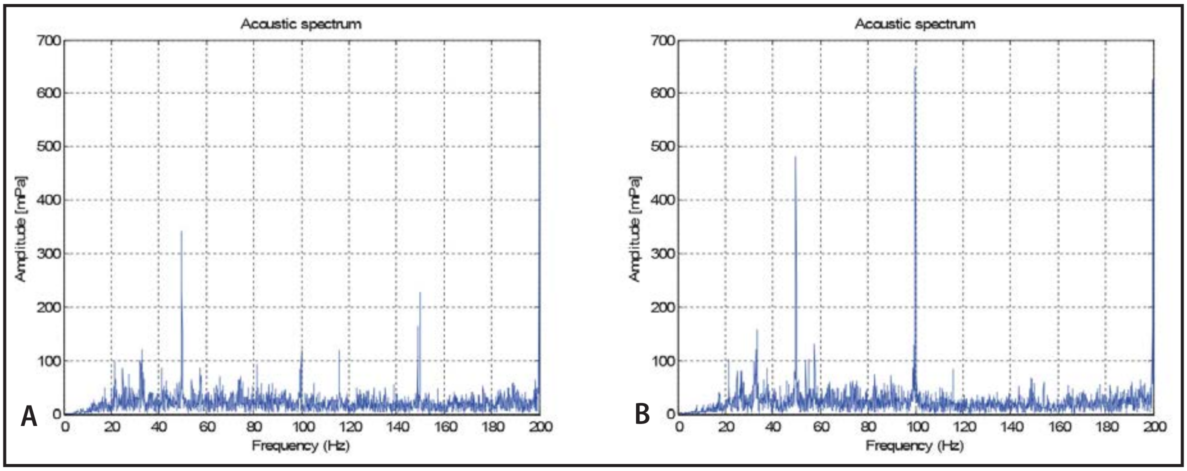


Figure 2 **A) Acoustic spectrum for healthy case; B) acoustic spectrum for combination of static eccentricity and soft foot.**

where f_{line} is power supply frequency. In the above case, both motors were supplied by 50 Hz; therefore static eccentric-related frequency f_{ecc} is visible at 100 Hz. By taking the amplitude of f_{ecc} frequency as the static eccentricity indicator, it is clearly visible that the motor in case 2 reached a higher level of static eccentricity than the healthy motor from case 1. With the *MACHsense-P* the indicator of static eccentricity is calculated automatically.

Results based on acoustic measurements. For industrial applications, when performing measurements using a microphone, background noise cannot be avoided. The background noise can be filtered out by post-processing methods of the measured signals. This is possible due to the different nature of the measured sound. The background noise (including the aerodynamic noise of the cooling device) is usually a broadband signal with a more or less constant spectrum (Ref. 1).On the contrary, the induction machine generates sound that is characterized by many pure tones — at least for the sound produced by electromagnetic origin. Reference 1presents a method where before operating the induction machine, a measurement of only the background noise is conducted. This spectrum of the measurements is later subtracted from the measured spectrum, with the induction machine in operation. But this noise filtering approach is not accepted in industry because it affects the industrial process.

Reference 11 describes a method that isolates the frequencies related to the motor presented in electric current measurements. The same approach can be applied for vibration or acoustic signal. As presented in (Ref. 11), by knowing motor parameters and motor slip, all the frequencies related to motor condition can be identified. Likewise, all motor-related frequencies can be found and identified in the acoustic signal — even if the signal contains background noise.

Figure 2 presents an acoustic spectrum of average signal via microphone array. Figure 2A presents acoustic spectrum of a healthy motor case, while Figure 2B presents an acoustic spectrum of a combination of static eccentricity and soft foot motor case. Both figures are obtained for frequencies ranging from 0 Hz to 200 Hz. Similar to vibration cases, it is possible to notice that Figure 2B consists of a high peak at around 100 Hz, while Figure 2A does not. Value of this peak is above 600 mPa, while in Figure 2A this peak is smaller than 350 mPa. Those results are very similar to vibration-based results, and they are clearly indicating static eccentricity; however, in case of acoustic signal there is no assurance that this frequency emanates from the motor.

To solve this problem the acoustic holography technique can be applied to find the sound source of the frequency of interest — in this case, 100 Hz. Figure 3 presents results of the acoustic holography technique applied for the 48-microphone acoustic camera. Sound intensity is indicated by color, and it is easy to see that the highest amplitude — 100 Hz — comes from the motor body, meaning that this particular frequency is not caused by any background noise — but by the motor itself.

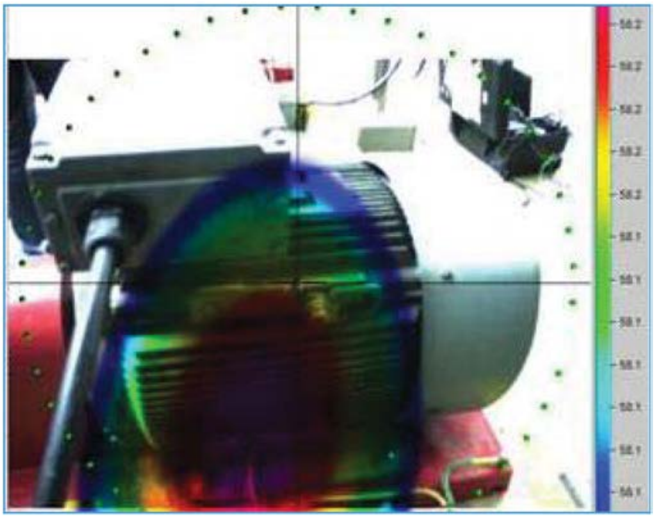


Figure 3 **Localization of 100 Hz via acoustic holography technique.**

Conclusions

In this paper an acoustic-based technique for the condition monitoring of electric motors was presented. Vibration analysis was used as a reference for assessment of the value of acoustic measurements. Acoustic measurements were performed via 48-microphone acoustic camera.

Two induction motor cases were examined — 1) a healthy motor case and 2) a combination of static eccentricity with soft foot case. For fault case respective frequencies were identified in both vibration and acoustic signal. Based on acoustic holography technique, the fault-related acoustic frequency source was localized in the center of the body of the faulty machine.

As presented in the results section, one can say that acoustic signals can be successfully used for condition monitoring of electric motors in noisy industrial applications. Obviously, single- acoustic signal is disturbed and noisy compared to vibration signals; therefore sound localization technique via acoustic camera was needed to solve this problem. An additional benefit of sound analysis is the fact that the acoustic sensors need not be attached directly to the motors, which is often difficult in industrial applications. **PTE**

References

1. Van Riesen, D., C. Schlensok, F. Henrotte and K. Hameyer. "Acoustic Measurement for Detecting Manufacturing Faults in Electrical Machines," *17th International Conference on Electrical Machines,* 2006.
2. Verma, S. P. "Noise and Vibrations of Electrical Machines and Drives; Their Production and Means of Reduction," *International Conference on Power Electronics, Drives and Energy Systems for Industrial Growth*, Vol. 2, pp.1031, 1996.
3. Verma, S. P. and W. Li: "Measurement of Vibrations and Radiated Acoustic Noise of Electrical Machines," *Sixth International Conference on Electrical Machines and Systems*, Vol. 2 (2003), pp. 861.
4. Gaylard, A., A. Meyer and C.A. Landy. "Acoustic Evaluation of Faults in Electrical Machines," *Seventh International Conference on* (*Conf. Publ. No. 412*), Durham, p. 147 –150.
5. Employment Trends Unit of the ILO Employment Sector, "Global Employment Trends 2012: Preventing a Deeper Jobs Crisis," International Labor Office, Geneva, 2012.
6. WorldWideLearn. "Top-Ten Jobs," *WorldWideLearn.com,* Quinstreet Inc., 2012.
7. Miljko, E. M. "Some Research Challenges of Acoustic Camera," *19th Telecommunications Forum Telfor*, pp. 1036–1039, 2011.
8. Michel, U."History of Acoustic Beamforming," *Berlin Beamforming Conference* , Nov. 21–22, 2006.
9. Tavner, P.J. "Review of Condition Monitoring of Rotating Electrical Machines," *IET Electrical Power Applications*, Vol 2 (4), pp. 215–247, 2008.
10. Orman, M., M. Orkisz and C.T. Pinto. "Slip Estimation of a Large Induction Machine Based on MCSA Diagnostics for Electric Machines," *IEEE International Symposium on Power Electronics & Drives*, Bologna, pp. 568 – 572, 2011.
11. Orman, M., M. Orkisz and C.T. Pinto. "Parameter Identification and Slip Estimation of Induction Machine," *Mechanical Systems and Signal Processing*, Vol 25, Elsevier, pp. 1408–1416, 2011.
12. Guidati, S. "Advanced Beamforming Techniques in Vehicle Acoustics," *Berlin Beamforming Conference,* 2010.
13. Cariou, C. and O.Delvedier. "Localizing Aircraft Noise Sources with Large-Scale Acoustic Antenna," *27th International Congress of the Aeronautical Sciences.*
14. Pascal, J.S and J.F.Li. "Use of Double-Layer Beamforming Antenna to Identify and Locate Noise in Cabins," *EURONOISE*, Finland, 2006.
15. de Bree, H.E., J.W. Wind and E. Druyvesteyn. "Battlefield Acoustic," *Microflown* E-book, Chapter 21.
16. Korpel, A. "Acoustic Imaging and Holography," *IEEE Spectrum*, Volume 5, Issue, 10, pp. 45–52, 1968.
17. Mueller, R.K. "Acoustic Holography," *Proceedings of the IEEE*, Volume 59, Issue 9, 1971.
18. Long, W. "Separating Load Torque Oscillation and Rotor Faults in Stator Current-Based Induction Motor Condition Monitoring," Georgia Institute of Technology, 2007.
19. Mijic, M., D.Masovic, D. Pavlovic and M. Adnadevic. "A Model of Planar Microphone Array Realized with Low-Cost Multimedia Microphones," *Telecommunications Forum* (*TELFOR*), pp. 1040–1043, 2011.

Maciej Orman received a MSc. engineering degree in automation and robotics in 2008 at AGH, University of Science and Technology, Krakow; he was awarded his PhD — also at AGH — in 2011. Since 2009 he has worked at ABB's Corporate Research Center in Krakow, where he has dealt with condition monitoring of electric machines. Since December 2011 he has worked at ABB's Corporate Research Center in Shanghai, where he continues working in the same capacity.

Cajetan T. Pinto studied electrical engineering at the University of Mumbai and at the University of California Irvine (U.S.). During his Masters of Science studies he worked on electromagnetic energy conversion systems at the University of California. He is currently global head of R&D for motors and generators service at ABB Global & Industrial Services Ltd, Mumbai India. His main areas of focus include diagnostics; condition monitoring and reliability; motor and generator re-engineering; maintenance technologies; new service processes; and materials for service.

Leaky Shaft Seals

James K. Simonelli

Scenario

Half of the gearboxes on a brand-new conveying system on the varnishing line for a manufacturer of high-end kitchen cabinets were leaking. Oil was dripping on the cabinet parts—ruining the finish. Why were half of the gearboxes leaking?

Background

I commonly hear people complain that shaft seals always leak. Many accept leaking seals as normal gearbox operation. But properly done, shaft seals do not leak, and will last for a long time. Remember when new cars—say 1970s and prior—always left a puddle of oil on the garage floor under the hood area? Like putting down newspaper for a new puppy, our family kept a sheet of cardboard on the ground under the engine to keep the garage clean. Cars don't do that anymore—their seals take years to wear out.

Improper shaft surface is the leading cause for shaft seals leaking prematurely; shaft surface factors are surface finish (i.e., roughness) and machine lead.

The most common shaft seal (Fig. 1) is spring-energized and typically referred to as a "lip seal." A garter spring adds light radial tension (energizes) to the rubber (elastomer) lip to assure good contact with the shaft. This article is based around application of lip seals, but works equally well for applications using O-rings and quad-rings sealing rotating shafts.

Surface Finish

If the shaft surface finish is too rough, it will prematurely abrade the lip. If extremely rough, the lip will not be able to conform to the surface and leak immediately. If the surface is too smooth the seal will overheat; this is because the lip rides on a thin film of lubricant. Fluid surface tension prevents it from escaping. A small amount of shaft roughness forms tiny lubrication pockets.

There are a number of recommended ranges of surface finish, depending on the seal manufacturer, industry association, or engineer. They span from 6 to 32 micro-inch R_a, with a common overlap from 10 to 20 micro-inch R_a. Personally, I specify 8 to 20 micro-inch R_a; it has worked well in applications as diverse as steel mill equipment to light-duty pumps.

Starting and stopping causes more wear than continuous operation. When running, hydrodynamics maintains the oil film between the seal lip and the shaft. When stopped, the oil film collapses. On start-up the lip seal rubs the shaft until the oil film is generated. This causes increased wear. During long, idle periods the seal elastomer begins to bond to the shaft surface. Anybody who has left something with rubber feet on a glass table for a few days has witnessed the effect. When this happens a small layer of rubber can be torn off the seal, causing leaks. Often, in the first few idle re-starts, the seal will wear back into sealing again. I have an antique car that experiences this problem every spring when I start using it again. Sitting in the garage, no leaks—even the seals below the oil level. When I back it out for its spring cleaning, it leaks in the driveway. After a long drive on the freeway the seals stop leaking. Within a few years I have to replace the seals as they will not stop. But if you look at both mileage and calendar days between having to replace them, it is a fraction of my daily vehicle.

Inspection showed all of the shafts had excessive lead. The mirrored arrangement of the conveyor meant half the gearboxes rotated clockwise, and half counter-clockwise. One rotation the shaft lead pumped the oil in, and the other rotation pumped it out.

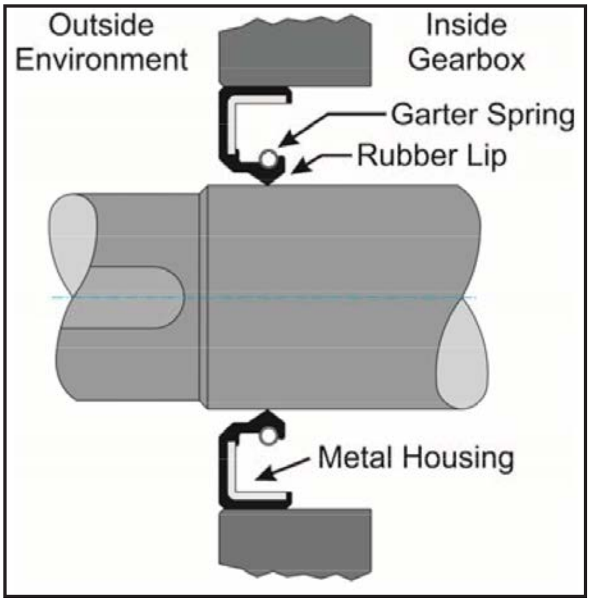


Figure 1 Typical elastomeric lip shaft seal.

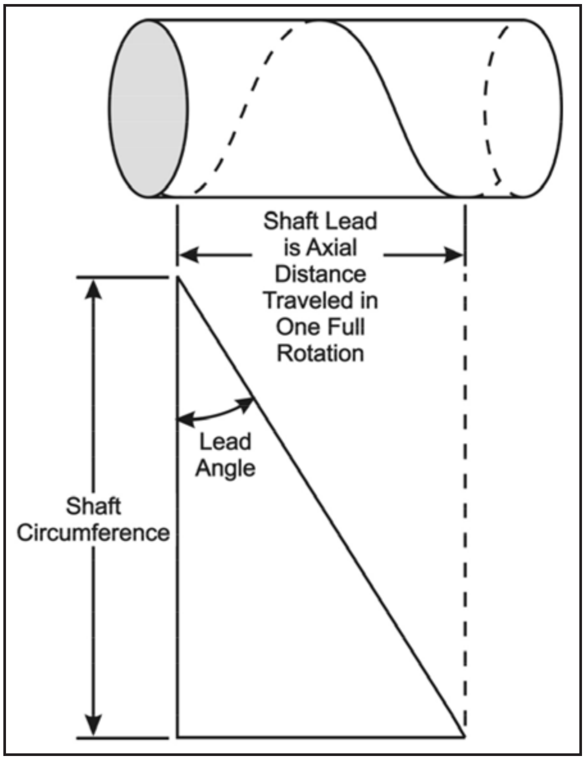


Figure 2 Shaft lead.

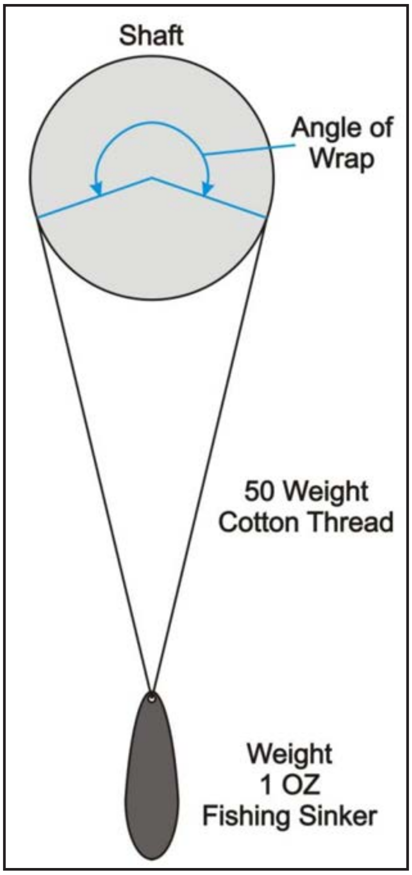


Figure 3 Lead test diagram.

Machine Lead

Manufacturing a shaft generally is done by 'turning'; removing material by rotating the part on its axis and moving a cutting tool axially. Turning leaves a helix pattern similar to a screw thread, commonly called machine lead or shaft lead (Fig. 2). Beyond the visible lead on the surface, the cutting tool also burnishes (*to move material by plastic deformation*) shaft in a helix. Subsequent finishing operations, ex. plunge grinding (*the grinding wheel is brought into contact with the shaft radially with no axial movement*), may not remove this burnished lead. The helix may remain even if the surface finish is correct and there is not a visible pattern.

The best test for shaft lead is not very high-tech, but it works. All of the special equipment that is not already in a typical machine shop can be purchased at a Wal-Mart.

A separate page of the test procedure was created so it can be given to an inspector to perform as a work instruction. At the end is the math (Eqs. 1 – 5), should you want to wade through it to better understand the theory behind the procedure. Seeing the math makes the procedure less like magic.

Theory. A loop of thread is used to act as a stylus that rides in the lead grooves (Fig. 3). A light weight is attached to the thread to hold it in contact and prevent it from rotating with the shaft. The shaft is coated with a thin film of oil and rotated at a consistent speed to mitigate problems with friction and inertia. By knowing the shaft rotation speed and the time it takes the thread to travel a distance, the lead angle can be determined (Fig. 4).

As the angle of wrap increases towards 360°, the tension in the thread and its grip on the shaft approach infinity. The thread length is sized so that the tension in the loop is kept low. The maximum wrap should be less than 255° and preferably less than 240°. Typically, less wrap (i.e., longer thread) is better.

The standard test speed is considered to be 60 rpm. However this is based on the diameters of standard shaft seals available, and does not account for extremes in shaft diameters. With large diameters the speed must be reduced because of the high surface speed. High surface speed will prematurely wear out the thread, or make it begin to travel with the shaft rotation, which is evidenced by the weight bouncing. With small diameter shafts the speed must be increased because the surface speed is too slow to mitigate problems with friction and inertia. This is evidenced by the weight swinging like a pendulum. The low rubbing velocity makes the coefficient of friction vary. Thus the weight should remain relatively stable in its motion.

This is not something where deviation from the rules will invalidate the test. Depending on your application you may be required to use trial and error to find the best combination of thread wrap, shaft speed, oil, and weight.

Every company where I implemented this test thought it was a joke—until they saw the results. At one company the VP of operations disliked the concept so much he spent thousand dollars on a sophisticated surface finish tester to prove it would predict shaft seal leaks, and the piece of thread would not.

He lost!

Residual machine lead test procedure

Equipment

- Stopwatch
- Cotton quilting thread (i.e., 50 weight cotton thread) or un-waxed dental floss; thread length 5 times the shaft diameter
- One-ounce fishing sinker
- 3-In-One machine oil (*a brand produced by WD-40 and generically is a severely hydro-treated, heavy naphthenic oil*), sewing machine oil or silicone oil viscosity 5 to 10 cps
- Lathe or other device to hold the shaft horizontally and rotate consistently at a set speed
- Distance indicator; piece of metal or cardboard to mark two lines a distance apart

Steps

1. Make a thread loop by knotting both ends at the weight
   a. Check that the free loop perimeter is 4 or more times the shaft diameter
2. Place the loop around the shaft
3. Mount the shaft in the lathe
4. Thinly coat the surface to be tested with oil
5. Position distance indicator near the shaft in the sealing area; mark 2 lines near the limits of the seal area and record the distance
6. Place the string to one end of the sealing surface outside of the indicators
7. Set the lathe rotation speed; nearest available speed to $w = 130/\text{diameter}$ in inches, or $w = 5/\text{diameter}$ in mm
8. Start the lathe; if the thread is moving away from the first position mark, reverse the lathe
9. Start the stopwatch when the thread reaches the first position mark
10. Stop the stopwatch when the thread reaches the second position mark; record the time
11. Check the thread for wear; replace as needed — every 50 to 100 tests

The Math

Producing Shafts for Successful Sealing

As harder surfaces are better for shaft seals, traditional practice for shaft calls for hardening and plunge-grinding the seal areas. Both are expensive operations. As previously noted, plunge-grinding may not resolve the problem with shaft lead. To not create the problem when turning the shaft, the feed rate can be set to the allowable for seal shaft lead. With old manual machines this was not very practical, as it would slow production. CNC machines can be programmed to reduce the feed rate just in the seal area. Roller burnishing the seal area is useful as it can improve the surface finish and the hardness.

For low volume I use traditional practice. With high volume applications, where I have the opportunity for production trials, turned and roller burnished seal areas offer large savings without sacrificing performance. **PTE**

D = Shaft Seal Diameter
X = Distance Between Position Indication Marks
t = Time to Travel X Distance (sec)
ω = Shaft Rotation Speed (rpm)
λ = Lead Angle

$$\lambda = \tan^{-1}\frac{60 \times X}{\pi \times D \times \omega \times t}$$

Equation 1 Lead formula.

Diagnosis

Observed Thread Movement	Interpretation
Stationary in both rotations	No lead present
Thread travels axially with rotation. Reversing rotation reverses axial travel.	Lead present Maximum Allowable Shaft Lead 0.05° (3.5 arc minutes)
Results where shaft lead cannot be determined	
Thread travels away from the center for both rotations	Crowned shaft; Barrel
Thread travels toward the center for both rotations	Cupped shaft; Hour Glass
Thread travels in same direction for both rotations	
Remount the shaft end-for-end and retest	
Reverses direction of thread movement	Tapered shaft
Does not reverse direction of thread movement	Machine holding shaft not level

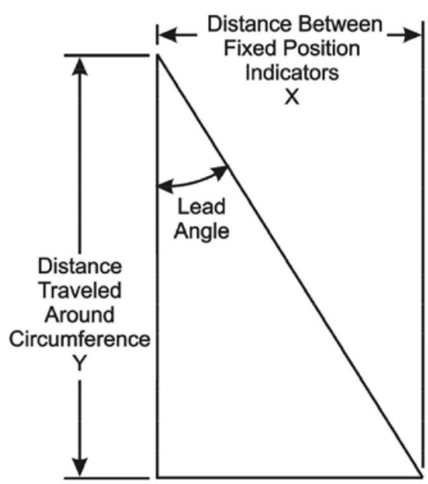


Figure 4 Test diagnostics, interpretation.

D = Shaft Seal Diameter
C = Shaft Circumference
Y = Distance Traveled Around Circumference
X = Distance Between Fixed Position Indicators
t = Time to Travel X Distance (sec)
ω = Shaft Rotation Speed (rpm)
n = Number of Shaft Rotations
λ = Lead Angle

$$C = \pi \times D$$

$$n = \frac{\omega \times t}{60}$$

60 converts w in rev/min and t in seconds

$$Y = C \times n \Rightarrow Y = \frac{\pi \times D \times \omega \times t}{60}$$

$$\tan\lambda = \frac{X}{Y} \Rightarrow \lambda = \tan^{-1}\frac{X}{Y}$$

$$\lambda = \tan^{-1}\frac{60 \times X}{\pi \times D \times \omega \times t}$$

Equation 2 Calculating lead angle.

D = Shaft Diameter
C = Shaft Circumference
s = Surface Speed
ω = Shaft Rotation Speed (rpm)

$$C = \pi \times D$$

$$s = \frac{C \times \omega}{12} \Rightarrow s = \frac{\pi \times D \times \omega}{12}$$

12 Converts inches to feet

$$\omega = \frac{s \times 12}{\pi \times D}$$

$$s = 20 \text{ fpm} \Rightarrow \omega = \frac{240}{\pi \times D} \Rightarrow \omega = \frac{76.4}{D}$$

$$s = 50 \text{ fpm} \Rightarrow \omega = \frac{600}{\pi \times D} \Rightarrow \omega = \frac{191.0}{D}$$

Select mid-range to create a rule of thumb

$$\omega = \frac{130}{D} \text{ for } D \text{ in inches or } \omega = \frac{5}{D} \text{ for } D \text{ in mm}$$

Equation 3 Calculating shaft rotation speed.

General Concepts of Lubrication

Background

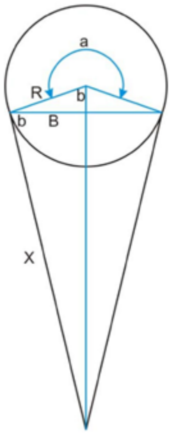
Lubricants simultaneously perform many functions. Most obviously they reduce friction. They also transfer heat, prevent surface contact, dampen vibrations, inhibit rust, and spread the contact load over larger area. Improper lubrication is the most common cause of reducer failure. This can be improper oil selection, property break down or contamination.

Elasto-Hydrodynamic Lubrication

When a speeding car hydroplanes on a rain puddle, the car's tires float on a wedge of water. In general engineering terms this phenomenon is called "elasto-hydrodynamic lubrication (EHL)" — also known as "thick film lubrication." For the components not to contact, the film thickness must be greater than the surface roughness of the contacting parts. Film thickness is proportional to the relative surface velocity and lubricant viscosity, and inversely proportional to the unit load. Meaning, viscosity is the oil's contributing factor to film thickness.

Viscosity and velocity are the predominant factors influencing the lubricant film thickness, whereas load has less importance. Analytical rela-

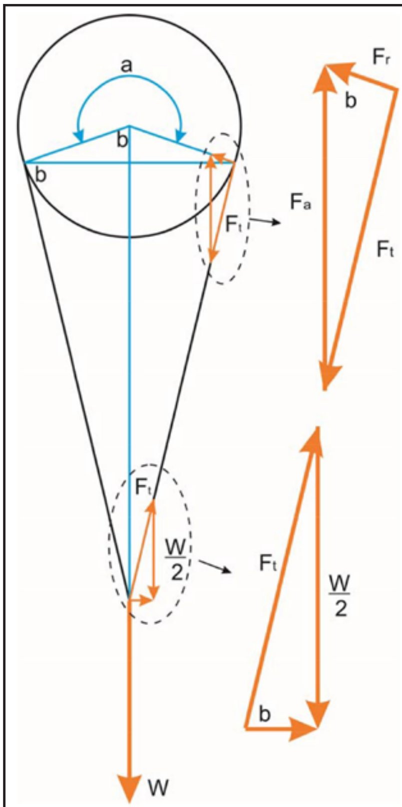
a= Angle of Wrap in Degrees
R= Shaft Radius
A= Thread Length in Cotact with Shaft
X= Length of Thread to Weight
T= Total Length of Thread (not including length knotted at weight)



$$T = A + 2 \times X$$
$$R = \frac{D}{2}$$
$$A = \pi \times D \times \frac{a}{360}$$
$$b = \frac{360 - a}{2} \Rightarrow b = 180 - \frac{a}{2}$$
$$B = R \times \sin b$$
$$B = X \times \cos b \Rightarrow X = \frac{B}{\cos b}$$
$$X = R \times \frac{\sin b}{\cos b} \Rightarrow X = \frac{D \times \tan b}{2}$$
$$\tan(180 - \theta) = -\tan\theta$$
$$X = \frac{-D \times \tan\frac{a}{2}}{2}$$
$$T = \pi \times D \times \frac{a}{360} + 2 \times \frac{-D \times \tan\frac{a}{2}}{2}$$
$$T = D \times \left[\pi \times \frac{a}{360} - \tan\frac{a}{2}\right]$$
$$a = 240° \Rightarrow T = D \times 3.83$$

5 times the shaft diameter easily gives enough extra thread length to tie the knot at the weight

Equation 4 Calculating thread length.



a= Angle of Wrap in Degrees
R= Shaft Radius
A= Thread Length in Cotact with Shaft
W= Weight Hanging in Thread
F_t= Tension Force in Thread
F_r= Radial Force on Shaft from Thread
F_a= Apparent Force

By Symetry, Force Applied to Each Thread Strand is Half the Total Weight

$$b = \frac{360 - a}{2} \Rightarrow b = 180 - \frac{a}{2}$$
$$\sin b = \frac{\left(\frac{W}{2}\right)}{F_t} \Rightarrow F_t = \frac{W}{2 \times \sin b}$$
$$\tan b = \frac{F_t}{F_r} \Rightarrow F_r = \frac{F_t}{\tan b}$$
$$F_r = \frac{W}{2 \times \sin b \times \tan b}$$

Trigonometric Identities
$$\frac{\sin\theta}{\cos\theta} = \tan\theta$$
$$\sin\theta \times \tan\theta = \sin\theta \times \frac{\sin\theta}{\cos\theta} = \frac{\sin^2\theta}{\cos\theta}$$
$$\sin(180 - \theta) = \sin\theta$$
$$\cos(180 - \theta) = -\cos\theta$$
$$\sin\frac{\theta}{2} = \pm\sqrt{\frac{1 - \cos\theta}{2}} \Rightarrow \sin^2\frac{\theta}{2} = \frac{1 - \cos\theta}{2}$$

Substituting into F_r

$$F_r = \frac{W}{2 \times \sin b \times \tan b} \Rightarrow F_r = \frac{W \times \cos b}{2 \times \sin^2 b} \Rightarrow F_r = \frac{-W \times \cos\frac{a}{2}}{2 \times \sin^2\frac{a}{2}} \Rightarrow F_r = \frac{-W \times \cos\frac{a}{2}}{1 - \cos a}$$

$$a = 202° \Rightarrow F_r \cong \frac{W}{10} \qquad a = 240° \Rightarrow F_r = \frac{W}{3} \qquad a = 283° \Rightarrow F_r \cong W$$
$$a = 320° \Rightarrow F_r \cong 4 \times W$$
$$a = 207° \Rightarrow F_r \cong \frac{W}{8} \qquad a = 255° \Rightarrow F_r \cong \frac{W}{2} \qquad a \to 360° \Rightarrow F_r \to \infty$$

Equation 5 Calculating thread grip.

tionships for calculating the minimum and the average film thickness have been developed. The equations are shown here (EQs. 1 and 2) are only for illustration of the variables' relative effects.

Boundary Lubrication

High loads can collapse the oil film, allowing the surfaces to contact. This is called "boundary lubrication." In this mode lubricity (slipperiness) and other properties of the lubricant become more important than the viscosity. Mixed lubrication, sometimes referred to as thin film lubrication, is where the oil film has not entirely collapsed, but the surfaces contact on the higher points of surface roughness.

Extreme pressure oils (EP oils) are a type of lubricant formulated to improve performance in boundary or mixed lubrication. At the high pressures and temperatures that occur in the contact area of gears and bearings, a chemical reaction forms a protective skin. Most EP oils use sulfur, phosphorus, and/or chlorine additives, and are designed to work in steel-on-steel applications. Note that care should be taken when using EP oils in applications using bronze components.

Synthetic lubricants are becoming very common; they reduce wear, increase efficiency, reduce friction, and lower sump temperatures — all of which increase component life. Their viscosity index is much higher than mineral oils. This allows one lubricant to provide adequate service over a broader temperature range. And they have longer service life, thus reducing the number of oil changes required. Efficiency increases of 20% of lost power are possible. Under severe conditions, properly selected synthetic oils are outstanding. Many companies have found cost advantages using the more expensive synthetic oil.

James K. Simonelli, inventor on multiple patents, is a Licensed Professional Engineer with over 30 years' experience designing and troubleshooting machine automation, heavy-duty equipment and industrial products. He has a broad background, with leading roles in engineering, project management, quality, business development, and division management in companies varying from start-ups and turnarounds to Fortune 100 corporations. Simonelli has served on committees developing industrial standards for the American Gear Manufacturers Association and the Hydraulics Institute. Mobile: (404) 702-3050; Email: *j.simonelli@att.net*; Skype: jim.simonelli; Linkedin: *www.linkedin.com/in/jsimonelli.*

Industrial Careers Pathway (ICP)

RAISES AWARENESS OF INDUSTRIAL DISTRIBUTION CAREERS

Industrial Careers Pathway (ICP) works with volunteers in their local communities to facilitate participation in career fairs and other activities to raise awareness of the rewarding careers available in the field of industrial distribution. The first of three February events took place at Carman-Ainsworth High School, Flint, Mich. Called ICP Ambassadors, volunteers Keith and Eric Nowak, a father son team from MPT Drives, Inc., Madison Heights, Mich., represented ICP to an estimated 1,700 participating students. Keith said, "One of the faculty stopped by and was interested in what we did. I accepted his invitation to come back and address a group of seniors on real world opportunities."

ICP Ambassadors have participated four times since 2013 at career fairs at The Williamson Free School for Mechanical Trades, Media, Pa., most recently on February 10. ICP Ambassadors Tom Tesoro, Jason Industrial Inc. A Megadyne Group Co., and Bill Moore, trustee with the PTDA Foundation Board, reported both current students and alumni were in attendance. Moore said, "There were about 125 companies present and many of the students stopped by to talk with us. I was impressed with the caliber of the students at the school. Industrial distributors would find these students to have all the positive work attributes needed to succeed."

ICP Ambassador David Drudge, Bishop Wisecarver Group, volunteered at a career fair at Hart County Comprehensive High School, Hartwell, Ga., where students demonstrated enthusiasm by returning two and three times with more questions on the field, he recounted. David, a first-time volunteer, said, "I think it went really well. The ICP booth was the busiest at the event. I brought some company literature as well as ICP handouts and had lots of interest. I am ready to do another event."

Mouser Electronics

LAUNCHES INNOVATION LAB AND COLLABORATES WITH MARVEL ENTERTAINMENT

Mouser Electronics, Inc., a global authorized distributor of electronic components, announced the launch of a new series in the second year of the Empowering Innovation Together program with former *Mythbusters* star and longtime Mouser customer, Grant Imahara. The new program will also see the debut of the Mouser Innovation Lab, where Imahara and special guests will build several cutting-edge projects powered by the newest products and technologies from Mouser's manufacturer partners.

In the first project Mouser will team up with Marvel to build Super Hero technology straight from the movie *Captain America: Civil War* — including real-life working versions of Captain America's shield and Iron Man's gauntlet. Imahara will team up with viral video celebrity Allen Pan in a series of videos to highlight the full build process — from concept to the final unveiling. This first project is sponsored by Molex and Analog Devices, who will supply new, advanced parts for the challenging build.

"With Mouser combining engineering and Marvel's characters into an entertaining and easy to understand STEM-oriented video segment, it will help students and others gain new insights into the technology field," stated Mindy Hamilton, senior vice president of global partnerships at Marvel Entertainment LLC. "We enjoy working with any partner that helps to highlight the benefits that STEM brings to young minds."

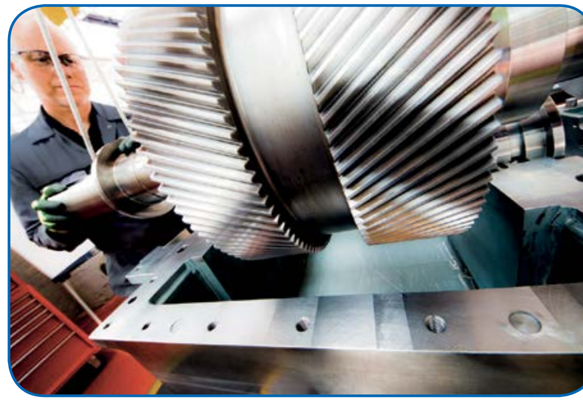
"I'm really excited to get into the new Mouser Innovation Lab and start working on these cool devices from the Marvel Cinematic Universe," said Imahara. "I've seen several of Allen's project videos. I can't wait to see what we can come up with in the lab."

"The goal of the Empowering Innovation Together program is to inspire and engage engineers of all ages — from students to millennials to lead engineers," stated Glenn Smith, president and CEO of Mouser Electronics. "During the year we'll be exploring space tech, pushing the boundaries of drone capabilities and even 3D printing a car."

Mouser provides a unique perspective to the industry for such programs with its broad product line, unsurpassed customer service and industry-first interactive catalog with vast amounts of engineering and technical data.

David Brown and Santasalo

MERGE TO SERVE GROWING GEAR CUSTOMER BASE



David Brown and Santasalo merged on June 1st to create David Brown Santasalo. With more than 1,000 employees, seven major manufacturing plants and 23 service centers across six continents, the business is ideally equipped to serve its growing customer base in commodities, marine, defense, power, industrial and consumer end markets. Through its highly responsive and capable local teams, David Brown Santasalo brings the connectivity and responsiveness to support the specific needs of more than 5,000 customers worldwide.

"I am delighted to have this opportunity to lead a business with such a diverse, international team," said Thomas Burley, CEO, David Brown Santasalo. "We now combine extensive sales and service presence in all regions with a world-class engineering and manufacturing capability. David Brown Santasalo covers varied end markets including naval ships, minerals processing and the manufacture of a wide range of pulp and paper products. Across all these markets, our core differentiator is our fundamental capability to design and engineer gear systems for the world's most demanding applications. We are committed to maintaining and growing this through continued investment in our people and manufacturing capabilities over the coming years."

Burley said David Brown Santasalo's strategy moving forward is to "Expand our sales and service network, becoming ever more local to our diverse customer base, use our in-depth gear engineering knowledge to enhance our product offering and support our customers in their end markets and invest further in world-class manufacturing, ensuring we have full production capability in key regions to meet the growing demand for our products." Jim McColl, chairman and CEO, Clyde Blowers Capital added, "In bringing together David Brown and Santasalo, we have created a large scale industrial gearing business with proven management, highly complementary products, a unique global service network and increasingly efficient manufacturing."

Schaeffler

INCREASES CAPACITY IN TWO U.S. LOCATIONS

The Schaeffler Group is increasing its capacity at two U.S. locations by building new manufacturing halls and administration buildings. Excavators have already started work in Fort Mill, South Carolina and a June groundbreaking is planned for its expansion in Wooster, Ohio. In total, Schaeffler is creating more than 350 new jobs in the United States. The automotive supplier is reacting to the increasing global demand for its systems and components by building new manufacturing and administration facilities at both locations. Schaeffler is investing a total of 83.6 million euros in the United States.

Expansions and 250 additional employees in Wooster

Schaeffler is investing a total of 60 million dollars, the equivalent of approximately 52 million euros, in its Wooster, Ohio facility. The expansion, which is approximately 8,500 square meters, will include production space, a shipping hall, and offices while creating 250 new jobs. Schaeffler is already the largest employer in Wooster with over 1,700 employees. The location in Northeast Ohio designs and manufactures components for automatic transmissions such as torque converters and converter lockup clutches for the automotive industry. The company will break ground in June 2016 and completion is planned for 2017.

New buildings and 105 new jobs in Fort Mill

Schaeffler is investing 36.5 million dollars, the equivalent of about 31.6 million euros, in the expansion of one of its two plants and the addition of a corporate office building in Fort Mill, South Carolina. The expansion will create additional space for production and the corporate office will include a conference center, offices and a company restaurant. In addition, the plant entrance is being remodeled. More than 100 new jobs will be created in Fort Mill within a short time. Around 1,200 people are currently employed at the Fort Mill facility. It produces rolling bearings, bearing components, and camshaft phasing units. It also serves as the regional headquarters. The project will be completed and production will launch in the fall of 2017.

C&U Americas

RECEIVES SUPPLIER AWARD

C&U Americas, LLC, the North American subsidiary of The C&U Group, has received the "2015 Supplier Quality Excellence Award" from BorgWarner Inc. The award was given to C&U Americas in recognition for consistently providing superior quality parts during the 2015 business year. C&U supplies various bearings for alternators and starters to the BorgWarner Power Drive Systems plant in San Luis Potosi, Mexico.

BorgWarner presented the award to C&U Americas during its Annual Supplier Conference, which was held February 25th, 2016 at the Holiday Inn Quijote San Luis Potosi, Mexico. On hand to accept the award were Victor Lopez Navarrete, C&U Americas regional manager-Mexico, Mike Caldwell, C&U Americas quality manager, and Tom Rouse, C&U Americas president.

"We are delighted to receive this prestigious award and honored to be recognized for excellence by a world leading manufacturer such as BorgWarner, states Rouse. "We are grateful for the opportunity to partner with BorgWarner and are very proud of our team's commitment and dedication in serving BorgWarner."

Bison Gear

ADDS TWO MEMBERS TO BOARD OF DIRECTORS

In a move to strengthen their independent board as they continue to further diversify their product and service capabilities, Bison is pleased to announce that Jack De Leon and Richard Drexler have accepted positions on Bison's board of directors. Both gentlemen have extensive leadership experience in the industry and will help guide the organization as Bison expands into new markets.

De Leon is a leader in manufacturing and engineering with 32 years of experience in aerospace & defense, automotive, food and beverage and industrial equipment markets. He has held executive level positions at Lord Corporation, Rockwell Automation and Texas instruments where he specialized in business strategy and development.

Drexler draws from 46+ years of experience working as a leader in manufacturing. During that time, he has served as president and CEO of Allied Products Corporation and chairman of the board for Quality Products Corporation. He also currently serves on the board for Prince Industries and GTI.

"We are pleased to welcome Jack and Richard to our Board," said Ron Bullock, Bison chairman and CEO. "We expect their combined experience will provide tremendous insight and guidance going forward."

Schafer Industries

HIRES GLOBAL SOURCING MANAGER

Nick Zizzo has joined Schafer Industries as global sourcing manager. He will oversee the procurement function at all company locations as well as collaborate with suppliers for business development, supply cost optimization and leveraging corporate purchasing.

Zizzo comes to Schafer Industries with more than 18 years of experience. Most recently, he spent six years in supply chain management with AM General. In addition to sourcing, he has expertise in inventory analysis, supplier collaboration, policy/procedure drafting and organizational compliance.

Zizzo received a bachelor's degree in business administration from the University of Wisconsin Milwaukee and a master's degree in business administration from Cardinal Stritch University, also in Milwaukee. He has earned the CPSD certification (Certified Professional in Supplier Diversity) and CPSM certification (Certified Professional in Supply Management).

Schafer Industries began in South Bend, Indiana in 1934 manufacturing high-quality gears as Schafer Gear Works. Today Schafer Industries is a leading producer of high-precision, custom-engineered gears and machined parts as well as assembled axles, transaxles, transmissions, brake assemblies and other components for wide variety of industries. Headquartered together with an operations facility in South Bend, Ind., Schafer also has manufacturing facilities in Illinois and Ohio.

June 21–22–47th International Symposium on Robotics Munich, Germany. Returning to Munich after two years, ISR 2016 is the international trade fair for automation and mechatronics. Automatica has been chosen as the conference platform which covers the entire spectrum of automation. ISR 2016 will offer the latest R&D efforts in robotics as well as the new developments in robotics, machine vision, assembly, handling and service. It is jointly organized by the Mechanical Engineering Industry Association (VDMA), the Information Technology Society (ITG) within VDE and supported by Fraunhofer IPA and the German Society for Robotics (DGR). For more information, visit *www.ifr.org*.

June 22–23–Sensors Expo & Conference 2016 McEnery Convention Center, San Jose, California. New this year, the Expo will feature an expanded two-day IoT track, expanded flexibles and wearables track, sensors and embedded systems design track, embedded security pre-conference symposia, flexible and wearables pre-conference symposia, hands-on workshops, university and non-profit program and a startup venture forum and pavilion. Technical sessions include "Embedded Vision: The Ultimate Software-Defined Sensor," "Building Success in the Internet of Things," "Sensor Subsystems for Vital Parameter Monitoring," "3D Robots," "Trends in Telematics," "Cloud-Based Data Analytics Using Next-Generation Medical Sensors," "Printed, Flexible Stretchable Sensors for Wearables, IoT and Other High Volume Applications" and more. Can't make the Expo in June? Sensors Midwest will be co-located with SMTA International, the industry's top conference on electronics assembly and advanced packaging for a two-day sensors event featuring education, networking and the latest sensor technologies. Sensors Midwest takes place September 27–28 at the Donald E. Stephens Convention Center in Rosemont, Illinois. For more information, visit *www.sensorsexpo.com*.

June 23–AGMA 2016 Gear Manufacturing & Inspection Cleveland, Ohio. This seminar provides the gear design engineer with a broad understanding of the methods used to manufacture and inspect gears and how the resultant information can be applied and interpreted in the design process. Please note: This seminar is not a tutorial in the mechanics of machine operation; rather, the content addresses the relation between the manufacturing/inspection sequence and the detailed gear design process. Gear design engineers, management involved with the design and manufacture of gearing type components, laboratory technicians, quality assurance technicians, and gear designers should attend this course. Raymond Drago is the instructor. For more information, visit *www.agma.org*.

June 26–30–International Conference on Nuclear Engineering Charlotte Convention Center, Charlotte, North Carolina. ICONE is a global conference on nuclear reactor technology. This conference is for anyone who wants to stay technically current and on top of industry trends and developments. It features industry forums, technical presentations, keynote, plenary and poster sessions as well as workshops where international subject matter experts present their views and expertise on current topics. Leaders from industry, government and academia gather each year to present and explore cutting edge technical issues and solutions for the challenges that the nuclear industry faces today. Through the ICONE student program, the conference also fosters the development of future nuclear professionals. The event is co-sponsored by the American Society of Mechanical Engineers, the Japan Society of Mechanical Engineers and the Chinese Nuclear Society. It is co-located with the ASME Power & Energy Conference & Exhibition. For more information, visit *www.asme.org*.

July 19–20–AWEA Regional Wind Energy Conference - Northeast Portland, Maine. AWEA's next regional conference will focus on the critical issues that will help advance wind power's growth issues in the northeastern U.S. The event will also provide attendees with a comprehensive view of both land-based wind power development and the nascent efforts to develop offshore wind power off the region's coast. Attendees will analyze where wind power stands today in the northeast and the critical issues specific to the region, evaluate the market and policy in the region, specifically the various growth strategies and demand drivers ,detail the critical issues affecting offshore wind development, siting & wildlife and transmission infrastructure needs, as well as manufacturing and supply chain opportunities in the region and examine the utility issues that can secure cost-effective wind energy supply, jobs growth, and economic development opportunities. For more information, visit *www.awea.org*.

August 2–4–Capture 3D Innovation Conference Plymouth, Michigan. Companies are advancing manufacturing processes to conquer today's challenges and to strategically plan for the future. The Capture 3D Innovation Conference and Expo occurs every two years. This event focuses on how companies are continuing to improve design, manufacturing and production processes with intelligent 3D measurement technology. This is a specialized conference designed for quality and manufacturing executives, managers and engineers. Register today, and start bringing meaning to your manufacturing with quantifiable measurement. Conference speakers include reps from Argon, Delcam, Tesla, Made in Space and more. For more information, visit *c3innovate.com*.

August 9–11–PC Applications in Parallel Axis Gear System Design and Analysis UWM School of Continuing Education, Milwaukee, Wisconsin. Attendees will gain an understanding of parallel axis gear design, and learn to use the software tool, *PowerGear*, to analyze the main parameters involved. (A student version of the software is included in the price of the course.) This course covers the basics of gear load capacity evaluation from a theoretical viewpoint and uses the PC as a tool to apply these theoretical concepts. Attendees will understand durability, strength and scoring concepts, discuss typical sets of problematic design parameters and experience hands-on design perspectives through group projects. For more information, visit *http://uwm.edu/sce/courses/pc-applications-in-parallel-axis-gear-system-design-and-analysis/*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The Stage Where It Happens

Old & New Theater Magic Help Tell the Story of Alexander Hamilton

Matthew Jaster, Senior Editor

Although David Korins had an impressive resume of Broadway, film, television and music credits, the New York-based production designer had something to prove when interviewing for the pop culture phenomenon *Hamilton*. "I prepped for the interview like crazy, sketching out my ideas, presenting a scene breakdown, basically doing everything I could short of begging for the job," Korins said. "Lin Manuel Miranda (the show's creator and star) had developed an incredibly effective blueprint. I just wanted the opportunity to help tell his story."

For the uninitiated, *Hamilton* is a hip-hop musical about the life of the founding father that appears on the $10 bill. The show highlights his many historic accomplishments, celebrates New York City (then and now) and takes several liberties because as Manuel himself stated, "History is entirely created by the person who tells the story."

Politicians love it, celebrities keep coming back for more and there's a great chance that by the time this article is published, the show will have some hardware to go with it (*Hamilton* was nominated for 16 Tony Awards, more than any show in the history of Broadway).

Korins nailed his interview and was given the gargantuan task of creating a set for a show that takes place over a span of 30+ years. "We had to create scenery that was both general and specific," Korins said. "We're not telling the story of the people that built the country, we're telling the story of the people that built the *foundation* on which this country was built." The New York carpenters during that time period were shipbuilders. This meant a stage full of ropes, joints, beams, pulleys and scaffolding. "It's an early American tapestry of architecture," Korins added.

After listening to all the song demos, Korins couldn't shake the cyclical motion of Alexander Hamilton's narrative. "I think it had to do with Hamilton's personal history, the emotional and political storm, the scandals he endured and his rocky relationship with Aaron Burr," he said. "I thought using a turntable on stage would help convey these ideas."

Director Tommy Kail and choreographer Andy Blankenbuehler had never used a turntable stage in a show before *Hamilton*. The idea was a rotating turntable (19 ft. in diameter) inside of another rotating turntable (25 ft. in diameter). "They asked me to come up with 10 places where the turntable would work in the show so I started drawing sequences where I thought it could really help tell the story," Korins said.

The eight-inch tall deck moves via a chain drive motor run by an automation operator 40 feet in the air. "It has multiple speeds and it's all timed within an inch of its life. There are obvious moments where the show is doing huge, pyrotechnic moves, and then moments where the stage is moving very slowly and subtlety," Korins said. "There's probably 40-something turntable cues in the show, some last 10 seconds, some last two minutes. The whole thing is perfectly synched to lines and music. It doesn't seem like much, but it's the single defining scenic element of the show."

As far as engineering goes, Korins said that *Hamilton* is fairly low tech. "We don't use friction drives or remote controls, things you'll see in other shows. It's kind of like old theater magic in a way. When we're not using the automated turntable, we're moving wagons and flying in things using stagehands like the old days (people power)."

But it's the turntable itself that has helped narrative elements on stage such as the duel between Hamilton and Burr or a musical number where characters are walking through New York Town Square. "I've done many complicated shows with crazy cantilevers and insane physical challenges, but *Hamilton* is pretty straight forward," Korins added. **PTE**

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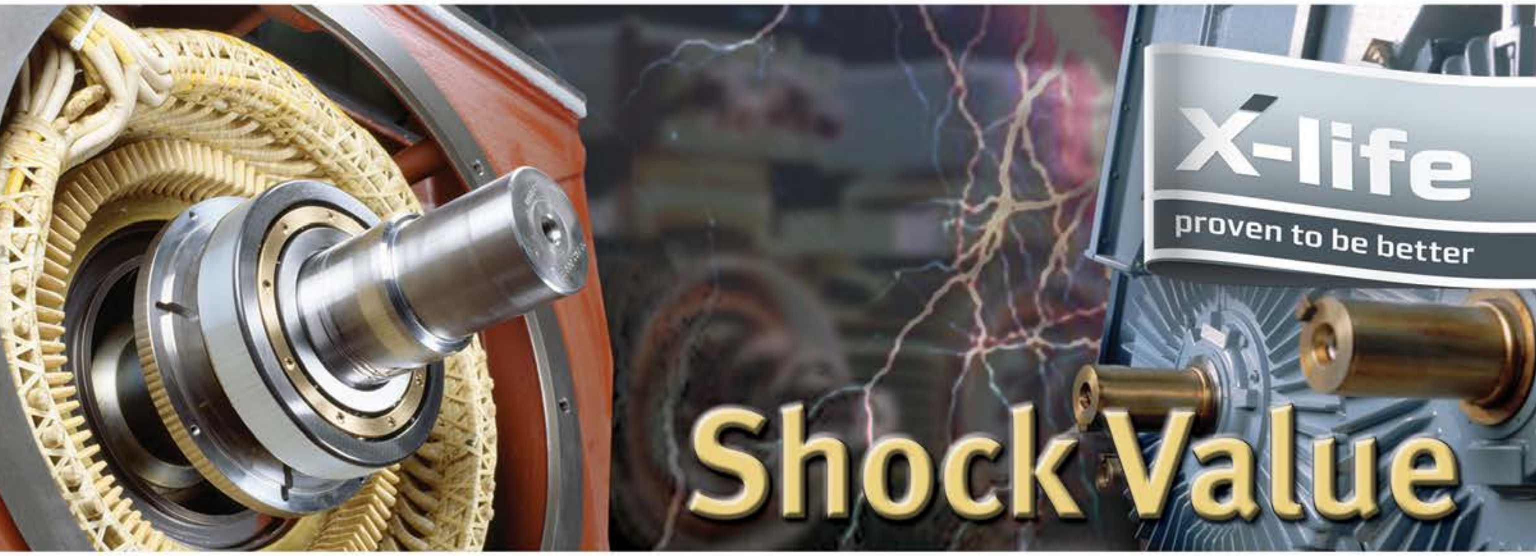

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